Energy Consumption, Financial Development and Economic Growth in India: New Evidence from a Nonlinear and Asymmetric Analysis

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1 January 2017

Energy Consumption, Financial Development and Economic Growth in India: New Evidence from a Nonlinear and Asymmetric Analysis

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Abstract

This paper investigates the asymmetric relationship between energy consumption and economic growth by incorporating financial development, capital and labour into a production function covering the Indian economy from $1960Q_1$–$2015Q_4$. The nonlinear autoregressive distributed lag bounds testing approach is applied to examine the asymmetric cointegration between the variables. An asymmetric causality test is also employed to examine the causal association between the considered variables. The results indicate cointegration between the variables in the presence of asymmetries. The asymmetric causality results show that only negative shocks in energy consumption have impacts on economic growth. In the same vein, only negative shocks in financial development have impacts on economic growth. By contrast, symmetrically, capital formation causes economic growth. Finally, over the study period, a neutral effect exists between the labour force and economic growth in India. The implications of these results for growth policies in India are also discussed.

Keywords: Financial Development, Energy, Growth, India, Asymmetries
JEL classification: O13

Acknowledgements: We would like to thank the editor, Professor Richard Tol (University of Sussex, Brighton, UK), as well as the three anonymous reviewers, for their valuable comments and suggestions that helped us improve our paper significantly. We also thank the participants at the 7th International Research Meeting in Business and Management (IPAG, Nice, France, 11–12 July 2016). We are also grateful to Jawad Kazmi for his technical assistance. The authors' are responsible for any remaining errors or shortcomings.

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1. Introduction

This study uses quarterly data to investigate the relationship between energy consumption and economic growth in India over the 1960–2015 period. Financial development (measured by domestic credit to the private sector),[1] capital formation and labour force[2] are also included in the Cobb-Douglas production function. This study's main contribution to the existing literature on the energy-growth nexus concerns its examination of the potential asymmetric relationship between the variables. Taking this asymmetry into account is important because a positive or negative variation on one variable does not have the same impact on the other variable. The existence of an asymmetric relationship between two variables can be caused by numerous factors, one of which concerns the complexity of economic systems and the mechanisms that generate the variables under study. This complexity may induce various channels through which one variable affects another. In our case, the relationship between energy consumption and economic growth has been found to be very complex because previous studies have shown four possible impact channels: the growth, conservative, feedback and neutrality hypotheses.[3]

On the one hand, the relationship between energy consumption and financial development can also be very complex because numerous impact channels can exist between them. One channel argues that financial development causes economic growth, which in turn causes an increase in energy consumption. On the other hand, financial development can also lead to an increase in investments in new technologies, which allow for the reduction of energy consumption (Sadorsky, 2010). In this context, examining how positive and negative variations of financial development can affect energy consumption is very important. As such, we propose using econometric methods that allow for the consideration of the asymmetry in studying the cointegration and causality between economic growth, financial development and energy consumption, including capital and labour, in India from 1960 to 2015. These methods were recently developed by Shin et al. (2014) and Hatemi-J (2012). Furthermore, we also use the Kim and Perron (2009) unit root test to consider potential unknown structural breaks that can exist in the time series under study. Another important point concerns the use of quarterly data instead of annual data, which have been used in most previous studies. Quarterly data allow us to increase the sample size and thus obtain more accurate empirical results.

For the case of India,[4] this study contributes to the understanding of the interplay between not only economic growth and energy consumption, as investigated in most previous studies, but also between financial development and energy consumption, which has received little attention. To the best of our knowledge, asymmetry has not been studied in either relationship. In this context, the results provided in this study can help policymakers better understand the causalities between these important economic variables and the ways in which an increase or a decrease in one variable can affect the others.

The rest of the paper is organized as follows. Section 2 reviews the literature on the two principal linkages that we study, which are the energy-growth and energy-finance nexuses. This study's contributions to these two research streams will be highlighted. Furthermore, a focus on India will also be elaborated. Section 3 presents the dataset and the methods used. The reasons that we chose to study India and its important energy and economic indicators will also be

[1] Our reasons for using this variable will be explained in Section 3.
[2] We would like to thank an anonymous referee for suggesting the inclusion of this variable.
[3] More information on each channel is found in Section 2.
[4] A focus on this country will be presented in Section 3.

analysed in Section 3.[5] Section 4 analyses the results, while Section 5 concludes the paper by paying particular attention to the policy implications of the results and the importance of taking the asymmetry into account.

2. Literature review: Economic activities and energy consumption

The interaction between human activities—or, more specifically, economic activities—and energy consumption is not a new topic. The first studies on this topic were published in the 1950s (e.g., Mason 1955, Frank 1959). The topic continued to be developed in later decades with particular attention on the U.S. economy (e.g., Schurr and Netschert 1960, Waren 1964, Janosi and Grayson 1972, Solow 1974, Rasche and Tatom 1977). Only after the study of Kraft and Kraft (1978) were these studies extended to numerous countries to study various periods with various methods (e.g., Humphrey and Stainlaw (1979) for the UK; Zilberfarb and Adams (1981) for developing countries; Yu and Choi (1985) for an international comparison; Adams and Miovic (1986) for Western Europe; Abakah (1990) for Ghana; Shafik and Bandyopadhyay (1992) for a panel of countries; Hawdon and Pearson (1995) for the UK; Masih and Masih (1996) for a panel of countries; Cheng and Tai (1997) for Taiwan; Naqvi (1998) for Pakistan). Since then, this topic has attracted an increasing number of researchers who have conducted numerous studies using data from longer periods and from a large number of countries with increasingly robust econometric methods. Different factors may explain this shift. First, energy and environmental issues have become the cornerstone of every human activity. Since the first annual United Nations meeting in Rio de Janeiro in 1992, environmental degradation has become a concern in many countries. Second, the data provided by the World Bank (World Development Indicators) have been publicly available since 2010. The existence of this online database explains the very large number of studies on this topic between 2010 and 2016, as we will demonstrate below. The relationship between financial development and energy consumption has been investigated more recently, mostly since the 2007 financial crisis (e.g., Claessens and Feijen 2007, Tamazian et al. 2009, Sadorsky 2010 and 2011, Islam et al. 2012, Coban and Topcu 2013, Tang and Tan 2014, Komal and Abbas 2015, Abbasi and Riaz 2016).

In this context, we divide our literature review into two parts. The first part will focus on the energy-growth nexus, while the second part will focus on the linkage between financial development and energy consumption. Particular attention will be paid to the case of India.

2.1. The energy-growth nexus

The results of previous studies have not been unanimous regarding the causal relationship between energy consumption and economic growth: some researchers validate the growth hypothesis, which holds that energy consumption leads to economic growth (e.g., Apergis and Payne 2009, Ozturk et al. 2010, Ouedraogo 2013, Aslan et al. 2014b), while others validate the conservative hypothesis, which holds that economic growth influences energy consumption (e.g., Huang et al. 2008, Narayan et al. 2010, Kasman and Duman 2015). Some support the feedback hypothesis, which states that a bidirectional causal relationship exists between energy consumption and economic growth (e.g., Constantini and Martini 2010, Belke et al. 2011, Coers and Sanders 2013), while others support the neutrality hypothesis, which posits that economic growth and energy consumption are independent (e.g., Wolde-Rufael 2009, Kahsai et al. 2012,

[5] We would like to thank an anonymous referee for suggesting this organization.

Smiech and Papiez 2014). These results seem to diverge based on the countries, periods or methods used.

As explained above, a large number of studies have been published between 2010 and 2016. For example, Jafari et al. (2012) found no significant relationship between energy consumption and economic growth in Indonesia from 1971 to 2007. Ouedraogo (2013) found causality running from GDP to energy consumption in the short run and the reverse in the long run for the Economic Community of West African States. Dogan (2014) showed unidirectional causality running from energy use to economic growth in Kenya but no causality in Benin, Congo or Zimbabwe from 1971 to 2011. Nasreen and Anwar (2014) revealed bidirectional causality between energy consumption and economic growth in 15 Asian countries from 1980 and 2011. Acaravci et al. (2015) found unidirectional short-run and long-run causality running from electricity consumption to economic growth, though not the reverse, in Turkey from 1974 to 2013. Dogan (2015a) confirmed the feedback hypothesis between natural gas consumption and economic growth in Turkey from 1995 to 2012. The same result was found for Belgium's energy consumption and economic growth from 1960 to 2012 (Dogan 2016a). In Turkey from 1995 to 2013, Dogan et al. (2016) found that agricultural electricity consumption caused the output for non-coastal regions, while bidirectional causality existed between these variables for the entire panel and coastal regions. Fang and Chang (2016) found that economic growth caused energy use in the Asia Pacific region (16 countries) from 1970 to 2011, but the relationship may have varied for individual countries. For China, Furuoka (2016) found unidirectional causality running from natural gas consumption to economic development from 1980 to 2012. However, for Japan, the author found results that supported the feedback hypothesis. Menegaki and Tugco (2016) demonstrated the neutrality hypothesis between GDP and energy use in 42 sub-Saharan countries from 1985 to 2013.

More recently, academic research has focused on the impact of renewable energy sources on economic growth. The renewable energy sources that have been considered include hydroelectric power, geothermal power, wood, waste, biofuel, and biomass. Because investigating the linkage between renewable energy and economic growth is not the principal objective of our study, we will not develop this part further. More details can be found in recent studies, such as Edenhofer et al. (2013), Kander and Stern (2014), Dogan (2015b), Alper and Oguz (2016), Bhattacharya et al. (2016), Dogan (2016b), Marques et al. (2016), Paramati et al. (2016) and Inglesi-Lotz (2016).

Of course, the above-mentioned studies do not fully represent the large body of literature on the energy-growth nexus, but this review allows us to state that the results are very different from one country to another, from one period to another and from one method to another. In our study, we will focus more on previous studies on India, which are reviewed below.

The energy-growth nexus in India

Masih and Masih (1996) found unidirectional causality running from energy to income for India's economy over the 1955–1990 period. Cheng (1999) showed that economic growth Granger-causes energy consumption over the short term and the long term. By contrast, Asaf-Adjaye (2000) validated the conservative hypothesis. Ghosh (2002) reported no long-term equilibrium between electricity consumption and economic growth but found that economic growth Granger-causes electricity consumption. Fatai et al. (2004) confirmed the growth hypothesis for India within a panel of countries. Furthermore, Paul and Bhattacharya (2004) revealed the feedback effect between energy consumption and economic growth over the 1950–1996 period. Asghar (2008) found a neutral effect between energy consumption and GDP in

India over the 1971–2003 period. Gupta and Sahu (2009) reported that electricity consumption Granger-caused economic growth over the 1960–2009 period. Similarly, Mallick (2009) showed that, over the 1970–2005 period, economic growth fuelled demand for both crude oil and electricity, while coal consumption drove economic growth.

Alam et al. (2011) showed no causal relationship between energy consumption and income. Abbas and Choudhury (2013) validated the feedback effect (or bidirectional causality) between electricity consumption and GDP in India's agricultural sector over the 1972–2008 period. Ghosh and Kanjilal (2014) exposed the unidirectional causality running from energy consumption to economic activity. Yang and Zhao (2014) found that energy consumption causes economic growth. Sehrawat et al. (2015) showed a neutral effect between energy consumption and economic growth in India over the 1971–2011 period. Ahmad et al. (2016) found a feedback relationship between energy consumption and economic growth in India over the 1971–2014 period. Shahbaz et al. (2016) showed that economic growth and energy consumption were complementary, i.e., a feedback effect.

Overall, the existing literature on the relationship between economic growth and energy consumption in India showed divergent results (see Table 1), with annual data over various periods from the 1950s to 2014.

Table 1: The linkage between economic growth and energy consumption in India

Growth hypothesis (Energy → Growth)	**Conservative hypothesis** (Growth → Energy)	**Feedback hypothesis** (Growth ↔ Energy)	**Neutrality hypothesis** (Growth >< Energy)
- Masih and Masih (1996) (1955–1990) - Asaf-Adjaye (2000) (1973–1995) - Fatai et al. (2004) (1960–1999) - Gupta and Sahu (2009) (1960–2009) - Mallick (2009) (1970–2005, for coal) - Ghosh and Kanjilal (2014) (1971–2008) - Yang and Zhao (2014) (1970–2008)	- Cheng (1999) (1952–1995) - Ghosh (2002) (1950–1997) - Mallick (2009) (1970–2005, for oil and electricity) - Shahbaz et al. (2016) (1971–2012)	- Paul and Bhattacharya (2004) (1950–1996) - Abbas and Choudhury (2013) (1972–2008, agricultural sector) - Ahmad et al. (2016) (1971–2014)	- Asghar (2008) (1971–2003) - Alam et al. (2011) (1971–2006) - Sehrawat et al. (2015) (1971–2011)

These different results may be explained by the methods used (e.g., autoregressive distributed lag (ARDL) bounds testing, Toda and Yamamoto (2003) causality test) and the period under consideration, which vary from 1952 to 2014. The results can also be explained by the different measures of energy consumption, such as oil, electricity or coal consumption (e.g., Mallick 2009). We will use overall energy consumption, measured by kilos of oil equivalent per capita, to neutralize this effect. Furthermore, no study has investigated the nonlinear and asymmetric causality between economic growth and energy consumption in India, although this gap may exist because of the complexity of the causal mechanism between these variables. Following Chiou-Wei et al. (2008), this complexity can be explained by economic events and regime changes, such as changes in the economic environment and changes in energy policies and energy prices. In the following subsection, the same statement will be addressed in the literature regarding the linkage between financial development and energy consumption.

2.2. The nexus between financial development and energy consumption

The causality from financial development to energy consumption runs through two possible channels: the positive or the negative. With regard to the first channel, financial development increases energy consumption because it supports economic growth, which triggers a higher demand for energy (e.g., Sadorsky 2010, 2011, Zhang 2011, Aslan et al. 2014a, Rashid and Yousaf 2015). Sadorsky (2011) explained this positive causality with three different effects: the *direct effect* (people buy more energy-consuming goods), the *business effect* (more businesses increase energy demand) and the *wealth effect* (higher economic confidence induces higher demand for energy). In the case of the second channel (i.e., the negative one), financial development leads to more modern and less energy-consuming technologies and, in turn, leads to a decrease in energy consumption. This channel is referred to as the *technological effect* (e.g., Tamazian et al. 2009, Jalil and Feridun 2011, Shahbaz et al. 2013, Mahalik and Mallick 2014). Some studies have also found bidirectional causality between financial development and energy consumption (e.g., Ali-muali and Sab 2012, Shahbaz and Lean 2012). Others have found that financial development has no impact on energy consumption (Coban and Topcu 2013, Ozturk and Acaravi 2013). Once again, the results of these studies differ based on the countries and methods used. For the methods, we have found only one study that takes into account the nonlinearity in a panel of 53 countries (Chang 2015). However, the asymmetry has not been taken into account.

Hereafter, we will focus first on studies that analyse the impact of financial development on energy consumption in India before analysing its impact in other countries.

Financial development and energy consumption in India

Sadorsky (2010) found a positive and significant relationship between financial development and energy consumption when financial development is measured by stock market variables in 22 emerging countries, including India. Boutabba (2014) validated the long-term unidirectional causality running from financial development to energy use. Mahalik and Mallick (2014) showed that financial development, economic growth and industrial development negatively affect energy consumption. Rashid and Yousaf (2015) found that the linkage between financial development and electricity consumption via economic growth is positive and significant. By contrast, Sehrawat et al. (2015) showed a neutral effect between energy consumption and financial development in India over the 1971–2011 period. Shahbaz et al. (2016) indicated that financial development reduces energy consumption.

Financial development and energy consumption in other countries

For Pakistan, Kakar et al. (2011) showed that financial development affects energy consumption in the long term but not in the short term. For nine Central and Eastern European frontier economies, Sadorsky (2011) showed a positive and significant relationship between financial development and energy consumption when financial development is measured by banking variables, such as bank deposits to GDP, financial system deposits to GDP, and liquid liabilities to GDP. For Tunisia, Chtoui (2012) showed long-term bidirectional causality between economic growth and energy consumption but only unidirectional and negative causality from energy consumption to financial development. Shahbaz and Lean (2012) found that a bidirectional causal relationship exists between financial development and energy consumption and between industrialization and energy consumption in Tunisia.

Xu (2012) revealed a positive relationship between financial development and energy consumption in China when financial development is measured by the ratio of loans in financial institutions to GDP and by the ratio of foreign direct investment (FDI) to GDP. For Malaysia, Islam et al. (2013) found that energy consumption is influenced positively by economic growth and financial development in both the short term and the long term. Coban and Topcu (2013) indicated no significant relationship in the E27 countries. However, the relationship is positive and significant in old member countries, irrespective of whether financial development is measured using the banking sector or the stock market.[6] For Turkey, Ozturk and Acaravci (2013) found that financial development has a significant and positive impact on energy consumption. Shahbaz et al. (2013) showed that, in China, financial development stimulates economic growth, which increases energy use. Tang and Tan (2014) indicated that energy consumption causes financial development in Malaysia, although the feedback effect exists between energy consumption and economic growth.

Altay and Topçu (2015) showed no significant relationship between financial development and energy consumption in Turkey. Using a panel of 53 countries, Chang (2015) found that, in the non-high income regime, energy consumption increases with financial development when both private and domestic credits are used as financial development indicators. However, the results differ when financial development is measured by stock market variables (energy consumption declines when these variables increase). Destek (2015) showed that, in Turkey, financial development has a negative impact on energy consumption in the long term. Komal and Abbas (2015) showed that financial development positively and significantly affects energy consumption via economic growth in Pakistan. Shahbaz (2015) found a feedback effect, i.e., bidirectional causality between electricity consumption and financial development, in Pakistan. By contrast, some studies have shown indirect impacts of financial development on energy consumption during the global financial crisis. For China, Yuan et al. (2010) showed that the decline in exports due to the crisis led to a 7.33% decrease in GDP and a 9.21% decrease in energy consumption. Zhao et al. (2016) confirmed these results for China by considering electricity consumption, which decreased by 14.31% in 2008.

Overall, the review of the existing literature on the nexus between financial development and energy consumption shows fewer studies than those on the energy-growth nexus. The results are still unanimous regarding the causality between these two variables (see Table 2). More importantly, to the best of our knowledge, nonlinearity and asymmetry have not been taken into account. However, when studying these two aspects, considering the ambiguous relationship between financial development and energy consumption is important. Zhang (2011) indicated that three channels explain the positive relationship between financial development and energy consumption. First, financial development attracts more FDI and thus more economic growth and energy consumption. Second, efficient financial intermediation results in more consumer loans being used to buy more energy-consuming goods, thus leading to more energy consumption. Third, stock market development helps listed firms finance more investment projects and thus increases energy consumption. By contrast, Chang (2015) explained that financial development offers more opportunities to develop the renewable energy sector by providing more funds to innovative firms. Furthermore, FDI can lead to more technology

[6] For new members, however, only banking variables have a significant relationship with energy consumption. The old members are Luxembourg, the UK, the Netherlands, Spain, Portugal, Germany, Austria, Belgium, Ireland, Denmark, France, Finland, Greece, and Sweden. The new members are Cyprus, Malta, the Czech Republic, Slovakia, Estonia, Hungary, Bulgaria, Slovenia, Poland, Latvia, Lithuania, and Romania.

innovations and thus help reduce energy use. This ambiguity regarding the impact of financial development on energy consumption may cause a nonlinear and asymmetric relationship between them, which is why taking these two aspects into account is important.

Table 2: The nexus between financial development and energy consumption

Positive effect (FD $\rightarrow^{+}$ Energy)	**Negative effect** (FD $\rightarrow^{-}$ Energy)	**Conservative effect** (Energy → FD)	**Feedback effect** (FD ↔ Energy)	**Neutrality effect** (FD >< Energy)
India - Sadorsky (2010) (1999–2006, stocks) - Boutabba (2014) (1971–2008, credit) - Rashid and Yousaf (2015) (1980–2011, credit) **Other countries** - Kakar et al. (2011) (1980–2012, Pakistan, money) - Sadorsky (2011) (1996–2006, EU, bank, stocks) - Xu (2012) (1999–2009, China, credit, FDI) - Islam et al. (2013) (1971–2009, Malaysia, credit) - Coban and Topçu (2013) (1999–2011, old EU members, credit, bank) - Ozturk and Acaravi (2013) (1960–2007, Turkey, credit, SR) - Chang (2015) (1999–2008, 53 countries, bank) - Komal and Abbas (2015) (1972–2012, Pakistan, credit)	***India*** - Mahalik and Mallick (2014) (1971–2009, credit) - Shahbaz et al. (2016) (1971–2012, credit) **Other countries** - Chtoui (2012) (1972–2010, Tunisia, credit, LR) - Chang (2015) (1999–2008, 53 countries, stocks) - Destek (2015)	**Other countries** - Chtoui (2012) (1972–2010, Tunisia, credit, SR) - Tang and Tan (2014) (1972–2009, Malaysia, bank)	***India*** - Shahbaz et al. (2016) (1971–2012, credit) **Other countries** - Kakar et al. (2011) (1980–2012, Pakistan, credit) - Shahbaz and Lean (2012) (1971–2008, Tunisia, credit, LR) - Shahbaz (2015) (1972–2012, Pakistan, credit)	***India*** - Sehrawat et al. (2015) (1971–2011, credit) **Other countries** - Coban and Topçu (2013) (1999–2011, new EU members, credit, bank) - Shahbaz et al. (2013a) (1971–2011, China, credit) - Altay and Topçu (2015) (1980–2011, Turkey, bank)

Notes: FD denotes financial development. EU denotes European Union. LR and SR denote long run and short run, respectively. The second set of parentheses show the study period and the variables used to measure financial development. "Credit" means domestic credit to the private sector, and "Stocks" means stock market variables. "Money" means money supply. "Bank" means banking variables.

3. Data and methodology

This section will present the dataset and the methodological framework. The reason that we have chosen to study India, as well as its important energy and economic indicators, will also be presented in the data section.[7]

3.1. Data

India is chosen because it is one of the largest energy consumers worldwide, behind China and the U.S. (*Global Energy Statistical Yearbook 2015*). According to the *International Energy Agency*, in 2015, India accounted for 18% of the world's population but only 6% of its primary energy usage, which shows the energy poverty in India, as analysed in Pachauri et al. (2004). However, India's energy consumption has almost doubled since 2000, contributing to 10% of the global energy demand, while the potential for further rapid growth of GDP is great (expected to be 8% in 2017 and 2018, *World Development Indicators*). Furthermore, as shown in Section 2, very few studies have investigated the relationship between financial development and energy consumption in India. However, none of these studies has investigated nonlinearity or asymmetry. Other studies have been conducted on a panel of countries, including India, such as Tamazian et al. (2009), Sadorsky (2010) and Talukdar and Meisner (2001). However, as argued in Boutabba (2014), any potential inference drawn from these cross-country studies is widely recognized to provide only a general understanding of the linkage between the variables; thus, detailed policy implications for each country cannot be drawn from such studies (Ang 2008, Lindmark 2002, Stern et al. 1996). As shown in Section 2, many studies have been conducted to investigate the relationship between economic growth and energy consumption in India. However, to the best of our knowledge, nonlinearity and asymmetry have not been taken into account in these studies. For all these reasons, we decided to investigate the case of India in this study.

The World Development Indicators (CD-ROM 2016) have been combed to collect data on real GDP (in constant 2010 Indian currency), energy use (kg of oil equivalent), real domestic credit to the private sector (in constant 2010 Indian currency), real gross fixed capital formation (in constant 2010 Indian currency) and labour force (measured by the proportion of the total population aged 15 to 64). We have transformed all the variables into per capita units by dividing them by the total population for each year. Real GDP per capita represents economic growth. Energy consumption is measured by energy use per capita. Real domestic credit to the private sector per capita is a measure of financial development. Real gross fixed capital formation per capita is a proxy for capital. Labour force is a proxy for the labour variable. This variable has been used in numerous studies, such as Soytas et al. (2007), Soytas and Sari (2009), Menyah and Rufael (2010), Dogan (2015b), and Streimikienne and Kasperowicz (2016). To increase the accuracy of our empirical results, quarterly frequency data are used for the period from 1960Q_1–2015Q_4. For this purpose, we have employed the quadratic match-sum method to transform the annual frequency data into quarterly frequency data, following Sbia et al. (2014).[8] All the

[7] We would like to thank an anonymous reviewer for this suggestion.

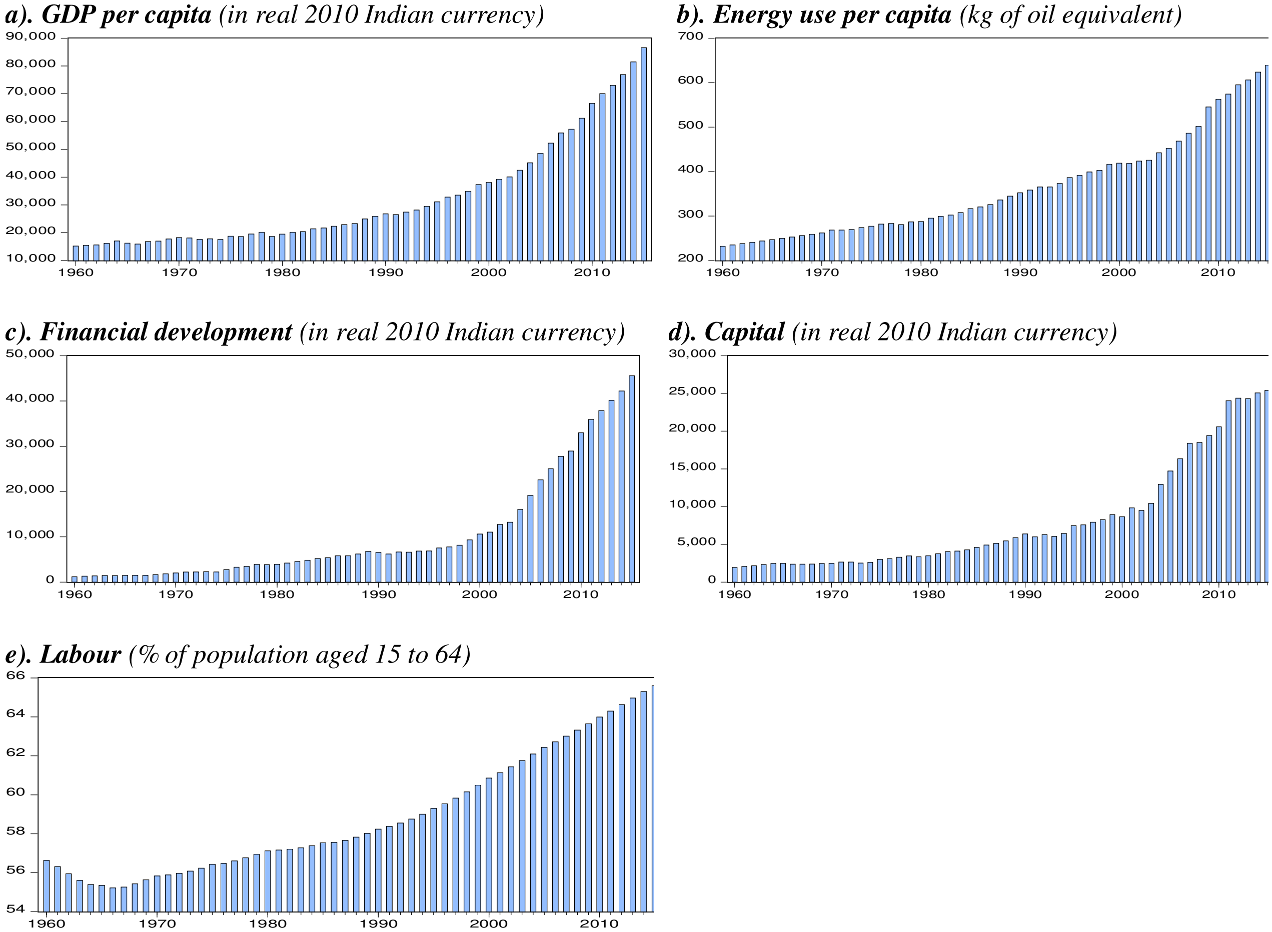
[8] A mechanism of data transformation from a low frequency into a higher frequency is said to enable the quadratic match-sum method that is used to adjust seasonal variations in the raw data used in the analysis. Similarly, Cheng et al. (2012) also noted that the quadratic match-sum method easily captures the point-to-point variations in the data to address the seasonality problem. Hence, we prefer the quadratic match-sum method, as it transforms annual data into quarterly data following Denton (1971).

variables have been transformed into natural logarithmic form for consistent and reliable empirical results (Shahbaz et al. 2016).

Numerous proxies of financial development are used by different researchers, as indicated in our literature review above. For instance, financial development can be measured by M_2 as a share of GDP or liquid liabilities as a share of GDP. The problem with these measures is that they are unable to capture the development of the financial sector. For example, M_2 is recommended by King and Levine (1993) as a financial depth measure, but it contains a large portion of currency and thus reflects monetization rather than financial development (Demetriades and Hussein 1996, Jalil and Feridun 2011). Liquid liabilities are also used as an indicator of financial development; while they indicate the size of the financial sector, liquid liabilities are irrelevant for financial development (Claessens et al. 2001, Creane et al. 2007). By contrast, domestic credit to the private sector refers to financial resources provided to the private sector through loans, purchases of non-equity securities, trade credit and other accounts receivable that establish a claim for repayment (Boutabba 2014). Furthermore, domestic credit to the private sector shows the actual level of savings allocated to productive investment ventures. As such, we choose to use this variable to reflect financial development in India. Numerous previous studies, such as Sadorsky (2011), Mehrara and Musai (2012), Polat et al. (2015) and Shahbaz et al. (2016), have also chosen this variable.

Figure 1 displays the time trend of the variables. More descriptions of these variables are detailed in Section 4.

Figure 1: Trends in GDP per capita, energy use per capita, financial development, capital and labour force in India from 1960 to 2015



3.2. Methodology

In this section, we will first detail the nonlinear and asymmetric cointegration test developed by Shin et al. (2014). We will then present the nonlinear and asymmetric causality test developed by Hatemi-J (2012).

3.2.1. The NARDL bounds testing approach for cointegration tests

We choose to use the multivariate nonlinear ARDL (NARDL) bounds testing approach developed by Shin et al. (2014) because it can capture the nonlinear and asymmetric cointegration between variables. Furthermore, it distinguishes between the short-term and long-term effects of the independent variable on the dependent variable. Even if all previous facts could also be tested within a nonlinear threshold Vector Error Correction Model (VECM) or a smooth transition model, these models suffer from the convergence problem due to the proliferation of the number of parameters. However, the NARDL model does not have this problem. Moreover, unlike other error correction models where the integration order of the considered time series should be the same, the NARDL model relaxes this restriction and allows for a combination of different integration orders. This flexibility is very important, as shown in

Hoang et al. (2016). Finally, this method also helps solve the multicollinearity problem by choosing the appropriate lag order for the variables (Shin et al. 2014).

The NARDL model proposed by Shin et al. (2014) represents the asymmetric error correction model as follows:

$$\Delta Y_t = \alpha_0 + \rho Y_{t-1} + \theta_1^{+} E_{t-1}^{+} + \theta_2^{-} E_{t-1}^{-} + \theta_3^{+} F_{t-1}^{+} + \theta_4^{-} F_{t-1}^{-} + \theta_5^{+} K_{t-1}^{+} + \theta_6^{-} K_{t-1}^{-} + +\theta_7^{+} L_{t-1}^{+} + \theta_8^{-} L_{t-1}^{-}$$
$$+ \sum_{i=1}^{p} \alpha_1 \Delta Y_{t-i} + \sum_{i=0}^{q} \alpha_2 \Delta E_{t-i}^{+} + \sum_{i=0}^{q} \alpha_3 \Delta E_{t-i}^{-} + \sum_{i=0}^{q} \alpha_4 \Delta F_{t-i}^{+} + \sum_{i=0}^{q} \alpha_5 \Delta F_{t-i}^{-} + \sum_{i=0}^{q} \alpha_6 \Delta K_{t-i}^{+} + \sum_{i=0}^{q} \alpha_7 \Delta K_{t-i}^{-} \quad (1)$$
$$+ \sum_{i=0}^{q} \alpha_7 \Delta L_{t-i}^{+} + \sum_{i=0}^{q} \alpha_8 \Delta L_{t-i}^{-} + D_t + \mu_t$$

In Equation (1), α_i denotes short-run coefficients, while θ_i denotes long-run coefficients with $i = 1...8$. We recall that a short-run analysis is intended to assess the immediate impacts of exogenous variable changes on the dependent variable. By contrast, a long-run analysis is used to measure the reaction time and speed of the adjustment towards an equilibrium level. We apply the Wald test to check the long-term asymmetry ($\theta = \theta^{+} = \theta^{-}$) and short-term asymmetry ($\alpha = \alpha^{+} = \alpha^{-}$) for all variables. Y_t represents economic growth; E_t represents energy consumption; F_t represents financial development; K_t represents capital; and L_t represents labour (more details in Section 3.1). D_t is a dummy variable that is used to capture the impact of the structural break date (*t*), which is determined by the unit root test developed by Kim and Perron (2009). p and q represent the optimal lags for the dependent variable (Y_t) and independent variables (E_t, F_t, K_t, L_t), which will be determined by the Akaike information criterion (AIC).

The independent variables are decomposed into their positive and negative partial sums for increases and decreases as follows:

$$x_t^{+} = \sum_{j=1}^{t} \Delta x_j^{+} = \sum_{j=1}^{t} \max\left(\Delta x_j, 0\right) \quad x_t^{-} = \sum_{j=1}^{t} \Delta x_j^{-} = \sum_{j=1}^{t} \min\left(\Delta x_j, 0\right),$$

with x_t representing E_t, F_t, K_t and L_t.

To test the existence of an asymmetric long-run cointegration, Shin et al. (2014) propose the bounds test, which is a joint test of all the lagged levels of the regressors. Two tests are used: the t-statistic of Banerjee et al. (1998) and the F-statistic of Pesaran et al. (2001). The t-statistic tests the null hypothesis $\theta = 0$ against the alternative hypothesis $\theta < 0$. The F-statistic tests the null hypothesis of $\theta^{+} = \theta^{-} = \theta = 0$. These two statistics are used in our study. If we reject the null hypothesis of no cointegration, a long-run relationship exists among the variables.

The long-term asymmetric coefficients are estimated based on $L_{mi^{+}} = \theta^{+} / \rho$ and $L_{mi^{-}} = \theta^{-} / \rho$. These long-run coefficients, with respect to positive and negative changes of the independent variables, measure the relationship between these variables in the long-run equilibrium. For the estimation of asymmetric dynamic multiplier effects, the following equation is used:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial E_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial E_t^-}, m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial F_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial F_t^-}, m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial K_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial K_t^-}$$

$$m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial L_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial L_t^-} \text{ for } h = 0, 1, 2.....$$

where, if $h \to \infty$, then $m_h^+ \to L_{mi^+}$ and $m_h^- \to L_{mi^-}$.

These dynamic multipliers show the asymmetric responses of the dependent variable to positive and negative variations in the independent variables. Based on the estimated multipliers, we can observe the dynamic adjustments from the initial equilibrium to the new equilibrium between the system variables following a variation that affects the system.

3.2.2. Asymmetric causality tests

To determine the direction of the asymmetric causal relationship between the variables, we employ the asymmetric causality test recently proposed by Hatemi-J (2012). This test incorporates the idea behind the Toda-Yamamoto (1995) test by considering nonlinear effects and discriminates between negative and positive shocks. Hatemi-J (2012) further argued that integrated variables can be represented as a random walk process in a general form as follows:

$$Y_t = Y_{t-1} + e_{1t} = Y_0 + \sum_{i=1}^{t} e_{1i} \text{ and } X_t = X_{t-1} + e_{2t} = X_0 + \sum_{i=1}^{t} e_{2i} \tag{2}$$

where $t = 1, 2, ..., T$, Y_0 and X_0 denote initial values, and e_{1t} and e_{2t} are the error terms. $e_{1i}^+ = \max(e_{1i}, 0)$ and $e_{2i}^+ = \max(e_{2i}, 0)$ represent positive shocks, and $e_{1i}^- = \min(e_{1i}, 0)$ and $e_{2i}^- = \min(e_{2i}, 0)$ represent negative shocks. In an asymmetric framework, it is also represented by $Y_t = Y_{t-1} + e_{1t} = Y_0 + \sum_{t=1}^{t} e_{1i}^+ + \sum_{t=1}^{t} e_{1i}^-$ and $X_t = X_{t-1} + e_{2t} = X_0 + \sum_{t=1}^{t} e_{2i}^+ + \sum_{t=1}^{t} e_{2i}^-$. In our sample, to capture the effects of both positive and negative shocks of all variables, we use the cumulative form of the following equation:

$$\begin{gathered} Y_t^+ = \sum_{i=1}^{t} e_{1i}^+,\ Y_t^- = \sum_{i=1}^{t} e_{1i}^-,\ E_t^+ = \sum_{i=1}^{t} e_{2i}^+,\ E_t^- = \sum_{i=1}^{t} e_{2i}^-, F_t^+ = \sum_{i=1}^{t} e_{3i}^+,\ F_t^- = \sum_{i=1}^{t} e_{3i}^-, \\ K_t^+ = \sum_{i=1}^{t} e_{4i}^+,\ K_t^- = \sum_{i=1}^{t} e_{4i}^-,\ L_t^+ = \sum_{i=1}^{t} e_{5i}^+,\ L_t^- = \sum_{i=1}^{t} e_{5i}^-, \end{gathered} \tag{3}$$

More specifically, both positive and negative shocks indicate asymmetric causality among the variables (Hatemi-J, 2012). This test can be estimated by employing the vector autoregressive (VAR) model with an order of p. The innovative lag-based criteria suggested by (Hatemi-J 2003, 2008) can be used to select the optimal lag length for the VAR model.

$$HJC = \ln\left(\left|\widehat{A}_j\right|\right) + q\left(\frac{n^2 \ln T + 2n^2 \ln(\ln T)}{2T}\right), q = 0,..., p \quad (4)$$

where $\left|\widehat{A}_j\right|$ is a determinant in the VAR model of the obtained variance-covariance matrix of the error terms with lag order q and shows the number of equations, and T is the total number of observations in the VAR model. The null hypothesis can be represented by the kth element of $\sum X_{it}^{+}$, which does not affect the wth Y_t^{+} because it is defined as H_0 : row ω, column k element in A_r equals zero for $r = 1,...., p$.[9] This hypothesis can also be tested by employing the Wald test (Hatemi-J 2012).

As has been the convention in previous studies, e.g., Hoang et al. (2016), we will model our regressions based on the natural logarithms of the series under study to ensure better distributional properties.

4. Results and interpretations

In this section, we will first present some descriptive statistics of the variables as well as the results of the unit root tests, taking structural breaks into account. In the second subsection, we will analyse the results of the asymmetric cointegration tests (NARDL, Shin et al. 2014). Finally, we will detail the asymmetric causalities between the variables based on the Hatemi-J (2012) test.

4.1. Descriptive statistics and unit root tests

Table 3 presents the results of the descriptive statistics and pair-wise correlations. We note that energy consumption is less volatile than economic growth and capital. Financial development is highly volatile compared with economic growth, energy consumption and capital. Labour has the lowest volatility, which suggests that the labour force has been stable from 1960 to 2015 in India. Furthermore, the data show an asymmetric distribution (see Skewness in Table 3).

As for the distribution of the series, we do not find a bell shape.[10] The Jarque-Bera statistics reveal the non-normal distribution of the series. These two characteristics of the series show the necessity of relying on asymmetric methods, as we do in this study. In the correlation analysis, we find a positive correlation between energy consumption and economic growth. Financial development is positively correlated with economic growth and energy consumption. A positive correlation is also found between capital and economic growth and between energy consumption and financial development. Labour force is positively correlated with economic growth, energy consumption, financial development and capital.

Table 3: Descriptive statistics and pair-wise correlations

Variable	Y_t	E_t	F_t	K_t	L_t
Mean	32385.06	363.1979	10533.27	8067.963	58.8983
Median	24134.27	330.9751	6007.104	5301.509	57.7425
Maximum	86579.14	639.4249	45583.94	25397.04	65.5957
Minimum	15203.85	232.0468	1171.907	1940.468	55.2194
Std. Dev.	19237.91	112.791	12011.13	7094.954	3.1069

[9] More details can be found in Hatemi-J (2012).
[10] Detailed results are available upon request.

Skewness	1.3231	0.9170	1.6063	1.3178	0.7103
Kurtosis	3.6869	2.8649	4.3597	3.4415	2.2223
Jarque-Bera	17.4426	7.8913	28.3970	16.6645	6.1201
Probability	0.0001	0.0193	0.0000	0.0002	0.0468
Y_t	1				
E_t	0.2271	1			
F_t	0.1970	0.5010	1		
K_t	0.3323	0.3596	0.3567	1	
L_t	0.3029	0.4210	0.3980	0.5901	1

Notes: FD denotes financial development; Y denotes economic growth; EC denotes energy consumption; K denotes capital; and L denotes labour.

The next step is to test the variables' stationarity properties to ensure that none is integrated at order 2 or I(2). These tests must be performed because the NARDL model of Shin et al. (2014) requires that the variables be integrated at orders 0 or 1 to examine the cointegration between the variables. For this purpose, we have applied the Augmented Dickey-Fuller (ADF, 1979), Phillips-Perron (PP, 1988) and Kwiatkowski et al. (KPSS, 1992) unit root tests, and Table 4 presents the results of these tests. The empirical evidence reported by the ADF unit root test shows that economic growth, energy consumption, financial development, capital and labour contain a unit root at levels associated with the intercept and trend. After being differenced once or integrated at order 1, the variables are found to be stationary. The PP and KPSS unit root tests generate similar empirical evidence.

Table 4: Unit root analysis without structural break

Variables	ADF		PP		KPSS	
	Level	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**
Y_t	3.1851 (9)	-3.0357 (8)**	6.3287 (0)	-7.6775 (17)***	1.8564 (11)***	1.3818 (6)
E_t	1.1253 (9)	-3.2709 (8)**	1.4551 (7)	-7.3955 (19)***	1.8957 (11)***	0.3514 (7)
F_t	2.1204 (9)	-2.3291 (8)*	5.3989 (2)	-8.4590 (22)***	1.8855 (11)***	1.4283 (7)
K_t	0.9300 (13)	-3.1927 (12)**	0.9953 (5)	-7.4546 (20)***	1.9097 (11)***	0.2692 (5)
L_t	-2.0495 (5)	-3.9202 (3)**	-2.4578 (3)	-3.6657 (3)**	2.1019 (9)***	0.9876 (5)

Notes: ***, ** and * show significance at the 1%, 5% and 10% levels, respectively. The optimal lag length for testing the unit root properties of the variables appears in parentheses.

Perron (1989) noted that the unit root problem in the series may cause structural changes, and researchers should remember that traditional unit root tests may provide biased empirical results. These tests may accept a false null hypothesis by stating that a series is stationary but that a structural break may occur. This potential bias raises the issue of developing a unit root test that contains information on structural breaks in the series to achieve reliable empirical results. Furthermore, Kim and Perron (2009) argued that traditional unit root tests provide ambiguous results due to their low explanatory power and poor size distribution, as structural breaks are treated asymmetrically not only in the null hypothesis but also in the alternative hypothesis. This issue is solved by applying the ADF unit root test that contains a single unknown structural break in the data developed by Kim and Perron (2009). Furthermore, this test accommodates a structural break point in the trend function with an unknown date in both the null hypothesis and alternative hypothesis. Table 5 presents the test results.[11]

Table 5: Unit root analysis with an unknown structural break

Variable	ADF Test at Level		ADF Test at 1st diff.	
	Statistics	**Break Date**	**Statistics**	**Break Date**
Y_t	1.0630	2002Q2	-4.6012***	1993Q1
E_t	-0.1100	2003Q2	-4.4788***	2003Q1
F_t	-1.6082	1998Q1	-4.2886**	1998Q1
K_t	-1.0669	1994Q2	-4.2192**	2011Q1
L_t	-2.1487	1979Q4	-4.5071**	1966Q1
Significance				
CV 1%	-4.949133			
CV 5%	-4.443649			
CV 10%	-4.193627			
Notes: *** and ** show the significance at the 5% and 10% levels, respectively.				

The variables are found to be non-stationary in the presence of structural breaks that occurred in 2002Q2, 2003Q2, 1998Q1, 1994Q2 and 1979Q4 for economic growth, energy consumption, financial development, capital and labour, respectively. Indeed, over the sample period, India implemented numerous economic, energy and financial policies to improve its macroeconomic performance. For example, the liberalization strategy that was adopted in the 1990s through the 2000s affected domestic production and, in turn, the overall growth of the India's economy. After the dismantling of the Administrative Pricing Mechanism (APM) on 1 April 2002,[12] India's government continued to fix the prices of liquefied petroleum gas (LPG) and kerosene oil for end users. As a consequence, the government subsidized national oil companies for the production of LPG and kerosene oil, which affected the energy demand. Furthermore, government policies to supply quality energy to the manufacturing sector also affected the energy demand in 2002. Similarly, financial reforms imposed by the International Monetary Fund (IMF) in the early 1990s also affected the financial sector's performance and increased capitalization.[13] In the first difference, economic growth, financial development, capital and energy consumption are stationary, which indicates that all the variables have the same integration order I(1). The existence of a unit root leads us to apply the NARDL bounds testing approach to examine the asymmetric cointegration among energy consumption, financial development, capital, labour and economic growth. The next subsection presents the test results.

[11] We considered both the intercept and the trend while applying the ADF structural break unit test.

[12] As a step towards free market pricing, the APM was dismantled in India on 1 April 2002. This step implies the removal of an administered pricing mechanism of petroleum products, such as petrol, diesel, kerosene and liquefied petroleum gas (LPG). Prior to 1 April 2002, the domestic prices of some petroleum products were partially insulated from volatile international crude oil prices (from which these products are derived), and some products were subsidized because of its wide scale usage among the oil consumers and companies in India. However, continuing with this practice was seemingly unsustainable, as the burden of energy subsidies was not only undermining India's fiscal sustainability but also reducing its energy security through investment shortfalls. These discussions also reveal that India's government has taken serious steps to deregulate energy prices from an APM regime (https://www.dnb.co.in/IndiasEnergySector2012/OilPrice.asp).

[13] As such, the implementation of economic, energy and financial reforms also affected domestic output and energy consumption.

4.2. Cointegration results

The NARDL (Shin et al. 2014) results are shown in Table 6.

Table 6: Cointegration results

Dependent Variable: Y_t			
Variable	**Coefficient**	**T-Statistic**	**Prob.**
Constant	1.7063***	7.5549	0.0000
Y_{t-1}	-0.2070***	-7.5469	0.0000
F^{+}_{t-1}	-0.0289***	-5.1273	0.0000
F^{-}_{t-1}	0.0721**	2.0828	0.0385
E^{+}_{t-1}	0.1038***	4.6360	0.0000
E^{-}_{t-1}	-0.5788**	-3.2785	0.0012
K^{+}_{t-1}	0.0666***	5.5533	0.0000
K^{-}_{t-1}	0.0737*	1.8286	0.0689
L^{+}_{t-1}	1.3996***	5.2177	0.0000
L^{-}_{t-1}	**-0.1214**	-0.6469	0.5184
$D_{2002-QII}$	0.0081**	2.4800	0.0141
ΔY_{t-1}	0.4616***	7.7617	0.0000
ΔY_{t-2}	0.2155	3.5486	0.0005
ΔF^{-}_{t}	0.3148***	4.3628	0.0000
ΔE^{-}_{t}	-1.1696***	-2.6400	0.0089
ΔK^{+}_{t}	0.2168***	5.3810	0.0000
ΔK^{-}_{t}	0.3000***	4.8718	0.0005
ΔK^{+}_{t-1}	-0.0991**	-2.2000	0.0275
ΔK^{+}_{t-2}	-0.0965**	-2.2866	0.0223
ΔK^{-}_{t-1}	-0.1138***	-1.8571	0.0648
ΔL^{+}_{t}	8.4480***	3.0391	0.0027
ΔL^{+}_{t-1}	-5.2268*	-1.8899	0.0602
R^2	0.6631		
Adj-R^2	0.6293		
D-W Test	2.0377		
χ^2_{SC}	1.3611	[0.2587]	
χ^2_{HET}	1.2780	[0.2322]	
χ^2_{FF}	1.4020	[0.1090]	
L^{+}_{F}	-0.1400***	L^{-}_{F}	0.3482**
L^{+}_{E}	0.5016***	L^{-}_{E}	2.7961***
L^{+}_{K}	0.3218***	L^{-}_{K}	0.3560***
L^{+}_{L}	6.7614***	L^{-}_{L}	-0.5867
$W_{LR,F}$	7.3811***	$W_{SR,F}$	13.2161***
$W_{LR,E}$	8.0114***	$W_{SR,E}$	16.9004***
$W_{LR,K}$	9.0610***	$W_{SR,K}$	19.1180***

$W_{LR,L}$	23.8206***	$W_{SR,L}$	16.6276***
F_{PSS}	9.3023***		
T_{BDM}	-7.5469***		

Notes: The superscripts "+" and "-" denote positive and negative variations, respectively. L^+ and L^- are the estimated long-run coefficients associated with positive and negative changes, respectively, as defined by $\hat{\beta} = -\theta / \rho$ (section 3.2.1). $D_{2002QII}$ is a dummy variable that equals 1 when *t* equals 2002Q2. This date is the structural break date for the dependent variable, which is determined by the Kim and Perron (2009) test above. χ^2_{SC}, χ^2_{FF} and χ^2_{HET} denote LM tests for serial correlation, functional form and heteroscedasticity, respectively. W_{LR} and W_{SR} represent the Wald test for the null of long-term and short-term symmetry for the respective variables. F_{PSS} shows the statistics from the Pesaran et al. (2001) bounds test. T_{BDM} shows the statistics from Banerjee et al. (1998). The p-values appear in brackets. ** and *** indicate significance at the 5% and 1% levels, respectively.

First, we note that financial development, energy consumption, capital and labour explain 66.31% (R^2 = 0.6631) of economic growth. Therefore, financial development, energy consumption, capital use and labour explain 66.314% of economic growth, and the error term in the model explains the rest of the variation in economic growth (33.69%). The Durbin Watson (DW) test statistic is 2.0377, indicating the absence of autocorrelation in the model estimation. This result implies that the variables considered in the production function can explain the variation in economic growth in the absence of autocorrelation. We also note the absence of serial correlation (χ^2_{SC}) and White heteroscedasticity (χ^2_{HET}). The functional form of the empirical model is well-designed and confirmed by the Ramsay Reset test (χ^2_{FF}). This finding indicates the reliability and consistency of the empirical results. More importantly, we find that the F-statistic exceeds the upper critical bound at the 1% level of significance, which confirms the presence of cointegration among financial development, energy consumption, capital, labour and economic growth for the period of $1960Q_1$–$2015Q_4$. The Wald tests show the significance of asymmetry for both the long run and short run, which implies that taking nonlinearity and asymmetry into account is important when studying the relationship between economic, financial and energy variables. The t-statistic (T_{BDM}) developed by Banerjee et al. (1998) validates the cointegration of the variables at the 1% significance level. The NARDL F-statistic (F_{PSS}) from Shin et al. (2014) confirms the existence of asymmetric cointegration among the variables, which indicates that energy consumption, financial development, capital, labour and economic growth have a long-run asymmetric association in the Indian economy. This finding confirms the importance of taking asymmetry into account when studying the relationship among these variables. More detailed results are presented below.

In the long term

A positive shock in financial development has a negative and significant effect on economic growth (a significant coefficient of -0.0289), which indicates that any positive shock to financial development hampers economic growth in India. During the development of the Indian banking sector in the 1990s,[14] India followed an easy monetary policy to enhance credit allocation to the private sector at lower costs. This policy enabled people (e.g., households and businesses) to access financial resources to mitigate their consumption and investment activities. In this context, the negative coefficient indicated above thus suggests that credit allocated to people by the banking sector was not invested properly. People may have carelessly consumed and invested borrowed money for unproductive consumption and investment activities. This inefficiency in credit use diminishes the potential growth of the Indian economy. By contrast, a negative shock in financial development is positively linked with economic growth (a coefficient of 0.0721). This finding implies that any negative shock to financial development plays a stimulating role in India's long-term economic growth. If an easy monetary policy (promoted by the Central Bank, for example) leads to an inflationary situation, then commercial banks are asked to increase the interest rate (costs of borrowing) on both consumer and investment loans. At the same time, commercial banks are also asked to increase the interest rate on banking deposits to maintain price stability. Such conventional tight monetary policy reduces the level of credit granted to various economic sectors (e.g., households and business firms). This explanation further reveals that a negative shock to the development of the banking sector can create a predictable rationality in the minds of consumers and investors, whereby further credit expansion will be limited. Hence, they tend to become much more careful about the future productive use of loans granted by the banking sector. As a result, the economy's real production and growth are enhanced.

In the long term, energy consumption (positive shock) always positively affects economic growth (with a coefficient of 0.1038), indicating that any positive shock to energy consumption plays an enabling role in stimulating growth and development in the Indian economy. Both economic growth and energy demand are highly correlated in the long term, which explains this finding. We also find that a negative shock in energy consumption has a negative effect on economic growth (with a coefficient of -0.5788). This negative coefficient indicates that any negative shock to energy consumption will hamper economic growth in India. For instance, if the Energy Conservation Act[15] (ECA 2001) by India's government took effect due to unpredictable climate change and global warming, various sectors would be directed to reduce excessive

[14] India's banking sector was initially composed of 28 public sector banks—the majority government-owned—23 private banks and 27 foreign banks. Private sector banks were barred from the banking market after the nationalization of 14 private commercial banks on 19 July 1969. In 1980, 6 additional commercial banks were nationalized. After this period, the public sector expanded their banking activities, and the nationalization of private commercial banks created a new chapter in Indian banking history, primarily for two reasons. First, the central government needed financial help in monetizing the fiscal deficit and thus took ownership of these banks. Second, the central government took ownership of 20 private commercial banks between 1969 and 1980 to increase the confidence level of the people. Other important changes were implemented after 1990. First, the market was opened up to private sector banks and foreign banks. Second, the regulations that governed the establishment of branches were amended. Third, regulations relating to lending were eased. Fourth, public sector banks were allowed to procure financial resources from the stock market up to 49% of their paid capital. The state of affairs began to change after 2000. The government adopted a policy of converting financial institutions into banks, and the Industrial Credit and Investment Corporation of India (ICICI) became a bank in 2001, followed by Industrial Development Bank of India (IDBI) in 2004. During this period, one public sector bank and four private sector banks were established, and 16 foreign banks entered the market. In March 1991, foreign banks had 151 branches in India, increasing to 205 branches by March 2001 and to 295 branches by March 2009 (Khan and Fozia 2013).

[15] The main objective of the ECA (2001) is to reduce the long-run demand for energy consumption and to achieve sustainable economic development. Moreover, the novelty of this act shows that India is not worse off by reducing the intensity of energy consumption, which is required for the production and consumption of goods and services; the Indian economy has been able to maintain a high growth momentum over the years.

energy use. This negative shock to energy demand would eventually reduce the expansion of various economic activities and thereby lower economic output and growth in the long term. Drawing on our understanding of these discussions, we urge the Indian government and policymakers to be very careful and sensible in harnessing the effective use of energy in various productive sectors of the economy through proper energy efficiency channels. Doing so allows for the reduction of energy consumption while maintaining economic growth.

In the long term, positive shocks in capital always have positive effects on economic growth (a coefficient of 0.0666). Any positive shock to capital warrants greater long-term fiscal investments in infrastructure development and thereby increases economic growth in the long term. From a policy perspective, both policymakers and governments in emerging countries, such as India, should always monitor productive capital investments when designing public policy that aims to achieve sustainable long-term economic growth and development. By contrast, negative shocks in capital also have a positive effect on economic growth (a coefficient of 0.0737). However, this coefficient is significant only at the 10% level, indicating that capital formation is the ultimate engine of economic growth in India.[16] This finding is also consistent with the results of Sahoo and Dash (2009) for India and Sahoo et al. (2010) for China, who find a positive effect of capital formation on economic growth. Although the positive effect of capital on economic development has been well documented in the literature, surprisingly, the positive effect of a negative shock in capital formation on economic growth is found in India. This may be possible in the sense that the distinctive developmental feature of the Indian economy is accepted with added characteristics from both the agriculture sector and the industrial sector. The agriculture sector in India mostly operates with a capital shortage (e.g., a negative shock in capital formation), coupled with labour abundance that not only produces disguised labour unemployment but also creates productivity losses in existing surplus labour. Increasing labour unemployment and productivity losses are the products of the capital shortage in the agriculture sector, which may harm economic growth in the long run. However, the harmful effect of a negative shock to capital formation on economic growth may not occur in the Indian case mainly due to the better connectivity between the agriculture and industrial sectors. The industrial sector normally absorbs excess labour from the agriculture sector for its own production purposes. As a result, increasing labour employment in the industrial sector will not only increase the efficiency level of the agriculture sector but also increase economic growth in India.

Finally, the relationship between a positive shock in the labour force and economic growth is positive and significant (a coefficient of 1.3996). However, a negative shock in the labour force does not have a significant impact on economic growth. The positive impact of an increased labour force on economic growth shows that any policy in India that aims to increase the level of labour employment will not only stimulate consumption and investment activities but also contribute to economic growth. As such, policymakers in India should consider the labour force an important determinant of economic growth, mainly in the augmented production function. By contrast, a negative shock in the labour force has an insignificant effect on economic growth in India. Increased life expectancy and a lower fertility rate due to an ageing population are accepted as the most important demographic factors that reduce the number of young working-age people participating in the total labour force, which explains this insignificant effect (Yenilmez, 2015). This reduced participation further increases the proportion of the older people

[16] The role of capital formation in economic growth and development has been well established in the field of macroeconomics (Aschauer, 1989; World Bank, 1994; Sahoo and Dash, 2012; Sahoo et al., 2010).

in the labour force and thereby limits the growth of the total labour supply in the economy. Such a negative shock in the labour force does not have any effect on economic growth, which may be due to the increasing retirement age in India. Moreover, increasing the retirement age is only one factor that resolves the labour supply shortage, along with maintaining a similar trend of Indian economic growth in the short run.[17] Our finding is not consistent with the recent results of Ismail et al. (2015) for the Malaysian economy, where they have found that a declining fertility rate contributes to higher economic growth.[18] However, our finding predicts that Indian economic growth may not be stable in the long run mainly due to the ageing population. We argue that, to have a stable 'growth miracle' for the Indian economy and a constant age structure over time, policymakers in India must consider taking advantage of the demographic dividend associated with increasing the employment of the young working-age population in the total labour force. India represents an emerging economy with a relative abundance of labour, where the population is assumed to be very young; as such, the Indian government should recognize the young population as a gift or a demographic dividend by providing them with an essential skill-based education in the long run.

In the short term

A negative shock in financial development is positively related to economic growth (a coefficient of 0.3148), which shows that, due to increasing borrowing costs, the limiting credit multiplier practice in the banking sector will not reduce economic growth in India. Indeed, the number of loans granted by the banking sector at higher interest rates will serve as a worthy lesson to various types of borrowers; they will learn to use borrowed money more efficiently, especially in the short term. This understanding becomes important for borrowers because, unless they use money in a productive manner, they will fail to repay the principal amounts and higher interests. If such failures occur, the borrowers' lack of creditworthiness will be highly visible to financial institutions, which, in turn, will deny them further credit. As such, we also believe that granted loans will be effectively used by borrowers for productive purposes and will thus contribute to greater economic growth in the short term.

In addition, we find that energy consumption (a negative shock) is negatively linked to economic growth in the short term (a coefficient of -1.1696). An adverse effect of a negative shock in energy consumption on economic growth is possible in respecting any energy conservation act proposed by any government. If producers make any attempt to reduce energy usage in production activities, economic growth will be diminished in the short term in India. For capital use, both positive and negative shocks have a positive impact on economic growth in the very short term (at lag 0, coefficients of 0.2168 and 0.3, respectively). However, a positive shock in capital in the previous periods (lags 1 and 2) is negatively linked with economic growth (coefficients of -0.0991 and -0.0965, respectively). A negative shock (at lag 1) has an inverse relationship with economic growth (coefficient of -0.1138). These findings highlight the important role of capital use in short-term economic growth, as any positive shock to capital formation in the previous period will have an adverse effect on economic growth in the following period. These findings further imply that, if the Indian government gives greater investment priority to infrastructure development in the previous period, the economic output in

[17] See a recent study by Yenilmez (2015) for the economic consequences of population ageing in the 21st century.

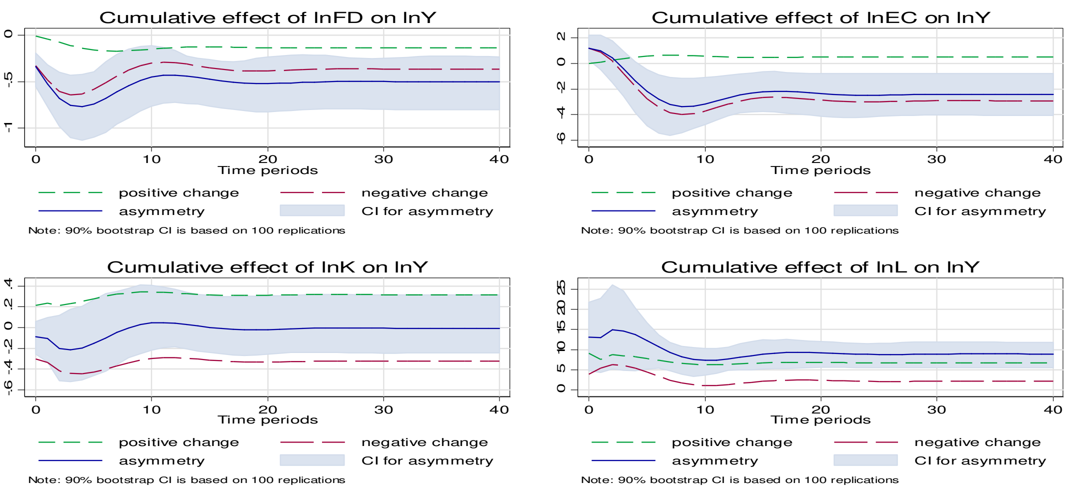
[18] Our finding is also consistent with the results of Lahoti and Swaminathan (2013), who fail to find a significant long-run relationship between female labour force participation and economic development in India.

the present period will not be greatly affected. Positive shocks in labour increase economic growth in the same period (coefficient of 8.448 at lag 0), but positive shocks in the labour force in the previous period significantly decrease economic growth in the present period (coefficient of -5.226 at lag 1). For instance, although the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA, 2005) has been implemented in India, the rural poor have been unable to benefit from this scheme, which may be due to the lack of effective implementation at a district level. Hence, the positive shock to the labour force will increase unemployment and thus undermine economic growth. On policy grounds, we suggest that fiscal governments in India need to check the effective implementation of the Employment Guarantee Act to increase long-run economic growth. Last, a dummy variable ($2002Q_{II}$) has a positive and significant impact on economic growth (a coefficient of 0.0081), which implies that the liberalization adopted in the 1990s and 2000s has proved to be a fruitful tool for enhancing domestic production and, in turn, economic growth (see Section 4.1. for more details).

Finally, we applied multiple dynamic adjustments (more details in Section 3.2.1). The results are shown in Figure 2, which plots the cumulative dynamic multipliers. These multipliers show the pattern of adjustment of economic growth in its new long-term equilibrium following a negative or positive unitary shock in energy consumption, financial development, capital and labour, respectively. The dynamic multipliers are estimated based on the best-fitted NARDL model chosen by the AIC. The positive (continuous black line) and negative (dashed black line) curves capture the adjustment of economic growth to positive and negative shocks of the above-mentioned variables at a given forecast horizon, respectively. The asymmetric curve (continuous red line) reflects the difference between the dynamic multipliers associated with positive and negative shocks, i.e., $m_h^+ - m_h^-$. This curve is displayed with its lower and upper bands (dotted red lines) at a 95% confidence interval to provide a measure of the statistical significance of asymmetry at any horizon h.

The graphs in Figure 2 confirm the existence of an overall positive relationship between energy consumption and economic growth. The effect of a positive shock in energy consumption is found to dominate that of a negative shock with an initial positive effect. Moreover, a significant asymmetric response to shocks in energy consumption is observed. Similarly, we note the positive association between financial development and economic growth. This result indicates that a positive shock in financial development dominates a negative shock in financial development. Thus, the role of a positive shock in financial development exceeds that of a negative shock in financial development on economic growth in the long term. This finding confirms that the long-term coefficient of a positive shock in financial development is higher than that of a negative shock in financial development (0.0721 vs -0.0289, see Table 6). Furthermore, an overall positive association exists between capital and economic growth because negative shocks in capital have dominating positive effects on economic growth. However, a positive shock in labour dominates its negative shock. This finding confirms the previous result, in which a negative shock in labour has an insignificant impact on economic growth.

Figure 2: Dynamic multiple adjustments of economic growth to a unitary variation of energy consumption, financial development, capital and labour



Notes: FD denotes financial development; Y denotes economic growth; EC denotes energy consumption; K denotes capital; and L denotes labour.

4.3. Asymmetric causalities between energy consumption, financial development and economic growth in India

As explained in Section 3.2.2, we also applied asymmetric and non-asymmetric causality tests of Hatemi-J (2012) to examine the causality between energy consumption, financial development, capital, labour and economic growth in India. The results are reported in Table 7.

Table 7: The asymmetric and non-asymmetric causality analysis

Causalities	Test value	CV at 1%	CV at 5%	CV at 10%
$Y_t \neq E_t$ *(1)*	8.578	25.928	20.525	17.860
$Y_t^+ \neq E_t^+$ *(2)*	0.053	13.874	7.712	5.040
$Y_t^- \neq E_t^-$ *(3)*	10.470	25.932	16.114	11.633
$E_t \Rightarrow Y_t$ *(4)*	32.510***	28.791	22.324	19.152
$E_t^+ \neq Y_t^+$ *(5)*	0.0790	11.119	7.158 0	5.0140
$E_t^- \Rightarrow Y_t^-$ *(6)*	77.538***	51.963	17.024	10.875
$Y_t^+ \neq F_t^+$ *(7)*	1.637	10.112	6.547	4.768
$Y_t^- \neq F_t^-$ *(8)*	0.783	21.096	7.765	4.515
$Y_t \Rightarrow F_t$ *(9)*	30.994***	28.472	22.248	18.982
$F_t^+ \neq Y_t^+$ *(10)*	0.602	10.149	6.399	4.877
$F_t^- \Rightarrow Y_t^-$ *(11)*	12.483**	25.743	9.004	4.622
$F_t \Rightarrow Y_t$ *(12)*	12.483**	25.743	9.004	4.622
$Y_t \neq K_t$ *(13)*	16.690	28.305	21.146	18.144
$Y_t^+ \neq K_t^+$ *(14)*	1.557	9.743	6.940	5.278
$Y_t^+ \neq K_t^-$ *(15)*	1.245	15.138	7.769	4.517

$K_t^+ \neq Y_t^+$ *(16)*	0.270	11.142	6.575	4.816
$K_t^- \neq Y_t^-$ *(17)*	1.006	17.192	6.259	4.090
$K_t \Rightarrow Y_t$ *(18)*	17.515*	26.180	21.044	17.326
$Y_t \neq L_t$ *(19)*	5.837	31.893	20.647	17.519
$Y_t^+ \neq L_t^+$ *(20)*	1.935	11.482	6.706	4.850
$Y_t^- \neq L_t^-$ *(21)*	0.386	13.992	7.116	4.831
$Y_t \neq L_t$ *(22)*	9.813	29.612	22.604	18.958
$L_t^+ \neq Y_t^+$ *(23)*	0.371	8.546	6.069	5.095
$L_t^- \neq Y_t^-$ *(24)*	1.084	13.616	7.023	4.968
Notes: The figures in parentheses indicate the line that will facilitate the interpretation of results. $\neq / \Rightarrow$ indicates no causality / unidirectional causality, respectively. CV denotes the critical value. The information criterion used for lag selection is the Hatemi-J Criterion (HJC). An extra unrestricted lag was included in the VAR model to account for the effect of a unit root, as suggested by Toda and Yamamoto (1995). *, ** and *** show significance at the 1%, 5% and 10% levels, respectively.				

From Table 7, a neutral effect is noted between positive shocks in energy consumption and economic growth (line 5), but a negative shock in energy consumption is found to cause a negative shock in economic growth (line 6). The symmetric causality between economic growth and energy consumption is unidirectional (line 4), running from energy consumption to economic growth. This empirical evidence is consistent with Paul and Bhattacharya (2004), Wolde-Rufael (2010),[19] Alam et al. (2011) and Mahalik and Mallick (2014). However, when we observe the asymmetric results, they are only true for a negative shock in energy consumption (line 6). Previous studies have not addressed this result because the asymmetric effect has not been investigated. However, this finding partly supports the findings of Mallick (2009), Mandal and Madheswaran (2012), and Shahbaz et al. (2016), who report a feedback effect between energy consumption and economic growth. Energy conservation policies are thus suggested to impede economic growth, which, in turn, reduces energy demand (positive causality from negative shocks in energy consumption to negative shocks in economic growth, line 6). This finding again underlines the importance of considering the asymmetric causality between energy consumption and economic growth.

The asymmetric causal relationship between positive shocks in financial development and economic growth is not significant (line 10). This finding reveals that the relationship between domestic financial development and economic growth appears to be neutral, as increasing economic output and growth do not necessarily depend on positive shocks to financial development, and vice versa. Any fiscal and monetary efforts to expand financial services to people will not increase economic output and growth. However, the unidirectional causality is confirmed to run from a negative shock in financial development to a negative shock in economic growth (line 11). A negative shock in financial development will thus hamper economic growth in India. For example, following the increasing prices of goods and services, monetary policy is forced to use a contractionary policy mechanism by increasing the costs of borrowing (interest rates) to maintain price stability. An increasing interest rate on borrowed amounts becomes expensive for people seeking credit from financial institutions. This expense

[19] Wolde-Rufael (2010) used nuclear energy consumption as a measure of energy use.

leads to a decrease in credit demand, thereby reducing economic output and growth. Therefore, negative shocks in financial development may have negative impacts on economic growth. The symmetric causality analysis reports that financial development causes economic growth (line 12), a supply-side effect; in return, economic growth causes financial development (line 9), a demand-side effect. This finding contrasts with Chakraborty (2010), who reported that stock market development plays a minor role in stimulating the domestic economy. Similarly, Pratap and Kumar (2014) reported that financial development plays an insignificant role in economic growth. However, the empirical findings of Sehrawat and Giri (2015) validated the presence of a supply-side effect for the Indian economy.

By contrast, we find no significant causality between financial development and energy consumption,[20] which indicates that increasing financial development will not increase energy demand, and vice versa. In this case, adding financial development to the energy demand function will not help policymakers in India reduce the target level of energy use for the sake of better environmental quality. Policymakers should instead promote financial development by adding potential variables other than energy consumption, as it has no effect on financial development. This result confirms that of Sehrawat et al. (2015) for India, Coban and Topçu (2013) for European countries, that of Shahbaz et al. (2013a) for China and that of Aytay and Topçu (2015) for Turkey.

A neutral effect is found between positive shocks in capital and economic growth (line 16). A similar result is also found for negative shocks in capital and economic growth (line 17). In the symmetric causality results, we find that economic growth does not Granger-cause capital; instead, capital Granger-causes economic growth (lines 18 and 19). This finding implies that economic growth is not possible in the absence of capital formation but that capital formation is possible in the absence of economic growth. From a policy perspective, we suggest that any fiscal policy designed to reduce gross fixed capital formation will hamper economic growth. Similarly, Mehta (2009) indicated that capital formation plays a vital role in enhancing the domestic economy and thus promotes economic growth.

Finally, we note the neutral causal effect (both in symmetric and asymmetric analyses) between the labour force and economic growth in India (lines 20 to 24). This finding further suggests that the Indian economy can grow and prosper without a substantial contribution from the labour force in the short run. Alternatively, it confirms that the growing pace of the Indian economy may be intensified with continued support from capital formation in the exogenous production function, where greater technological progress plays a vital role rather than the labour force. Above all, this noteworthy finding is consistent with the recent empirical results of Lahoti and Swaminathan (2013), who also find a non-significant long-run relationship between the female labour participation rate and economic growth in the Indian case. This may be possible thanks to the stability of the labour force in India within the study period, as shown by its low standard deviation in Table 3. On policy grounds, these results suggest that policymakers in India should pay less attention to the role of the labour force when augmenting the production function. Such policy further justifies India's reduced spending attitude towards labour market development in the short run.

[20] The results regarding the causality between the independent variables are not shown in Table 7, but they are available upon request.

5. Conclusion and Policy Implications

This paper applied a neo-classical augmented production function in examining the relationship between energy consumption and economic growth by incorporating financial development, capital and labour into the Indian economy. The study used quarterly frequency data for the 1960Q1-2015Q4 period. Furthermore, we employed the nonlinear and asymmetric ARDL cointegration approach developed by Shin et al. (2014). The causal relationship between the variables was investigated with the asymmetric Granger causality test developed by Hatemi-J (2012). The empirical results provide strong support for the presence of an asymmetric cointegration association between the variables under study. The causality results also show the importance of considering asymmetry, as we will demonstrate below.

If we only relied on symmetric analysis, we would be unable to conclude that only negative shocks in energy consumption have negative impacts on economic growth. By contrast, positive shocks in energy consumption do not have a substantial impact on economic growth. This finding is important because it suggests that any policy that aims to reduce energy consumption in India will impede economic growth but that an increase in energy consumption will not be the solution to improve economic growth in India. In this case, the Indian government should maintain stable energy consumption but not reduce it. To do so, the government can make efforts to encourage the use of more energy-saving technologies in various sectors' production and consumption activities and the efficient harnessing of given energies through the proper channels.

As for the interaction between financial development and economic growth, the results show that taking asymmetry into account is important. Indeed, a positive shock in financial development does not affect economic growth, but a negative shock in financial development hampers domestic economic output. For instance, the recent Financial Stability Report (2016) of the Reserve Bank of India (RBI) reveals increasing non-performing assets (NPAs) or bad loans mainly in the Indian public sector and scheduled commercial banks. This report shows that both the public sector and scheduled commercial banks have imprudently lent large sums of money to large corporations[21] without evaluating their creditworthiness (Ranjan and Dhal, 2003).[22] Eventually, these banks reported losses due to the payment failures of large corporations in India. The greater losses in these banks not only harm their balance sheets due to unrealistic lending practices in relation to large corporations but also adversely affect Indian macroeconomic performance as a whole. In such circumstances, we hint that the monetary policy committee (MPC) in India should direct both the public sector and scheduled commercials banks to advance their credit allocation only towards productive sectors by tightening credit provisioning rules for the bad loans that they generated in the economy. If such a policy continues in right direction, then the credit expansion of these banks in an ethical monetary policy framework will be unlikely to undermine India's economic growth in the long run. From a policy perspective, this result further suggests that policymakers in India should carefully check the proper allocation of financial resources across various competing consumption and business activities to minimize

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[21] The FICCI-based Indian Banking Association Report recently showed that corporate loans comprised 62% of total loans, followed by 38% of retail loans during the July–December 2015 period.

[22] Banks' lending policies are a major driver of non-performing loans (McGoven, 1993, Sergio, 1996; Bloem and Gorters, 2001). In a seminal study on the Indian banking literature, both Mohan (2003) and Reddy (2004) argue that Indian public sector banks' careless lending policies, coupled with the lack of an improved credit culture, are very much crucial in determining the increase of non-performing loans.

the negative consequences of growth, such as increasingly stressed assets in the public sector and scheduled commercial banks.

However, regarding capital formation, we find symmetric unidirectional causality running from capital to economic growth, which implies that capital is vital for achieving long-run economic growth. For sustainable economic growth, we suggest that fiscal governments in India invest more money in establishing better infrastructure development. In addition, policymakers should augment the production function by adding capital as a growth-enhancing determinant in the Indian economy. If collaboration and better understanding between fiscal governments and policymakers in India continue to fail, then the Indian economy will be more likely to grow and prosper, but the level of development will not be sustainable. As a consequence, retarding "people and energy poverty" will remain a serious challenge for the Indian economy in the future.

Finally, we find no significant causal relationship between the labour force and economic growth in India over the study period, which shows that economic growth is possible without heavy investments in the labour force. The simple reason for this finding is that, in the age of technology, producing agricultural output is becoming much easier. With rapid economic growth and advancing urbanization, the labour force is migrating to urban areas in search of better job opportunities. As a result, farmers in the Indian agriculture sector also experience the labour shortage and, in turn, tend to utilize new technologies for better production. As such, agricultural output is expected to increase with the help of technology. Finally, we suggest that policymakers in India protect the rapid and environmentally friendly growth of the Indian economy by adding 'energy-saving' and 'growth-stimulating' technologies to the production function.

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