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# How did the US economy react to shale gas production revolution? An advanced time series approach

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ABSTRACT

This paper aims at examining the impacts of shale gas revolution on industrial production in the US. To this end, this paper, first, throughout literature review, exposes the features of shale gas revolution in the US in terms of energy technology and energy markets. However, the potential influences of shale gas extraction on the US economy are not explicit in the existing literature. Thus, considering mainly the output of shale gas revolution on the US economy in this research, later, the paper conducts econometric models to reveal if there exists significant effect(s) of shale gas revolution on the US economy. Therefore, the paper employs unit root tests and cointegration tests by following relevant US monthly data from January 2008 to December 2013.

Then, this paper observes long run impact of shale gas production on industrial production in the US through dynamic ordinary least squares estimation with dummy structural breaks and conducts Granger causality test based on vector error correction model. The dynamic ordinary least squares estimator explores that shale gas production has a positive effect on industrial production. Besides, the Granger causality test presents that shale gas production Granger causes industrial production in the long run. Based on the findings of the long run estimations, the paper yields that industrial production is positively related to shale gas production. Eventually, upon its findings, this paper asserts that (i) the shale gas revolution in the US has considerable positive effects on the US economy within the scope of the validity of the growth hypothesis, (ii) new technologies might be developed to mitigate the possible negative environmental effects of shale gas production, (iii) the countries having shale gas reserves, as in US, may follow energy policies to utilize their shale reserves more in the future to meet their energy demand and to increase their economic welfare.



## 1. Introduction

This work underlines explicitly two facts; the one is *'The shale gas revolution'* which depicts an outstanding development in production technology, and hence, considerable increase in production volume of shale gas in the US. The other one is *'The US economy's possible potential reaction to the revolution'*. The latter issue, to the best of our knowledge, has been uncovered quantitatively so far.

In order for us to be able to measure efficiently the quantitative causality from shale gas revolution to the US economy, we follow the methodologies to conduct time series analyses of high frequency US data.

Therefore, this work employs monthly industrial production index of the US as a proxy for monthly real economic activities of the US economy. To this end, we promote our research in this work by applying quantitative analyses through time series cointegration and causality models in which one might observe the short and long term quantitative responses of US monthly industrial production to the monthly shale gas production in the US for the period 2008:1–2013:12.

This section aims at (i) explaining what the 'shale gas revolution' is, and, (ii) underlining the motivation of this paper following the notion of shale gas revolution to reveal possible response of the US

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GDP to the intensive shale gas production.

Why is shale gas production in the US considered 'a shale gas revolution'? Before the 21st Century, obtaining natural gas from shales was thought impossible since, in the 20th Century, producers used to extract the sources of water, oil and natural gas through vertical wells [1]. The US succeeded, however, to extract prominent amount shale gas by the application of horizontal drilling and hydraulic fracturing in the US [2]. These new technological applications (i) enabled the US to supply excessively the liquefied natural gas and hence, in turn, (ii) caused gas prices to diminish across the countries in general [3]. Although there also exist other countries having massive sources of shale gas, none of them, unlike the US, could catch the shale gas production boom [4]. The US natural gas production exceeded the Russian natural gas production since 1982, and, natural gas spot price in the US declined from $8.69 per million BTU in 2005 to $2.75 per million BTU in 2012 [5]. The economic impact of shale gas extraction on the US economy, is, on the other hand, ambiguous [6,7] because no study concerning the effect of shale gas on GDP and/or employment is published in the literature [7], and, hence, since there appears scientific uncertainty of shale gas' significance in the literature [6].

The US, having massive natural gas production, and, hence, facing relatively lower energy prices, aims at, also, mitigating Greenhouse Gas (GHG) emissions through the usage of shale gas. Although there available some studies observing some possible negative effects of shale gas on environment, the majority of the works published in relevant literature [8–10] emphasize the positive influence of shale gas on environment by reducing the GHG emissions. Wang et al. [9] explore that the shale gas produces less GHG emissions than the coal produces when the greater power generation efficiency is provided in the long term. On the other hand, the drilling shale gas might affect environment negatively since it needs considerable amount of water resources. The usage of large volume of underground water might bring about excessive cost of shale gas production. Rahm and Riha [11], Rahm et al. [12], and Vengosh et al. [13] consider these potential possible environmental risks of extracting shale gas in terms of water sources. As Vengosh et al. [13] specifically underline the potential risks of shale gas drilling and hydraulic fracturing on the water source quality, Rahm and Riha [11] and Rahm et al. [12] suggest that authorities follow the features of regional water resources in designating competent management strategies for shale gas development across the countries in which rich shale gas reserves are available.

The environmental impact of shale gas is out of scope of this paper. This serious subject needs be launched, of course, in some potential future studies. This paper explicitly focuses on the economic effects of shale gas revolution in the US since there is no work, to the best of our knowledge, conducting a relevant data to measure the influence of shale gas drilling on the US economy. Some reports and/or papers also verify the gap in the literature investigating economic impulses of shale gas production within microeconomic and/or macroeconomic perspectives as explained in Melo-Martín et al. [6] and Kinnaman [7].

Shale gas is the natural gas that is squeezed in rocks below ground. In contrast to methods extracting natural gas and oil, the shale gas is extracted through hydraulic fracturing method together with pressurized water. Shale gas, which is called unconventional natural gas, is evaluated as the basic factor of the structural transformation of the US energy sector [14]. Many studies in the literature use statements "Energy Revolution", "Golden Age of Gas", and "The Biggest Energy Story of the US" for shale gas of which production has increased so much in a short time [2,15–22]. In fact, the developments in shale gas appear in 1970s. In these years, the oil crisis induced the US to focus on energy issues more, and thus the US government sought alternative energy sources and made R&D expenditures on energy sources including shale gas. The Gas Research Institute was established in 1977, then the National Energy Technology Laboratory was established in 1990, and large-scale companies began to enter the energy sector as a result of advancements in R&D of alternative energy sources. A structural transformation process began due to the hydraulic fracturing method developed by these companies. Even though important improvements occurred in shale gas production during the period 1970–2000 [2], the main advancements in shale gas production appeared after the year 2000. Accordingly, while the share of shale gas in total gas supply was nearly 0% in 1990, this ratio rose to 20% in 2010 [16]. According to Energy Information Administration (EIA) [23], this ratio was 30% in 2011 and was 34% in 2012. Observing this sharp increase in shale gas production, one may claim that, in terms of today, the shale gas might be a prominent source of the natural gas supply of the US [18]. Besides, it is estimated that the US will be able to procure the required natural gas quantity during next 100 years at current consumption rates via shale gas production [2].

In the literature, two main advances are emphasized as the reasons of the boom in production of shale gas. The first one is that gas producers have improved drilling techniques much as a result of considerable investments [5,24]. The drilling techniques are defined as the techniques that were developed through the combination of horizontal drilling and hydraulic fracturing methods particularly expanded production capacity and that were utilized to explore new sources [2]. The cost of shale gas production has decreased in parallel with improvements in drilling techniques in the US. The cost of shale gas production in the US is lower than the cost of natural gas production in most of the world, and this might be the initiator for the increasing global attention on shale gas. The second reason of shale boom is the rapid increase in prices of natural gas and crude oil in the US due to the increase in demand for natural gas and crude oil and the decrease in supply of natural gas and crude oil during 2000s [10]. According to the EIA [23], the price of natural gas for residential consumers peaked at $13.89/thousand cubic feet in 2008. Similarly, the price of crude oil peaked in this period. For instance, while the price of crude oil was generally lower than 25$/barrel, it was $30/barrel, $60/barrel, and $100/barrel in 2003, 2005, and 2007, respectively, and exceeded $140/barrel in 2008 [2]. These progresses induced a boom in production of shale gas. Fig. 1 depicts production of natural gas from shale gas in the US during the period 2008.01–2013.12. The natural gas production from shales in the US, in terms of January 2008, January 2010, and, December 2013 are 234084, 406673, and, 1024749 million cubic feet, respectively. Thereby, Fig. 1 reveals sharp increases in shale gas supply in the US within relevant period.

Overall, this paper aims at examining the effects of shale gas revolution and shale gas production on industrial production in the US by employing monthly data from January 2008 to December 2013.

The contribution of this paper is threefold: First, in the energy economics literature, papers examining the impact of energy production and/or consumption on economic growth usually follow either conventional energy sources (such as coal, oil, and natural gas) or electricity generation produced from conventional sources. Due to searches for alternative energy sources and technological development, unconventional energy sources (such as shale gas and shale oil) have gained importance and have substantially been utilized in recent years. Within this outlook, when one examines the energy economics literature, he/she will observe that there exists a research gap about the relationships between unconventional energy sources and economic growth. To the best of our knowledge, this is the first paper exploring the energy-growth nexus within the framework of unconventional energy sources. Hence this paper aims at filling the relevant gap of the literature by