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# Identifying the determinants of energy intensity in China: A Bayesian averaging approach

Dayong Zhang [a,*], Hong Cao [b,c], Yi-Ming Wei [b,c]

[a] Research Institute of Economics and Management, Southwestern University of Finance and Economics, China
[b] Centre for Energy and Environmental Policy Research, Beijing Institute of Technology, China
[c] School of Management and Economics, Beijing Institute of Technology, China

## HIGHLIGHTS

- Bayesian averaging approach is used to find determinants of China's energy intensity.
- This method can reduce potential subjectivity of empirical model building.
- The relative importance of each key determining factor can be identified.
- Policy makers should have priorities and focus on relatively more important factors.

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## ABSTRACT

Facing serious energy constraints and environmental challenges, policy makers in China have set up clear targets to reduce energy intensity in order to secure a sustainable economic growth; however, it is unclear in theory what the determining forces are. The empirical evidence, although intensively discussed in the literature, also remain divided in opinion. This paper contributes to the existing literature full of heated debates using a Bayesian averaging approach to identify robust determinants of energy intensity in China. Using provincial level data, key contributors that help explain the level of energy intensity across China are found. By ranking the relative importance of explanatory variables according to their posterior inclusion probabilities, this study can also offer support to policy makers in designing intensity reduction policies. It is suggested that policies should focus on those robust and relatively more important factors such as fiscal expenditure, infrastructure and economic structure.



## 1. Introduction

Energy intensity is typically defined as the ratio of energy consumed by a country over its real output during a certain period of time. It has often been considered a proxy of a nation's energy efficiency. Since the consumption of energy relates to many key issues such as pollution and climate changes, it has strong policy relevance. As a result of decades of global economic growth after the second world war, energy demand have been increasing and there have been ever more increasing concerns on the environmental impacts of using fossil fuel. Though there are still conflict of interests and unsettled arguments, the international community has generally agreed with each other in the needs to reduce emission and protect environment.

Relative to the advanced economies who have generally achieved lower level of energy intensity, the majority of developing economies find difficulties to use energy more effectively. Taking China as an example, the level of energy consumption per unit of output has been continuously falling (see the left panel of Fig. 1) since the open up policy and economic reform in the late 1970s. However, its level is still far above Europe, the US and the world average (see the right panel of Fig. 1), and the trend of improvement started to slow down in the 21st century (see Liao et al. [1] for the discussion of this fluctuation).

As the largest 'factory' in this planet, China has lead the world in terms of economic growth and made astonishing achievements in the last couple of decades. Unfortunately, such growth is not without consequence. China needs more energy to fuel its fast growth. It has imported over 50% of its oil consumption from international market since 2008 and this number has kept increasing.

* Corresponding author at: Research Institute of Economics and Management, Southwestern University of Finance and Economics, 555 Liutai Avenue, Chengdu 611130, China. Tel.: +86 28 87092878.
*E-mail address:* dzhang@swufe.edu.cn (D. Zhang).

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**Nomenclature**

| | |
|---|---|
| BACE | Bayesian Averaging of Classical Estimation |
| BTU | British Thermal Unit |
| CDF | Cumulated Density Function |
| CPI | Consumer Price Index |
| EBA | Extreme Bound Analysis |
| FDI | Foreign Direct Investment |
| GDP | Gross Domestic Product |
| GRP | regional GDP |
| ODI | Outward Direct Investment |
| OLS | Ordinary Least Squares |
| SSE | Sum of Squared Errors |
| TCE | Tons of Coal Equivalent |
| $\bar{k}$ | prior mean model size (predetermined) |
| $\beta$ | coefficient (beta) on the variable of interest |
| $\epsilon_i$ | i.i.d. random error terms |
| $F$ | free variables |
| $f$ | number of free variables |
| $I$ | variable of interest |
| $i$ | index of cross-sectional units $(1,\ldots,N)$ |
| $K$ | total number of potential explanatory variables |
| $k_m$ | model size in the $m$ random draws ($m$th regression) in BACE model |
| $m$ | the $m$th regression in EBA/BACE |
| $N$ | total number of cross-sectional units |
| $P(M_m)$ | prior probability of model $M_m$ |
| $T$ | total number of regressions in EBA/BACE |
| $Z$ | control variable set from the pool of explanatory variables (excluding $I$) |

Meanwhile, environment across the whole country has been deteriorating. People in almost all cities across China have been exposed to polluted air as the results of burning more fossil fuels. In order to maintain a sustainable growth and the benefits of billions of its population, China has headed into this crucial stage of having to solve the longstanding conflict between constraints in energy consumption and desire for fast growth.

Policy makers in China have already noticed the importance of reducing energy intensity and have incorporated this into its strategic development plans. For example, the 11th Five-year Plan explicitly set the target of a 20% energy intensity reduction from 2005 to 2010. This is the first time that energy intensity targets has appeared in China's strategic level planning documents. The most recent 12th Five-year Plan set a target of 16% reduction between 2010 and 2015 with more detailed instructions relate to energy consumption and efficiency. Achieving these targets is clearly not straightforward. Without fully understand the market mechanism and fundamental driving forces of energy intensity, executive orders given by the central government may find difficulties to implement. Policies without acknowledging the role of market and regional differences can only result in short-run behavior in local government. This is especially relevant given the size of China's economy and its significant regional variations.

The policy significance of energy intensity in China have also attracted intensive academia attention. Over the last decades, there are a great many relevant studies bring forward the importance of energy intensity in China. Existing literatures have made much necessary efforts trying to understand the dynamics of energy intensity across time and regions (for example, Liao et al. [1], Chai et al. [2], and Zhao et al. [3]). However, the empirical evidence have been mixed and what exactly determines the dynamics of energy intensity has still been unclear.

Although a large number of intensive discussions can be found in the literature, which suggest several factors that may affect energy intensity, such as technology, economic structure, investment, and income, there has been no consensus achieved so far in terms of both theoretical or empirical models. Each study on this issue tries to focus on a subset of factors that can be potentially interesting or economically intuitive. The choices of variables are often subjective or depend on availability of data. For example, income is often included in the analysis, while others such as economic structure, international trade, demographic factors, investment, are often popular factors to choose. Even within each category of factors, there are many possible choices.

The consequence of conducting empirical studies without a clear theoretical guidance is that we often end up with conflicting conclusions. In other words, the results are often sensitive to the choice of the empirical model. Therefore, policies based on these empirical results can be potentially misleading. In addition, it is also difficult for researchers to choose one model against another alternative model.

In fact, the question of model selection does not only exist in finding the determinants of energy intensity, but is a rather prevalent problem in most empirical studies. Econometric analysis often requires researchers to have prior beliefs in the empirical models they choose, which are often derived from a theoretical model or variables that are intuitively appealing. However, the reality is often that a theoretical model may not be available and the intuitive choice of variables can be controversial. So, in order to ensure robust empirical results, researchers often check the stability of their model by replacing variables on the right hand side of their equation, or even specify an alternative model.

Leamer [4,5] and Leamer and Leonard [6] criticize that the empirical researches following this type of standard practice induces data-mining, pre-screening, or extensive model searching. When the results are sensitive to the choice of control variables or information set, it is often down to the researchers' subjective choice or their particular interest to decide which model to follow. A even stronger criticism by Sala-i-Martin [7] suggests that without the knowledge of a 'true' model or prior information of variables that should be used in the regression, economists are likely to run hundreds or even thousands of regressions with various combinations but report only those in their best interest. These critics and discussions have resulted in the Extreme Bound Analysis (EBA hereinafter) proposed by Leamer [4] and a series of variants. The basic logic of such methodology is to let the data decide what the most relevant determinants are. Given the fact that no explicit theoretical guidance for the determinants of energy intensity can be found, these methods enable us to provide a more objective solution.

Following the above discussions, the main objective of this paper is therefore to contribute to the existing literature and identify robust determinants of energy intensity in China. Using provincial level data of energy intensity in China, we aim to establish a set of variables that not only contribute to the dynamics of energy intensity in China, but more importantly, these factors are insensitive to the researcher's subjective choice of information set. In other words, these factors are fundamentally important in affecting energy intensity and should always be taken into account when studying the driving forces of energy intensity in China.[1]

[1] It is worth noting that this study is focusing on the provincial level determinants of energy intensity in China. Thus, the factors found are not necessarily the same if directly extended to cross country studies.