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# Production function with electricity consumption and its applications

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ABSTRACT

Researchers have tried to track the pattern of economy activities for decades. Cobb–Douglas production function has been adopted for almost one hundred years, while modern economists tend to analyze the economy via the aspect of individual agents. A different perspective of reviewing Cobb–Douglas function is needed. This paper finds a closer relationship between electricity consumption and economy, which can be represented via a strong similarity between four characteristics of "genes". A second finding is that countries after post-industrialization should enter the phase of up-industrialization, which largely focuses on technology accumulated value added for the secondary industry. Case study in this paper illustrates that the U.S. is entering the up-industrialization period. Countries that deemphasize on technology innovations will sooner or later result in severe economic consequences or financial crisis. This paper also initially encourages the wide application of smart meters and integration of smart grid to obtain timely and accurate data of electricity consumption to observe unusual economic activities.



## 1. Introduction

In the early 20th century, the Cobb–Douglas production function was generally agreed as a landmark in the economy. It studies the relationship between economic input and output, inclusively considered labor and capital input, together with technology change as an element of total factor productivity. For almost one hundred years, this model has been widely adopted to estimate and analyze the industrial production of a firm, sector, and industries in a country or a region, commonly recognized as 'production function'. Upon the development of industrial activities, a great volume of modern economic analysis has been transformed from imposing a functional form on an entire economy to analyzing production activities of individual firms (Walsh, 2003). Therefore, a production model that provides investigations from the perspective of firm level studies is highly desired.

Like the comprehensive economic structure, human body has complicated combinations of genes. The disordering gene combinations can result in cancers. By studying the patterns of DNA, characteristics of genes will be helpful to understand our body system. After looking into the historical data and economic trends via the performance of electricity consumption, we found high similarities between the four major characteristics of genes and production function with electricity during economic activities as replication, mutation, uniqueness, and evolutionary. This paper initially explores a similar pattern to track and to forecast economic activities, to substitute the Cobb–Douglas function by production function from electricity consumption which has four genetic-liked characteristics of economy.

In the field of biology, there is a common agreement that replication and mutation are the most fundamental functions of gene, and that functions of evolutionary and uniqueness are deduced based on replication and mutational activities (Armisén et al., 2008; Kitsberg et al., 1993). Biologists perceive replication and mutation functions as the core characteristics of DNA studies, the other two functions, evolutionary and uniqueness are also influencing gene splicing, which can be evolved through the development of core functions, as well as being influenced from external conditions under the catalysis of time and space (Stenson et al., 2008).

There are generally two kinds of DNA synthesis, either expressing cells, where the globin domain replicates early, or non-expressing cells which are characterized by late replication of the same region (Armisén et al., 2008). Gene mutation is a permanent change in the DNA sequence that makes up a gene. Mutations range in size from a single DNA building block (DNA base) to a large segment of a chromosome. Some genetic changes are very rare; others are common in the population. They are common enough to be considered a normal variation in the DNA (Stenson et al., 2008). High proportion of duplicated genes as a result of numerous whole, segmental and local duplications leads up to the formation of gene families, which are the usual material for many evolutionary studies (Wade, 2008). Meanwhile, all characterized genomes including unique genes are also receiving attentions despite of the influence of gene replication; gene uniqueness is influenced by functional selections. Furthermore, although most mutations are neutral

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with no effect on fitness or harmful, some mutations have a small, positive effect on fitness and these variants are the raw materials for gradualistic adaptive evolution (Stenson et al., 2008). According to Kitsberg et al. (1993), natural selection is the only evolutionary force which can produce adaptation; the fit between organism and environment, or conserve genetic, states over very long periods of time in the face of the dispersive forces of mutation.

Likewise, production function with electricity for economy has four prominent characteristics comparing with biological genes. Measuring the economy by electricity consumption data is accurate, important and representative in two major ways (Yuan et al., 2008): first, electricity is one of the most essential elements during economic activities. The greater the electricity consumption, the more the economic activity in the nation and as a result a greater economy emerges (Odularu, 2009). Electricity could be seen as the representative of all kinds of economic activities, from agricultural irrigations to manufacture assemblies, and then to tertiary services, as well as playing a great role in people's lives. Second, electricity has high representativeness in terms of economic input. Under the same condition of skills and technologies, each unit of electricity consumption would require a certain amount of other related inputs of the production.

How to trace the electricity data timely and accurately might be a concern. This has been an issue for many countries where data is collected approximately six months to one year. Besides, minor mistakes can influence the accuracy of the analysis to certain degrees. As a solution, wide uses of smart meters and integrated smart grid can help countries to achieve timely and accurate data. With the common application of smart meters, people nowadays can have real time access to electricity data of all kinds of electric applicants. For instance, China can release accurate data of electricity consumption two weeks afterwards (Zhang and Cheng, 2009).

This paper traces the patterns of value added and GDP changes via observing electricity consumption data, and provides analysis of how electricity consumption can substitute the Cobb–Douglas production function. Our research also find out that the production function with electricity consumption under natural economic activities significantly shows the four genetic characteristics, replication, mutation, uniqueness, and evolutionary. We can therefore transform the genetic characteristics into characteristics of the production function with electricity. The connections between electricity consumptions and product amounts have been studied. As a result, we are able to demonstrate how electricity consumption influences value added during production. The research of product amounts and value added is conducted at three levels, level of firms, of sectors and of industries. The firm level refers to the most fundamental level of an economic unit, such as a farm, a manufacturing company, or a service shop. At the sectoral and industrial levels, electricity consumption has direct influence to the value added of products. Production function with electricity is introduced in section two, and case studies of the U.S. are followed in the third section of this paper.

## 2. Production function with electricity and the characteristics

To begin with, according to Filipe and Adams (2005), the Cobb–Douglas production function in standard form for industrial production is presented as:

$$Y = AL^{\alpha}K^{\beta} \tag{0}$$

where:

- Y = total production (the monetary value of all goods produced in a year)
- L = labor input (the total number of person-hours worked in a year)
- K = capital input (the monetary worth of all machinery, equipment, and buildings)
- A = total factor productivity
- $\alpha$ and $\beta$ are the output elasticities of labor and capital, respectively. These values are constants determined by available technology.

The level of firms is the most fundamental level of an economic unit. During production activities at the firm level, electricity is one input index; it also matches with various types of output indexes, usually described as product quantity, revenue of sales, profits, value added, etc. The relationship between electricity consumption and production outputs at the firm level could be categorized as quantity product function of the electricity, revenue function of the electricity, profit function of the electricity and value added function of the electricity. Given constant technology in the production of the firms, more material inputs (including machinery, equipments, etc.) and product outputs depend on electricity consumption during a period of time. Nowadays instead of manual works, production in factories are realized via labor operating machines; thus labor input as an index can be also quantified by electricity consumption.

As many firms have the capacities to build up a sectoral economy, these sectors accumulate to be an industry. Since GDP is the total amount of value added for three structural industries, primary secondary and tertiary, it could be seen as the sum of total added production values of all firms. In this section, we study the functional intrinsic relationship of input and output between GDP and electricity consumption through studying the electricity-GDP function (E-GDP function). We begin with studying their relationship at the level of firms, and then move to levels of sectors and industries.

Under the constant technology level, the function of total production and electricity consumption displays a positive correlation (Yuan et al., 2008). Increasing power consumption will therefore result in higher production. This linear function could be called as product quantity function of the electricity and presented as:

$$tq = ce + d \tag{1}$$

where $tq$ means total quantity of the product, $e$ as electricity consumption, $c$ is the slope of the linear function and $d$ is the intercept of the function. Without significant changes on technologies and management skills, the slope and intercept can be treated as constant factors.

Secondly, since value added is positively correlated with the amount of products and the electricity consumption, the relationship between electricity consumption and value added of products of a firm is determined by the product quantity function of electricity. Material inputs are positively correlated with product amounts; therefore, value added is also positively correlated with product amounts. Based on the product quantity function of electricity, we have a value added function of electricity for firm:

$$v = ae + b \tag{2}$$

where $v$ means value added, $a$ is the slope of the function and $b$ is the intercept of the function. Formula (2) is also called e-v function of the firm. It is clear that this function is only suitable for the firm with specific $a$ and $b$ in formula (2). Since the technology and management are different from firm to firm, functions of each firm should also be different from others. The characteristic of uniqueness which is demonstrated at the firm level can then be applied to the sectoral and industrial levels as well.

Since technology and management of each firm typically remain the same during a certain period of time, $a$ and $b$ in formula (2) usually stay stable in the period. At the firm level, this is the characteristic of replication of e-v function, in which technologies and management structures are constant factors given a period of time.