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A strong argument for using non-commodities to generate electricity

Katarina Tatiana Marques Santiago *, Fernando Menezes Campello de Souza, Diogo de Carvalho Bezerra

Department of Production Engineering, Federal University of Pernambuco, Brazil

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ABSTRACT

An optimal control approach towards generating electricity is used to analyze the trade-off between using of primary sources which are regarded as commodities, such as fossil fuels, biomass and water to generate electricity, and exploiting these sources for their other economic uses (for example, in the petrochemical industry, in the production of fuels, in agriculture, in steelmaking, and so forth). In order to do so, a dynamic model is presented which establishes relationships between economic growth, the fossil fuel, water and biomass sectors, and energy policies, based on the application of the Pontryagin Maximum Principle. Among other results, the analysis establishes that, under the optimal path, the price of commodities for non-energy uses should be twice the price of the energy assets. This indicates that sources which are not commodities such as solar energy, wind energy, and geothermal energy, should be used to generate electricity.

1. Introduction

The classic definition of economics is that it is the study of the allocation of scarce resources between competing uses. Scarcity is a characteristic of exhaustible resources. Therefore, economists, by definition, must be concerned with them.

Hotteling's classic article, The Economics of Exhaustible Resources is the most important contribution towards understanding the role of these resources in economic growth. Hotteling's purpose was to find an extraction rate that ensured maximum growth continued. Although it was published in 1931, Hotteling's work only received its due recognition in the 70s during the two petroleum crises which showed the dependence on this resource and the danger to sustained economic growth brought about when supplies of oil are scarce.

The idea that when resources are exhaustible, there are limits to economic growth was first mentioned by Thomas Robert Malthus, in his book Essay on the Principle of Population (1798). He was the first to announce some stagnation in growth because of the scarcity of the resource of land. He believed that as the population grew geometrically and the land factor remained steady, there would be a lack of food in the future, and thus the need for a policy of population control. What Malthus did not predict was that technological development would be able to raise labor productivity and thus correct the problem. This was brought about by the Industrial Revolution.

However, the technological development that came with the Industrial Revolution, later added to by other advances, created industries that were heavily dependent on energy and a society with new habits of consumption, especially with regard to energy. Since then, finding and using resources to meet energy requirements has become one of the main inputs for production in every economy in the world. In fact, the global demand for primary energy compared to 2008 will have grown by 53% by the year 2035 according to Conti and Holtberg (2011).

Most of the world's energy sources known today are finite i.e., exhaustible. Oil comes first in the global energy matrix followed by coal and natural gas. These sources together account for approximately 80% of the world's energy supply according to Ministério das Minas e Energia (2009) Coal is the source most used to generate electricity. It accounts for generating 41% of the world's electricity supply. The United States and China are examples of countries that are highly dependent on this resource. In Brazil, water is the resource most used to generate electricity and is followed by biomass. These resources, although renewable, are limited.

What oil, coal, natural gas, water and biomass have in common is that they are conventional. Conventional resources, as argued by Campello de Souza (2005) represent stored energy; are found in specific and unchangeable locations; and offer a limited supply. Their scarcity and high demand create a capitalizable commodity and an avid and impatient market, i.e., these sources are goods with high marketability in the international market and thus subject to price variations.

The issue is that these natural resources are allocated both for producing electricity and for producing non-energy goods. Therefore, they are used as an input for production and as an input to produce a different kind of input, namely power.

* Corresponding author.
E-mail address: ktmsantiago@gmail.com (K.T.M. Santiago).

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So, what is the best use of these resources? Should oil be used in the petrochemical industry, in the plastics industry or for electricity generation? Similarly, should water be used in agriculture or in hydroelectric stations? Why? What alternatives are there to the use of coal, natural gas and biomass for generating power?

2. Multiple uses

The natural resources considered commodities (coal, natural gas, oil, water and biomass), which are widely used to produce electricity in Brazil and in the world at large, are allocated to producing both electricity and non-energy goods. Therefore, they are used as an input for production and as an input to produce a different kind of input, namely power. For example:

- coal is used to generate electricity in thermoelectric power plants and in industry to generate the heat (thermal energy) required for production processes such as drying products, and in the manufacture of ceramics and glass. Moreover, it is widely used in steelmaking;
- natural gas is used to generate electricity in thermoelectric plants and to produce the electric energy required to produce the heat and steam needed in industrial processes;
- oil is used by thermoelectric plants and in the petrochemical industry for the production of plastics, fuels, etc.;
- water, which is a renewable, yet limited, resource, is drawn from rivers, before they reach hydroelectric plants, for use in agriculture and to generate power; and
- biomass is used to produce electric energy and bio-fuels, as well as in the paper and cardboard industry, in the manufacture of a type of wood, in civil construction, besides as fodder for livestock (the chaff of sugar cane mixed with urea serves as food for cattle in the semi-arid region of Brazil).

3. The energy supply in the world

Oil is the raw material most used in the world. It accounts for 35% of the world energy supply matrix. Coal (25.3%) ranks second followed by natural gas (20.7%) Ministério das Minas e Energia (2009).

With regard to generating electricity, according to (Conti and Holtberg, 2011), coal is the most used resource, accounting for 41% of total energy production. Approximately 78% of electricity in China is powered by thermal coal. Another country heavily dependent on coal is the United States.

In fact, according to Conti and Holtberg (2011), the three primary energy sources for generating electric power in the United States are coal (48.5%), natural gas (21.6%), and nuclear energy (19.4%). These three sources consistently provided between 84.6% and 89.5% of the total net generation during the period 1997 through 2007. Petroleum's relative share of total net generation was unchanged in 2007 from 2006 at 1.6%. Conventional hydroelectric power continues to decline as a share of total net generation. In 2007, conventional hydroelectric generating capacity accounted for 6.0% of the total net generation, as compared to 10.2% in 1997. Renewable energy sources, excluding conventional hydroelectric generation, contributed 2.5% of the total net electricity generation in 2007. This marks the fourth consecutive year in which renewable' share of total net generation has increased.

4. Brazilian Energy Matrix

The Ministry of Mines and Energy (MME) conducts various studies and analyses that underpin the formulation of energy policies and guidelines for planning the sectors of the economy. One of the most important research centers is the National Energy Balance (NEB) agency, which gathers and publishes, annually, data on the consumption, production and marketing of various energy resources in Brazil. The data in this section are from the NEB 2011 for which the base year is 2010.

Table 1
Brazilian Energy Supply Matrix.
Source: BEN.

SPECIALIZATION	Milhes de Tep		09/10%	STRUCTURE %	
	2010	2009		2010	2009
HYDRO	38.3	37.1	3.4	14.2	15.2
NUCLEAR	3.9	3.4	12.3	1.4	1.4
NATURAL GAS	27.6	21.2	30.4	10.2	8.7
MINERAL COAL	26.1	24.6	5.9	5.1	4.7
PETROLEUM AND DERIVATIVES	102.8	92.3	11.4	38.0	37.8
BIOMASS	47.8	44.5	7.5	17.7	18.2
OTHER RENEWABLES	10.6	9.2	14.9	3.9	3.8
TOTAL	270.8	243.9	14.9	100	100

Domestic energy supply (DES)[1] reached 270.8 million toe (tons of oil equivalent) in 2010, which was 11% lower than the demand in 2009 and equivalent to about 2% of world energy. Final energy consumption (FEC) reached 226.094 million toe in 2010, a total that was 9.6% higher than in 2009.

The energy demand grew faster than the economic growth rate in 2010, which was 7.5%. The structure of the DES by energy source (the Brazilian Energy Matrix — BEM) is shown in Table 1.

As the table share the participation of natural gas in the national energy matrix increased in 2010 and reached 10.2%. Sugar cane products (ethanol, bagasse, juice and molasses to generate energy) also increased their share in the matrix, to 17.7%. So, the sugar cane ranks the second position among the main sources of primary energy in Brazil, coming behind only oil and derivatives (38%).

Producing energy from non-renewable rather than renewable resources is still greater in the DES (54.6%), with the emphasis on oil and its derivatives (38%). In recent years, the constant increases in the production of this resource and natural gas in Brazil are allowing successive reductions in depending on energy sources from overseas: 12.9% in 2004, 10.2% in 2005 and 8.3% in 2006. In 2007, this figure was 9.5% due to the increase in imports of coal.

In fact, in Brazil and abroad, ever since the oil crisis in the 70s, a concern has been to reduce dependence on fossil fuel due to its scarcity and its contributing to global warming from CO_2 emissions. Investment in non-conventional energy has grown considerably in Brazil with regard to energy generation as a whole, but is still not expressive in the Electric Power Matrix, as will be shown in the sections that follow.

5. Brazilian Electricity Supply Matrix

According to the National Energy Balance — NEB agency, one of the most important research centers for energy in Brazil, approximately 80% of the total electricity generated in the country is hydroelectric power, including imports, and the rest is generated in thermoelectric plants, which is fuelled mainly by natural gas, oil, and biomass or by nuclear means (see Table 2).

The Brazilian Electricity Supply Matrix makes the country's dependence on its hydrological hydraulic facilities clear. The preference for hydroelectricity is explained by natural conditions (the abundance of water in rivers, lakes and basins) and because the operational costs of plants are negligible compared to producing thermoelectricity from fossil fuels.

In 2010, the supply of electricity in Brazil supply grew 9.1% and reached 548.8 TWh. The increase in the use of natural gas (139.4%) was higher than that of petroleum and its derivatives (17%) and of nuclear power (12%). Hydraulic power remains supreme in the matrix with (80% of the total production), including imports. Next come gas (6.2%), biomass (5.9%) and petroleum (3.3%). Wind energy increased about 50.5% in 2010. The total consumption of electricity grew 10.2%.

[1] In NEB, as in energy balances from other countries, the domestic energy supply — DES, also known as total energy demand, is the sum of final energy consumption, loss of distribution and storage and losses in the process of transformation.