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Analysis of Revenue Allocation of Power Plants

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ABSTRACT

The study focuses on the returns to factors of electricity production by six (6) different technologies, which are natural gas-fired, coal-fired, biomass, hydropower, wind turbine, and solar photovoltaic power plants. Cash flow analysis is used to identify the allocation of the plants' revenues to the owners of the factors of production and stakeholders through the companies' financial statements to different factors of production, namely fuels, operation and maintenance expense, utilities, personnel wages, taxes, interests, loans, and dividends, in addition to the investment promoting parameters, like payback period, net present value, and internal rate of return, to fulfill the requirement for sustainable development. Power plants of different technologies, require different proportions of factors of production, and investments. The revenues are allocated to the owners of the factors of the production, including fuel and utility suppliers, workers, owners, financial institutes, as interests and loans, and the government and society as taxes. The major expenses of natural gas-fired, coal-fired, and biomass power plants are for operation activities, including fuel costs and O&M costs. Differently, for other technologies, which are hydropower, wind turbine, and solar photovoltaic power plants, the major portions of their revenue are re-turned to the investing activities of the power plants.

Keywords: Electricity generation, Returns to Factors, Cash flow analysis, Sustainable Development.

INTRODUCTION

It is customary to determine marginal productivity from a production function. A production function relates outputs with their inputs; generally labor, capital, and etc. There are a number of production functions introduced by economists, such as; 1) Linear production function, 2) Cobb-Douglas production function, 3) Leontief production function, 4) Constant Elasticity of Substitution (CES) production function, 5) Variable Elasticity of Substitution (VES) production function [1, 2].

In economics, there are four main factors of production: land, labor, capital, and entrepreneurs. When the produce is sold, revenue from the sale of the produce will be allocated as returns to the four factors of production (Returns to factors) as rent, wages, interest, and profits, respectively. For different power generation technologies, different factors of production are required. As an example, traditional power generation technologies, like natural gas-fired and coal-fired power plants rely heavily on the supply of fossil fuels, while power generations from renewable energy need natural power from wind and sun-light. The concept of returns to the traditional production factors does not effectively ex-plain the effects on returns to other factors of various technologies. Generally, electricity energy is subject to the same price, regardless of where and how it is produced. End users are paying for electricity energy at the same rate. It can be beneficial to the end users to learn how their payments are allocated to the factors of production.

The production functions have been widely discussed for their applications to various industries [3, 4]. Productivity is a significant indicator of competitiveness. An improvement in labor productivity and an advance in technology for the increase in capital productivity are the primary objectives for gaining advantages over industrial competition. Total factor productivity (TFP), which can be derived from assumed production functions, such as Cobb-Douglas production, Leontiff production function, and others, in the power-generating industry is considered a comparative measure of the industry [1]. Total factor productivity (TFP) indicates the average productivity of the industry, rather than the productivity of each factor input into the production process. TFP can be useful for the comparison of productivity of various industries. Reports on Total Factor Productivity (TFP) and contributions of labor and capital among the eight major European electricity-producing companies from 2009 to 2012 were reviewed and compared [2].

In order to estimate coefficients of a production function, the ordinary least square (OLS) method can be applied [5, 6]. There are limitations in the estimation of a production function, such as a) data problems, b) functional form assumptions, c) simultaneity, d) multicollinearity, e) endogenous exit/selection [6]. The endogeneity of inputs in the production functions, and the consequent bias of the estimated elasticities were discussed in several occasions [5], [7].

Marginal productivity is used as a framework to determine the price of the factor of production. The framework has been criticized majorly due to unrealistic assumptions and productivity measurement [8], [9], [10].

Due to the disadvantages of the determination of production function and marginal productivity, it is then worth exploring other methods for factor pricing. This study introduces an alternative method of the determination of returns to factors.

According to "Sustainable Development", which is defined by International Institute for Sustainable Development (IISD) as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [11]. Major parameters derived from cash flow statements, such as payback period, net present value, and internal rate of return, may not be adequate to fulfill the requirement for sustainable development. If financial indices, like returns to factors of production, are considered, it will be beneficial to promoting electricity production in the future by ensuring that the essential stakeholders in society, such as operators, and taxpayers, receive appropriate benefits. In economics, the main factors of production are land, labor, capital and entrepreneurs, etc. When the products are sold, the income from selling the products will be allocated as returns to the factors of production (Returns to factors), such as rent, wages, interest and profit, respectively, etc. The owners of each factor are the participants in the production (Factors) and usually come from various sectors of society (Society), including land owners, operators and maintenance personnel, financial institutions and owners who are involved in investing, entrepreneurs, the government sector and others. Therefore, the returns to factors of production (Returns to factors) by considering the proportion of income (Allocation of Revenues) of entrepreneurs to the owners of production factors is the returns to various sectors of society (Returns to society) of the business operation, which is an important matter that should be considered together with other impacts.

It can be of benefit the policy planners to be acknowledged the revenue allocations among all factors of production and stakeholders of different technologies for electricity generation; those are coal-fired power plants, natural gas-fired power plants, biomass power plants, hydropower plants, wind power plants, and solar photovoltaic power plants. Different revenue allocation proportions to production factors can lead the planners to initiate different programs for promotion, Ministry of labors to set the wage negotiation target, Ministry of finance to revise the tax system, and so on.

METHODOLOGY AND MATERIALS

Cash flow statement, which outlines the inflows and outflows of cash, is an important aspect of a company's financial management because it reveals the cash it has available to pay bills and invest in its business. Possible production factors and their owners are illustrated in Figure 1

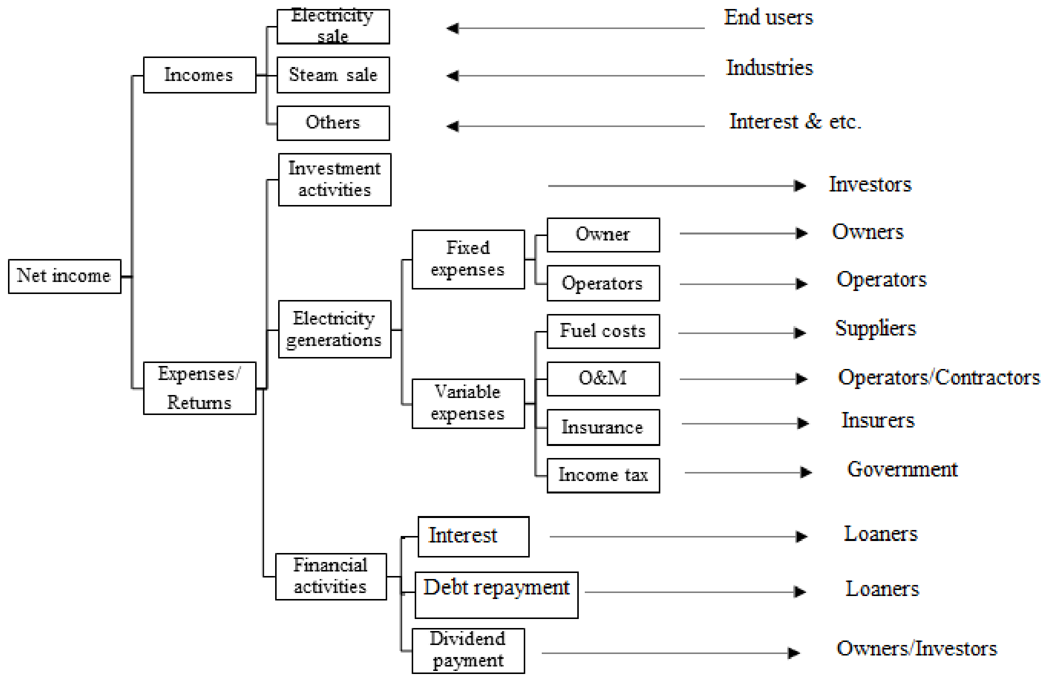

Figure 1: Overview of the financial categories of electricity generation.
Source: By authors

Figure 1 provides an overview of the cash flow categories that can be differentiated when determining the returns on production factors of the power plants. Thailand's power generation industry is structured in line with the enhanced single-buyer model, with state bodies being the sole buyers and distributors of power through the national grid. The revenues of power plants are divided into three flows, which are from electricity and steam sales and other income. The expenses are divided by activities: investments, electricity generation, and financial activities. The investment cost is in form of loan and investment capital. The operating expenses are fuel costs, O&M costs, insurance costs, and income tax, which are associated with generation activities. The financial activities include debt interest, debt repayment, and dividend payment. The returns are directed to stakeholders, such as generators/distributors, investors, and owners.

Cash inflows are generally received from the sale of the products as revenue. The revenue will then be allocated as expenses of three main activities, which are operating activities, financial activities, and investment activities. The revenue allocation can be viewed as returns to factors for production.

Cash Flow Analysis

Cash flow analysis is used to study the allocation of revenues from electricity sales to the factors of production and stakeholders through the companies' financial statements [12]. The analysis has been conducted through the disaggregation method and the comparison method. The disaggregation method refers to the breakdown of the items, both cash inflows and outflows, in the cash flow statement. The breakdown is generally performed by the activities of the process, which can be grouped into: operation, investment and financial activities. The disaggregation method helps to verify the contribution of each of the activities in the generation process. The comparison method enables the comparison of different items of the production process, the same items over two or more time periods and between companies. The most common practice is the comparison of the realized and planned cash flow statements.

Financial Indices

For the investment aspect, there are a number of parameters of interest for decision making. Those are as the follows;

$$Payback\ period\ (PB) = \frac{Initial\ investment\ (C_0)}{Net\ cash\ flow\ per\ period\ (C_t)}, \tag{1}$$

$$Net\ present\ value\ (NPV) = \sum_{t=1}^{n} \frac{C_t}{(1+i)^t} + C_0, \tag{2}$$

Internal rate of return (IRR) = i, where

$$0 = \sum_{t=1}^{n} \frac{C_t}{(1+i)^t} + C_0, \tag{3}$$

where

- t: period t,
- n: total periods,
- C_t: net cash flow at period t,
- C_0: Initial investment,

Ratio analysis is one of the most commonly used instruments of financial analysis. In addition to the ratio analysis based on the basic financial statements (balance sheet and income statement), the ratio analysis based on the Cash Flow Statement has recently become increasingly important.

Financial indicators based on cash flow can be divided into groups: a) Liquidity ratio, b). solvency ratio, c) Profitability ratio. Moreover, other ratios and indices are also employed for analysis, such as efficiency ratio, cash flow to sale ratio, operation index, cash flow return on assets, sufficiency ratio, debt service coverage ratio (DSCR), etc. [13].

The above parameters and ratios are designed to provide decision-making information for investors. However, investors are not the only participants in projects. There are stakeholders, such as operators, communities, and governments (local and central), who are involved in the projects and share the benefits of the projects. More ratios can be derived from cash flow statements to fill the gaps of other participants in the project. Those are the following:

$$Ratio\ of\ return-to-operators\ to\ revenue = \frac{Expenses\ for\ operators}{Revenue}, \tag{4}$$

$$Ratio\ of\ return-to-lenders\ to\ revenue = \frac{Expenses\ for\ lenders}{Revenue}, \qquad (5)$$

$$Ratio\ of\ return-to-Societies\ to\ revenue = \frac{Expenses\ for\ societies}{Revenue}, \qquad (6)$$

$$Ratio\ of\ return-to-owners\ to\ revenue = \frac{Expenses\ for\ owners}{Revenue}, \qquad (7)$$

The proposed ratios can be used to analyze the benefits among participants in the project, and to compare those of different projects or technologies. The information can be useful for planners to layout the future power generators.

Power Plant Information

According to the national plan, Thailand targets to commission a new power plant capacity at 56,431 MW by 2037, of which 18,696 MW would be electricity from renewable energy. For solar energy, the target of new solar PV power plant capacity in 2037 has been set at 8,740 MW, plus an additional 550 MW capacity target of solar PV hybrid with another renewable energy source, and 2,725 MW floating solar PV as hybrid systems with large hydropower dams. As of 2020, the cumulative PV-installed capacity in the country was at 3,939.8 MWp, consisting of 3,933.7 MW of grid-connected PV systems and 6.1 MWp of off-grid PV systems. Most of the total installed capacity was ground-mounted PV systems. In 2020, the annual grid-connected systems installation in Thailand was 143.64 MWp, which included rooftop PV systems for the commercial sector 127.25 MW, 12.69 MW of floating PV systems, and 3.7 MW of ground-mounted systems [14].

There are six (6) technologies, of which the plant information was collected from various sources, included in the analysis. Those are a natural gas-fired power plant [15], a coal-fired power plant [16], a biomass power plant [17], a hydropower plant [18], a wind turbine plant [19], and a solar photovoltaic power plant [20]. The assumptions and basic data of electricity generation at plant level to calculate the cash flow is presented in ***Table 1***.

Table 1: Power plants' assumptions and basic data.

	Natural gas–fired [15]	**Coal–fired [16]**	**Biomass–fired [17]**	**Wind turbine [19]**	**Hydropower [18]**	**Solar photovoltaic [20]**
Capacity (MW)	118	220	20	210	200	50
Electricity generated (GWh/year)	769	1,380	126	1,645	617	66
Life time (Year)	20	25	20	25	25	25
Investment (MB)	3,239	2,345	1,915	617	9,507	1,420
Construction started	1996	2002	2020	1998	2020	2020
Interest rate (%)	1.4	4.9	1.4	1.0	1.4	1.4
Dept interest (%)	7	7	7	8.3	8	8

Income tax (%)	0-20	0-20	0-20	0-15	0-20	0-25

Source: References are provided in the Table.

The plant information in Table 1 was used to determine financial indices described in section 2.1 and presented in Table 2 and Table 3.

RESULTS AND ANALYSIS

This study evaluates the cost of electricity generation using various technologies. Cash flow statements are financial documents that provide insight into a project's present cash inflow and outflow values of a project, which are the parameters to be analyzed.

Project IRRs and equity IRRs of the selected power plants of different technologies are calculated as shown in Table 2. It can be summarized that the IRRs of wind turbine and solar PV power plants are much lower than those of natural gas-fired, coal-fired, biomass, and hydropower plants.

Table 2: Project IRRs and Equity IRRs of various technologies of power generation.

Technologies	Natural Gas	Coal	Biomass	Hydropower	Wind Turbine	Solar photovoltaic
Project IRR	13.22%	12.44%	7.50%	18.43%	8.30%	8.80%
Equity IRR	21.12%	17.66%	12.40%	29.24%	9.00%	10.20%

Source: By authors

In comparison with IRRs calculated by others, project IRRs for a distributed diesel generator, a wind turbine, and a solar photovoltaic system, of which their capacities are 1 MW, are 19.09%, 21.62%, and 11.33%, respectively.

In the calculation of cash flow analysis for the lifetime of the power plants, it was found that the share of expenses in electricity generation by technology is shown in
***Table* 2**. It can be summarized that fuel costs are the major cost for power plants using natural gas, coal, and biomass, ranging from 27.3% to 54.4% of their revenues. In contrast, hydropower, wind turbines, and solar photovoltaic power plants do not share their revenues for fuel costs.

The total expenses for operation activities for a natural gas-fired power plant, a coal-fired power plant, and a biomass power plant, ranging between 51.4% to 73.1% of their revenues, are much more than those for hydropower plant, wind turbine power plant, and a solar photovoltaic power plant, which are in the range of 17.8% to 40.6% of their revenues. On the opposite, the expenses on financial activities for a hydropower plant, wind turbine power plant, and a solar photovoltaic power plant, which range from 29.9% to 42.3% of their revenues, are higher than those for a natural gas-fired power plant, a coal-fired power plant, and a biomass power plant, which are in the range of 15.1% and 28.3%. It is worth mentioning that the larger shares of the revenue of the hydropower plant, wind turbine power plant, and solar photovoltaic power plant return to the owners, 29.4% to 43.3% of their revenues, compared with 11.8% to 16.1% for the natural gas-fired, coal-fired, and biomass power plants, as shown in

***Table* 2** and Figure 2. In addition, income taxes (business taxes), which can be viewed as returns to the government and society, range from 3.5% to 11.5% of their income. Taxes are subject to governmental requirements and promotional programs. The findings can be useful for future power plans and promotion program establishments.

Table 3: Share of expenses in electricity generation by technology

Expenses	Natural Gas	Coal	Biomass	Hydropower	Wind Turbine	Solar PV
Operation Activities						
Fuel cost	54.4%	44.2%	27.3%	0.0%	0.0%	0.0%
O&M (personnel & administration)	14.3%	7.2%	33.9%	12.4%	37.6%	14.7%
Owner's expenses & Others	4.4%	0.0%	0.0%	14.4%	3.0%	3.1%
Total Operation Activities	73.1%	51.4%	61.2%	26.8%	40.6%	17.8%
Financial Activities						
Income tax	3.5%	11.5%	4.8%	8.7%	1.5%	2.5%
Interest	5.4%	6.7%	6.3%	8.6%	10.0%	14.5%
Debt repayment	6.2%	10.1%	11.6%	12.6%	18.5%	25.3%
Total Financial Activities	15.1%	28.3%	22.7%	29.9%	30.0%	42.3%
Investment Activities						
Return to Owner	11.8%	20.3%	16.1%	43.3%	29.4%	39.9%
Total Investment Activities	11.8%	20.3%	16.1%	43.3%	29.4%	39.9%
Total cash cost	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: By authors

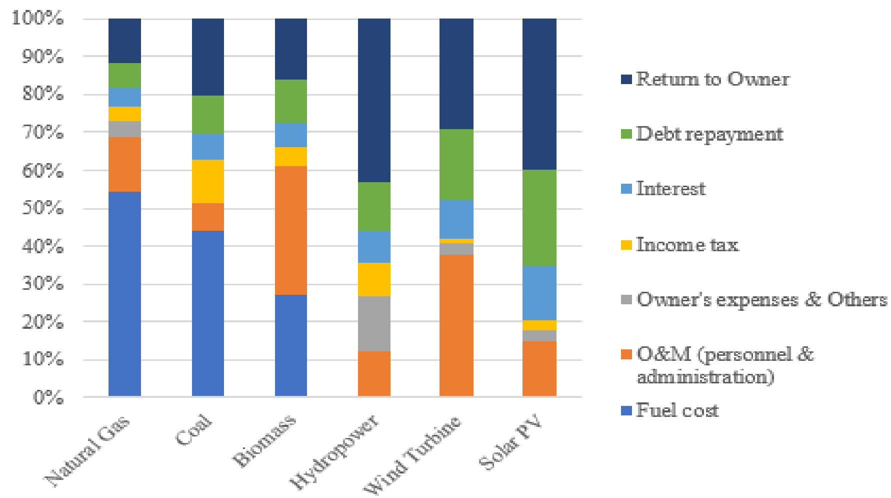

Figure 2: Percentage Returns to Factors of Electricity Generation by technology

Source: By authors

CONCLUSION

Investment induces employment, procurement, and other indirect effects and welfare. An establishment of a power plant in the country requires a large amount of investment, which can be foreign direct investment (FDI) or domestic investment. The initial investments are used for the construction of the power plant, such as civil works, building and construction materials supplies, engineering, procurement and construction (EPC) ser-vices, machinery and mechanical equipment manufacturing and fabrication, electrical and electronic equipment suppliers, as well as general equipment supplies. In addition to the initial investment, the power plant also requires operation factors and costs including fuel cost, operation and maintenance cost, tax, interest, etc. Power plants of different technologies require different amounts of investments and operation costs. The revenues received from the sale of electricity are distributed among the owners of the various factors. It was found that fuel costs are the major cost for power plants using natural gas, coal, and biomass, ranging from 27.3% to 54.4% of their revenues, while a hydropower plant, a wind turbine power plant, and a solar photovoltaic power plant do not share their revenues for fuel costs.

The largest shares of the revenue of the renewable energy power plants return to the owner, 29.4% to 43.3% of their revenues. The total expenses for operation activities for a natural gas-fired power plant, a coal-fired power plant, and a biomass power plant, ranging between 51.4% to 73.1% of their revenues, are much more than those for hydropower plant, wind turbine power plant, and a solar photovoltaic power plant, which are in the range of 17.8% to 40.6% of their revenues. On the opposite, the expenses on financial activities and investment activities for a hydropower plant, wind turbine power plant, and a solar photovoltaic power plant are higher than those for a natural gas-fired power plant, a coal-fired power plant, and a biomass power plant. The costs of operation activities for a natural gas-fired power plant, a coal-fired power plant, and a biomass power plant are also major portions, the returns of which range between 51.4% to 73.1% of their revenues, and are much more than those for hydropower plant, wind turbine power plant, and a solar photovoltaic power plant, ranging from 17.8% to 40.6% of their revenues. On the contrary, most of the renewable energy power plants require larger amounts of investment per unit capacity than the traditional fossil and biomass power plants. The expenses on financial activities, for the returns as interests and repayments, for a hydropower plant, wind turbine power plant, and a solar photovoltaic power plant, which range from 29.9% to 42.3% of their revenues, are higher than those for a natural gas-fired power plant, a coal-fired power plant, and a biomass power plant, which are in the range of 15.1% and 28.3%. The remainders of the revenue are turned to the owners. The larger shares of the revenue of the hydropower plant, wind turbine power plant, and solar photovoltaic power plant return to the owners, 29.4% to 43.3% of their revenues, compared with 11.8% to 16.1% for the natural gas-fired, coal-fired, and biomass power plants. It is also of interest to mention the income taxes (business taxes), which can be viewed as returns to the government and society, ranging from 3.5% to 11.5% of their income. Nevertheless, taxes are subject to governmental requirements and promotional programs. The returns to fuel costs of natural gas-fired, coal-fired, and biomass-fired are directed to resource owners. Most of the developing economies are net importers, who acquire fossil fuel from other countries. Revenues from power sales will be remitted to the fossil fuel suppliers. On the contrary, the return to the cost of biomass, which originated as a local resource in the country, goes to the farmers in the agriculture sector.

DISCUSSION

Returns to Factors as Decision Parameters for Power Development Plan

Financial parameters, such as payback period, net present value, and internal rate of return, are for investment perspectives or economic aspects, while returns to factors broaden the extent of projects' benefits into social aspects for the evaluation of policy makers, especially for electricity, which the government, as a distributor, should take into account the calculation of production costs to make decisions from pricing to long-term planning of electricity producers and return allocations to the factor owners. The determination of the allocation of revenues from sales promotes the establishment of sustainable development.

Foreign Direct Investment (FDI) and Foreign Currency Balance

Foreign direct investment (FDI) is a major parameter that concerns most of the eco-nomic planners in developing countries. The inflows and outflows of foreign currencies should be considered together to keep a positive balance of foreign currency accounts. It has been a regular practice that privileges are offered to attract investment from foreign investors. If the special privileges are provided for the foreign investment in the exporting industries, it will be more beneficial to the country. It should be more careful for the pro-motion for the foreign investment in the new development of power or other utilities to avoid the negative balance of foreign currency.

Promotion of Local Employment

Technologies that are not only efficient at generating electricity but also create jobs for local workers should be selected to promote domestic employment through the power generation industry. The returns to labor, supporting workforce training and skills development can be considered together with the requirement of labor at many stages and have the potential to create jobs in rural areas and promote local development for the selection of appropriate investments in technologies.

Indirect Impacts

The usefulness of electricity is well known, and it is the prime factor for most of the production processes in the industrial sector and the essential energy source for house-hold appliances in the residential sector. Apart from the positive effects, there are also ad-verse impacts on the generation, procurement, and utilization of electricity. This study limits the returns to factors, which are the direct effects of the generation of electricity due to the availability of data. Future studies that extend their scopes to cover the indirect im-pacts will be useful.

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