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The Impact of Interest Rates on Electricity Production Costs

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Abstract

Putting the economy on an environmentally sustainable path requires substantial investments in green energy technologies. Long-term interest rates play a crucial role for energy investments. Against this background, we study the impact of interest rates on the costs of producing electricity with different technologies, using renewable and non-renewable energy, respectively. We find that low interest rates increase the competitiveness of green energy technologies versus brown energy technologies, that stable interest rates are more beneficial for green investments than for brown investments, and that a discount on the interest rate charged for green investments may be more efficient than a premium on interest rates for brown investments to support the transition towards renewable energy.

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Contents

1 INTRODUCTION

Putting the economy on an environmentally sustainable path requires a serious shift into green technologies. Such a shift includes substantial investments in technologies that are based on renewable energy to produce electricity – referred to hereinafter as green energy technologies. Long-term interest rates play a crucial role in energy investments (as they do for any investment choice). In particular, interest rates[1] greatly affect the costs of capital for energy projects and are thus potentially an important factor in the competitiveness of green versus brown energy technologies – i.e. of technologies using renewables energy to produce electricity versus technologies using non-renewable energies.

Against this background, we study the impact of interest rates on the costs of producing electricity with different technologies, using renewable and non-renewable energy, respectively. We first estimate the levelized cost of energy (LCOE), which is the price at which electricity must be sold for a plant to break even, for several green and brown energy technologies. We then study the effect of interest rates on the relative LCOE of green compared to brown energy technologies. We identify which interest rate environment is the most favorable for green energy technologies, whether green energy technologies' production costs react differently to changes in interest rates compared to brown energy technologies, and whether interest rate discounts for green energy technologies would significantly improve their competitiveness compared to brown energy technologies.

2 METHODOLOGY

To compare the costs of green and brown energy technologies, we first estimate the LCOE of the different alternatives. The LCOE is a standard measure for production costs in the energy sector. It is an approximation of the (constant) price at which a plant must sell electricity over its lifetime to break even. It is expressed in US dollar per kilowatt-hour ($/kWh). Note, first, that the LCOE is a measure of the *costs* of producing electricity and not of its *price*. Both are related in the long run but they can deviate substantially and for long periods. Second, the LCOE is an *ex ante* estimation of the production costs and it is based on models; it is not the *ex post* observed costs. Finally, one should be aware that the LCOEs estimated below are only a rough measure of the real LCOE faced by firms because our calculations are based on a relatively simple model that omits several factors, e.g. the tax rate, the possibility of taking advantage of interest rate changes, etc. However, as these omitted factors are likely to influence all technologies in a similar way, we assume that they do not affect our cost ranking of technologies and thus our conclusions.

[1] In this note, the term "interest rates" refers to *long-term* interest rates as short-term interest rates only play a marginal role because of the very long investment horizon required by large electricity-generating plants.

The LCOE of a power plant can be decomposed into three parts: capital costs (the costs of reimbursing the initial investment to build the plant), operation and maintenance costs (the non-fuel costs of running and maintaining the plant) and fuel costs (the costs of fuel to produce power):

$$LCOE = LCOE_K + LCOE_{OM} + LCOE_F$$

To compute each of these components, we follow the approach proposed by Short, Packey and Holt (1995). Note that we estimate the LCOE *before* fiscal measures, i.e. the price at which energy must be sold to break even before adding taxes or subtracting subsidies. Under this assumption, the levelized capital cost can be expressed as the amount paid annually to recover the initial investment K plus interests divided by the annual energy production in kWh. This is

$$LCOE_K = \frac{K * CRF}{8760 * CF}$$

where CRF is the capital recovery factor (see below), 8760 is the number of hours per year and CF is the capacity factor, i.e. the yearly average percentage of total capacity that is effectively used to produce energy.

The capital recovery factor CRF is the rate that must be paid annually to reimburse the initial investment borrowed at interest rate r over the lifetime N of the plant. It is calculated as

$$CRF = \frac{r(1+r)^N}{(1+r)^N - 1}$$

The maintenance and operating costs can be divided into annual fixed costs FC_{OM} and variable costs per kWh VC_{OM}. To estimate the total maintenance and operating costs of one kWh, one must divide the annual fixed costs by the number of kWh produced per year and add the variable cost of one kWh:

$$LCOE_{OM} = \frac{FC_{OM}}{8760 * CF} + VC_{OM}$$

Finally, the costs of fuel is equal to

$$FCOE_F = P_F * HR$$

Where P_F is the price of fuel per million British Thermal Unit (MMBtu) and HR is the heat rate, i.e. the efficiency of the power plant in converting fuel into electricity, measured in MMBtu per kWh.

3 Data

The data to estimate the LCOE of different energy technologies are taken from the "Transparent Cost Database" collected by Open Energy Information (2014), a U.S. website sponsored by the U.S. Department of Energy, the National Renewable Energy Laboratory and the Renewable Energy and Energy Efficiency Partnership (REEEP). This database collects estimated costs for the United States based on models (and not on observed costs) from different studies that have been published between 2008 and 2014 (see Open Energy Information, 2014, for a detailed list of all the studies reviewed). We select estimated costs for 2014, which includes 237 observations.

Table 1 – Summary statistics

	Technology	Number of projects	Lifetime	Initial capital	Capacity factor	Fixed OM costs	Variable OM costs	Fuel costs	Heat rate
			Years	USD/kW	%	USD/kWh	USD/MWh	USD /MMBtu	MMBtu /kWh
Green energy	Biomass	32	43	2'246	84	78	5.8	2.0	12'379
	Geothermal	15	23	4'286	89	146	10.0	-	-
	Hydroelectric	7	100	1'679	93	13	2.8	-	-
	Photovoltaic	19	30	3'568	23	17	0.0	-	-
	Solar concentrator	15	30	5'403	38	59	0.01	-	-
	Wind, onshore	17	22	1'615	42	22	3.3	-	-
	Wind, off-shore	24	20	3'158	45	50	17.1	-	-
Brown energy	Coal	50	51	3'216	83	43	3.9	2.1	9'397
	Combined cycle gas turbine	23	33	1'049	77	12	4.7	4.7	7'082
	Combustion turbine	15	34	710	49	12	4.0	4.7	9'451
	Gas-based fuel cell	9	30	5'313	95	6	43.7	4.7	7'378
	Nuclear	11	40	4'435	90	90	0.8	0.5	10'371

For each technology, we take the mean of each variable to estimate the LCOE. Table 1 presents the values obtained. The fuel prices are taken from Open Energy Information (2014).

4 Empirical results

4.1 Levelized cost of energy

As the interest rate influences the costs of capital, the LCOE varies with the interest rate level. To compare the LCOE between technologies, we estimate it for interest rates between 0% and 15%. The indexes for green and brown energy technologies presented below correspond to the average LCOE over all green and brown energy technologies, respectively. Figure 1 presents the results.

Figure 1 – Comparison of estimated LCOE

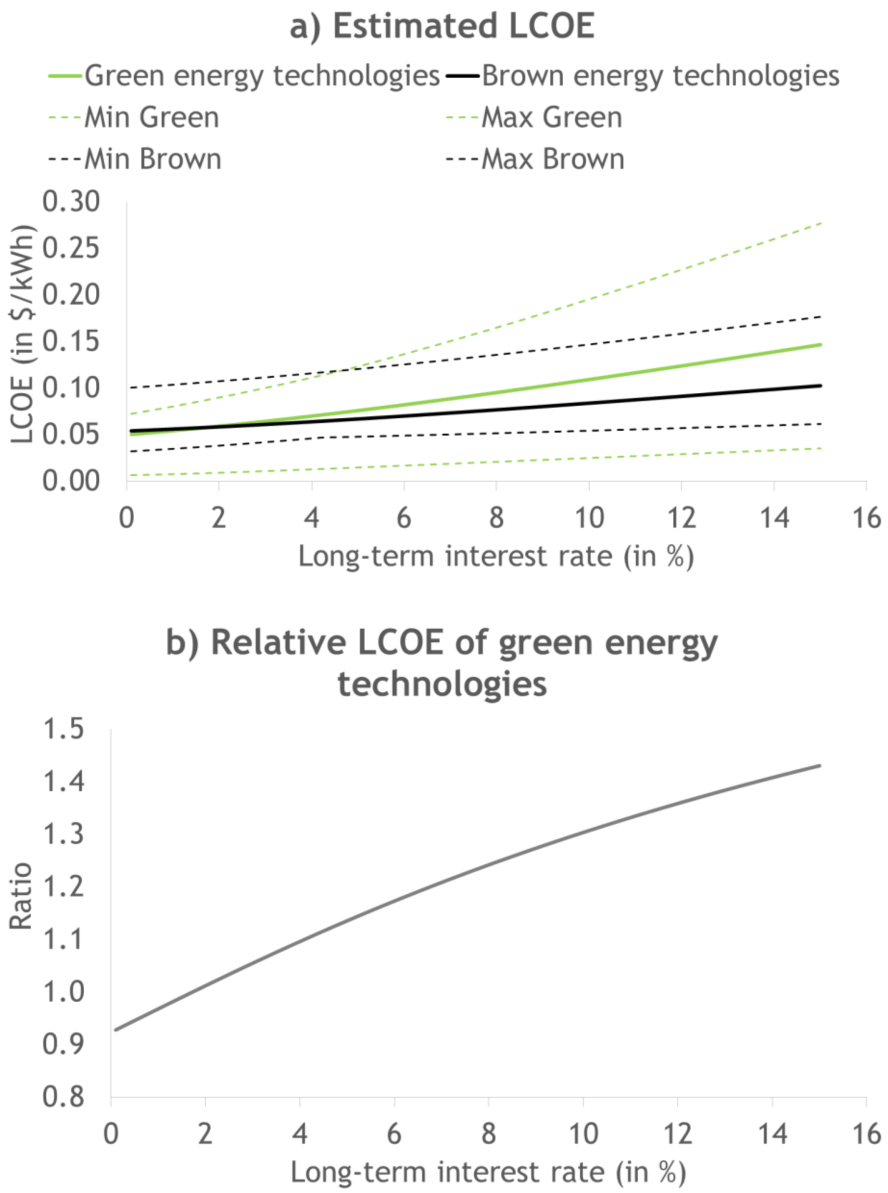


TABLE 2 – ESTIMATED LCOE FOR DIFFERENT LEVELS OF INTEREST RATES (IN $/KWH)

Interest rate	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
Coal	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10
Combined Cycle Gas Turbine	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06
Combustion Turbine	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08
Gas-based fuel cell	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.16	0.16	0.17	0.18
Nuclear	0.03	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.10
Biomass	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.10
Geothermal	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.11
Hydroelectric	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04
Photovoltaic	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.18	0.20	0.21	0.23	0.24	0.26	0.28
Solar concentrator	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.18	0.19	0.20	0.22	0.23	0.25	0.26
Wind, offshore	0.07	0.08	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.12	0.13	0.14	0.14	0.15	0.16
Wind, on-shore	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.08

Figure 1a shows that the average costs of producing electricity are higher for green energy technologies for interest rate levels above 2%. However, as reflected in Figure 1b, with interest rates at 2% the cost ratio of green energy technologies compared to brown energy technologies is 1.0 (i.e. reflecting cost parity) and drops further as interest rates go lower. Thus, green energy technologies become more competitive compared to brown energy technologies in a low interest rate environment.

We provide the average figures referred to above and below to illustrate the impact of interest rates on energy technologies. At the same time, we are conscious that energy choices are not determined by averages, but rather by the costs of individual technologies. Against this background, Figure 1a also compares the minimum and maximum LCOE of green and brown energy technologies, respectively. The least expensive green technology in that graph is hydroelectric. Solar technologies (both photovoltaic and concentrated solar) represent the upper bound. For brown technologies, the minimum costs are represented by nuclear for interest rates up to 6.5% and by combined cycle gas turbines as interest rates rise further. Gas-based fuel cell energy delineates the upper bound of LCOEs for brown energy technologies. Table 2 provides the details for all technologies and highlights the fact that various green energy technologies are competitive with brown energy technologies – in particular in a low interest rate environment.

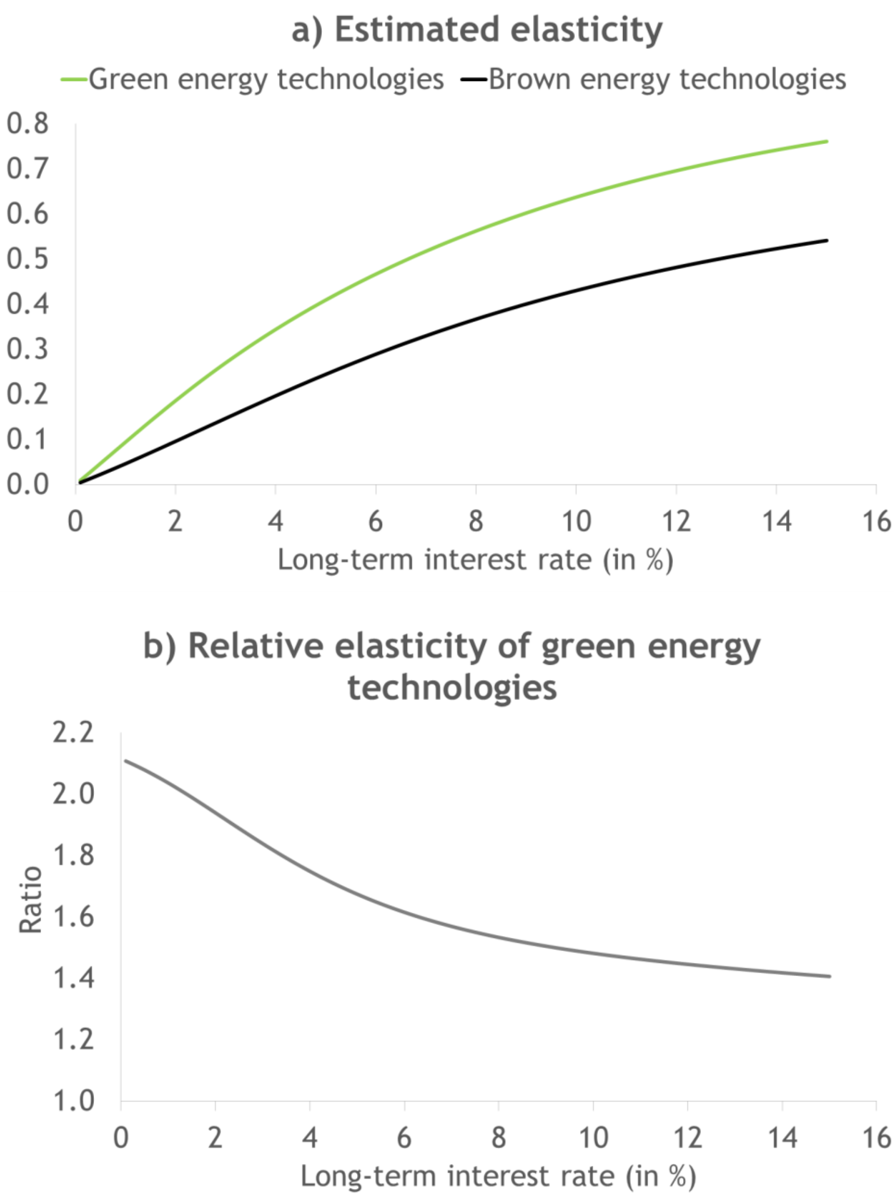
4.2 ELASTICITY TO INTEREST RATES

We now turn to estimating LCOE elasticity to a change in interest rates – measured as the reaction of production costs (in %) to a change (of 1%) in the interest rate. Figure 2 presents the results.

Our estimations in Figure 2a show that, on average, the LCOEs for green energy technologies have a higher interest rate elasticity than those for brown energy technologies. This is the case at all interest rate levels. The first implication of these results is that changes in interest rates will have a stronger impact on green energy costs than on brown energy costs. This induces that a decrease in interest rates will translate into a stronger decrease in green energy technologies costs than in brown energy technologies costs, and will probably stimulate investment in the former more than in the latter. Note also that the relative difference between the elasticity of green and brown energy technologies decreases with the level of interest rates (Figure 2b). Thus, changes in interest rates will have more impact on green relative to brown energy technology costs in a low interest rate environment.

Second, the higher elasticity for green energy technologies induces a greater volatility of their costs in response to interest rate volatility. A higher volatility is damaging because it brings more uncertainty in investment decisions. Higher uncertainty translates into a higher risk premium for green energy investments and may thus reduce investments into the sector.

FIGURE 2 – LCOE ELASTICITY WITH RESPECT TO INTEREST RATES

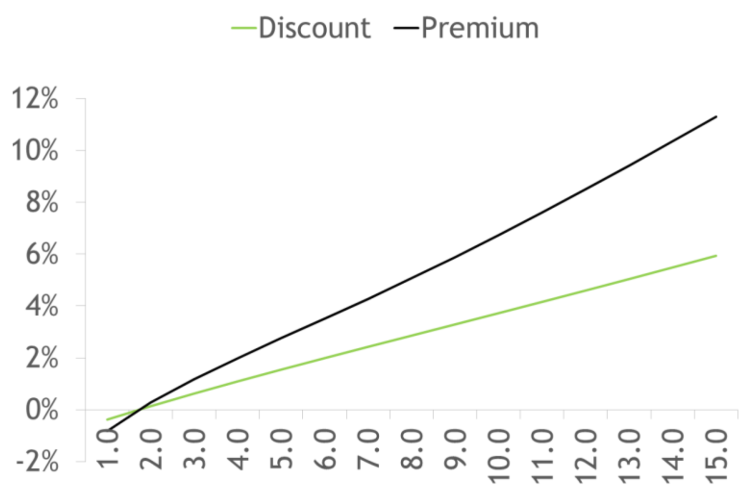


4.3 SUPPORTING GREEN ENERGY INVESTMENTS WITH INTEREST RATE DISCOUNTS OR PREMIA

The pollution generated by brown energy technologies constitutes an externality for society. This negative externality can be internalised with a Pigouvian tax that aligns private and social costs (Baumol, 1972). In our case, imposing a premium on the interest rate for loans to brown energy investments or giving a discount on the interest rate for loans available to green energy investments can correct this externality.

In this section, we estimate the discount in interest rates, which makes the average LCOE of green energy technologies equal to the one of brown energy technologies, or alternatively, which premium on brown energy technology interest rates makes their LCOE equal to green energy technologies' LCOE. Again, as stated in 4.1, we are conscious that it is not these averages that determine investment decisions between green and brown energy, but rather the costs of individual technologies. Nonetheless, the averages allow us to illustrate the different effects of a discount and premium. Figure 3 presents the results.

FIGURE 3 – EQUALISING THE LCOE WITH AN INTEREST RATE DISCOUNT OR PREMIUM



The discount necessary to create parity between the average green energy technology LCOE with the average brown energy technology LCOE is much smaller than the premium necessary to do the same – i.e. depending on prevailing interest rate levels between 0% and 6% for the discount and between 0% and 12% for the premium. Thus helping green energy investments with a discount would require a smaller intervention in market interest rates (compared to the original situation) than trying to penalize brown investments with a premium on the initial interest rate.

5 Policy conclusions

This short analysis of the impact of interest rates on green energy technologies costs points to three key conclusions:

1) **A low interest rate environment makes green energy technologies more competitive**. Hydroelectric power is less expensive than any other technology across the entire spectrum of interest rate levels that we analyzed in this paper. Wind on-shore is competitive with all other technologies up until interest rates of about 8%.

2) Green energy technologies' LCOEs react more significantly to a change in interest rates than the LCOEs of brown energy technologies. Thus the volatility for green energy technologies' costs in response to interest rate volatility is greater than for brown energy technologies' costs. A higher volatility is damaging because it brings more uncertainty in investment decisions. **As a result, stable interest rates are more beneficial for green energy investments than for brown energy investments**.

3) In order to increase the ratio of green to brown energy investments, we can consider a discount on the interest rates for the former or a premium on interest rates for the latter. Our estimations indicate that **a discount on green investments' interest rates would be more efficient than a premium on brown investments' interest rates**, as the discount would be lower than the premium required for the same effect.

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