Renewable Energy and Electricity Prices

Indirect Empirical Evidence from Hydro Reservoir

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Motivation

- Countries experience that energy prices go to zero in case of an excess of wind or solar output.
- Many countries have introduced policies to stimulate the production of electricity in a sustainable or renewable way. Theoretical and simulation studies provide evidence that the introduction of renewable energy promotion policies lead to lower electricity prices as sustainable energy supply as wind and solar have very low or even zero marginal costs. Empirical support for this result is relatively scarce possible due to a lack of data.
- Modeling day-ahead electricity prices: moving from pure stochastic towards more fundamentally based models.
- What is the impact of reservoir levels on electricity prices levels and variation (volatility)?
- Papers with Victoria Stradnic (ESE) and Sjur Westgaard (NTNU - Trondheim)

RE and electricity prices

- Feed-in tariff policy is the most preferred policy by investors (Hofman and Huisman (2012)).
- Amundsen and Mortensen (2001), Jensen and Skytte (2002) and Fisher (2006) provide theoretical evidence that the introduction of renewable energy promotion policies lead to lower electricity prices.
- This theoretical result has been confirmed from simulation studies by Sensfuss, Ragwitz and Genoese (2008) and Linares, Santos and Ventosa (2008).
- Empirical support is relatively scarce. Sáenz de Miera, del Ro and Vizcano (2008), Jonsson, Pinson and Madsen (2010) and Gelabert, Labandeira and Linares (2011) provide empirical support. The last studies examines the Spanish market between 2005 and 2009 and report that a marginal increase of 1GWh of renewable electricity production and cogeneration yields a 4% decline in electricity prices.

Our idea

The motivation for this study is to provide additional empirical evidence on how the growth production from sustainable energy sources influences power prices. We focus on hydro power.

- When reservoir levels are almost *empty*: marginal costs of production is high as the real option to delay is valuable. Supply has positive marginal costs such as in a fossil fuel market.
- When reservoir levels are almost *full*: marginal costs of production is low as the risk of spillover makes the option to delay of low value. This applies to almost all producers. Part of the supply has zero marginal costs as in a market with both fossil fuels and renewable energy sources as wind and solar.

Our idea: to analyze how the price of electricity changes from when reservoir levels are low (mimics a market without RE) to when reservoir levels are high (mimics a market with RE).

A simple demand / supply (fundamental) model

Barlow (2002) and Buzoianu, Brockwell and Seppi (2005) model the time dynamics of electricity prices by specifying demand and supply curves and a stochastic demand process. Barlow (2002) assumes that supply is non random and independent of time and uses a power function to relate quantity to prices. Buzoianu et al. (2005) assume that the supply curve varies over time and use an exponential form. We use a combination of both papers. We follow Buzoianu et al. (2005) as we allow for a time-varying supply curve and we apply Barlow's power function as we think that it better deals with potential price spikes.

A simple demand / supply (fundamental) model (2)

We assume that reservoir levels, coal prices and emission prices might influence the level and curvature of the supply curve. A change in reservoir level may have a non linear effect on the electricity price. We assume that demand is not price elastic.

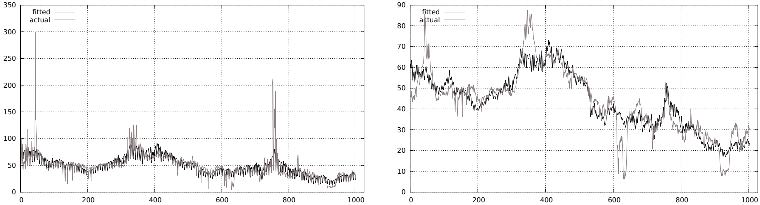
$$
\begin{aligned}
p_t(s_t) &= \bar{p} - a_t(\bar{s} - s_t)^{\alpha}, \\
a_t &= e^{a_0 + a_r r_t + a_c p_t^c + a_e p_t^e}, \\
\alpha &= \frac{1}{1 + e^{-\alpha^*}}, \\
s_t &= d_t, \\
p_t(d_t) &= \bar{p} - e^{a_0 + a_r r_t + a_c p_t^c + a_e p_t^e} (\bar{s} - d_t)^{\frac{1}{1+e^{-\alpha^*}}}.
\end{aligned}
$$

Parameter estimates

- Non-linear least squares to estimate the parameters a_0, a_r, a_c, a_e, and α^*.
- Hourly consumption and day-ahead prices from Nord Pool from 1 January 2010 through 7 October 2012 (24,264 observations) from Montel.
- Weekly percentage reservoir levels (we assume them to be constant during the week).
- We have divided consumption by 10,000 to make numbers comprehensible.
- We estimate expected demand / consumption: $c_t = v_1 c_{t-7} + v_2 + (c_{t-2} - c_{t-9})$.

Results

Figure : Actual (gray thin line) and fitted (black thick line) prices for hour 9 (left) and hour 23 (right).



Results

Table : NLS estimates of the parameters in the market clearing price model.

	model 1	model 2	model 3
a_0	7.528	7.529	7.548
	(6.260e-04)	(6.066e-04)	(6.478e-04)
a_r		2.110e-03	5.313e-04
		(1.999e-05)	(1.767e-05)
a_c			-3.046e-05
			(2.171e-06)
a_e			-1.458e-03
			(8.739e-06)
α^*	-3.483	-3.741	-3.525
	(0.012)	(0.016)	(0.012)
α	0.030	0.023	0.029
R^2_{adj}	0.334	0.481	0.719

The number of observations is 24,048.
Heteroskedasticity robust t-ratios are in parentheses.
Scientific notation: 1e-03 = 0.001

Concluding remarks (so far)

Our results show that variation in reservoir levels significantly change the level and convexity of the power supply curve and therefore the market clearing price. An increase in reservoir level lowers power prices. From this we conclude that more renewable energy supply reduce power prices as an increase in reservoir levels is equivalent to an increase in low marginal costs supply in an energy market.

This is good news for consumers, but it increases the costs of sustainable energy policies such as feed-in tariffs and at the same time lowers revenues and profits for power produces in case governments would abandon such policies. This makes sustainable energy a less attractive investment opportunity and will lower the supply of private capital for sustainable energy investments. Policy makers have to suggest different more sustainable policies if they want to stimulate a significant growth of sustainable energy supply.