Determinants of Regulated Hydro Power Supply in Norway

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1. Introduction

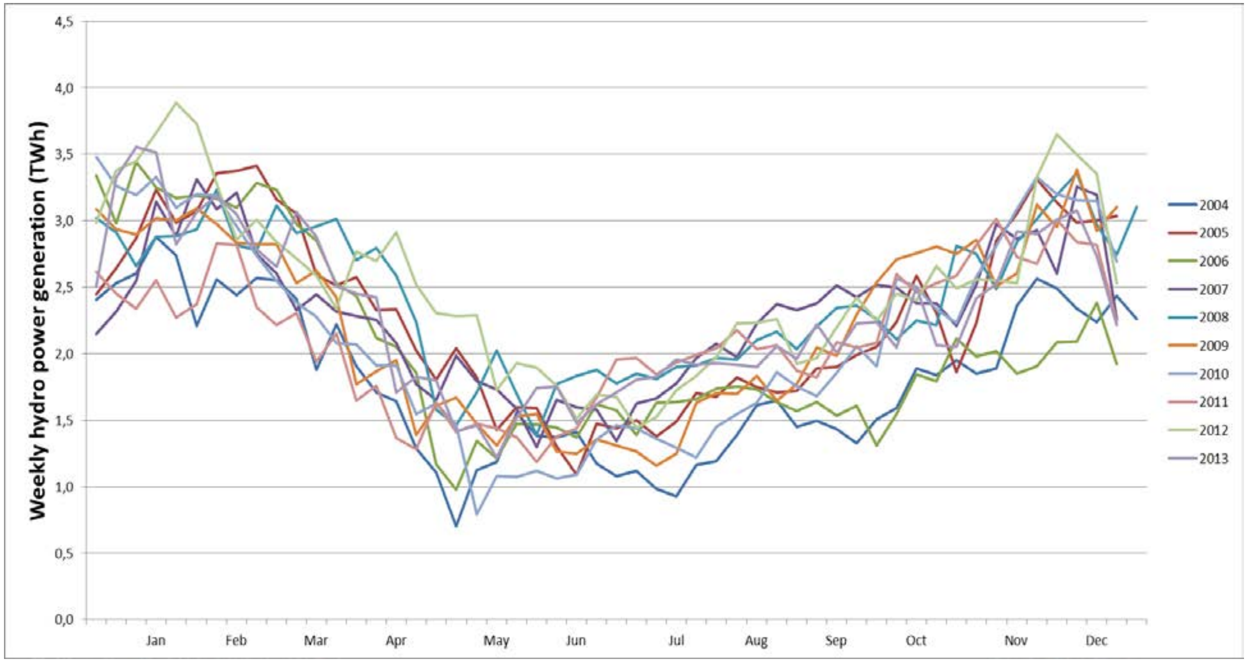
- Previous studies: Stochastic dynamic programming (SDP) or stochastic dual dynamic programming (SDDP) to *forecast* the behavior of hydro power suppliers

- Few studies have addressed hydro power supply based on *observed* data

- Approach useful to:
  - Verify/reject established views on drivers for hydro power supply
  - Assess the relative importance of various drivers
  - Prediction tool for future hydro power supply

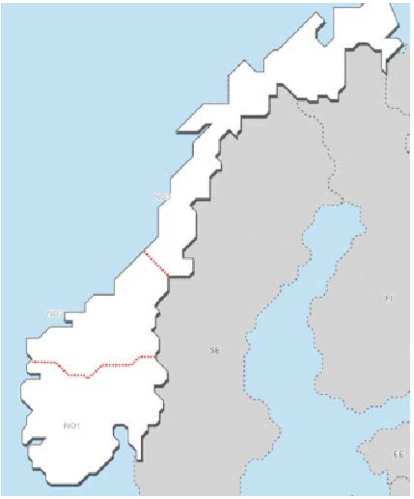
2. Data

- Weekly data for the years 2004 to 2013
  - Hydro power generation
  - Market drivers and factors affecting the water values
- 522 observations



2. Data

- Collected from
  - Thomson Reuters Point Carbon
    - Hydro power and run-of-river data
    - Hydrological balance
    - Inflow
    - SRMC coal
    - German power prices
  - Nord Pool Spot
    - Nordic power prices
  - eKlima
    - Temperatures



3. Method - Behaviour models

Ordinary Least Squares (OLS)

$$RegHP_{rt} = \beta_0 + \beta_1 lnPowerPrice_{rt} + \beta_2 HydBal_{rt} + \beta_3 Temp_{rt} + \beta_4 lnInflow_{rt} + \beta_5 lnSRMCcoal_{rt} + \beta_6 PriceExp_{rt} + u_{rt}$$

Two-Stage Least Squares (2SLS)

Step 1:

$$lnPowerPrice = \beta_1 HydBal_{rt} + \beta_2 Temp_{rt} + \beta_3 lnInflow_{rt} + \beta_4 lnSRMCcoal_{rt} + \beta_5 PriceExp_{rt} + \beta_6 lnGermanPowerPrice_{rt} + e_{rt}$$

Step 2:

$$RegHP_{rt} = \beta_0 + \beta_1 \widehat{lnPowerPrice}_{rt} + \beta_2 HydBal_{rt} + \beta_3 Temp_{rt} + \beta_4 lnInflow_{rt} + \beta_5 lnSRMCcoal_{rt} + \beta_6 PriceExp_{rt} + u_{rt}$$

4. Results: National supply - all-year model

OLS and 2SLS regression model result for all regions and seasons aggregated:

Variable	OLS regression for Y1: RegHP		2SLS First step for Y2: ln Power Price		2SLS Second step for Y1: RegHP	
ln Power Price NOK/MWh	0,401	***			1,680	***
Hydrological Balance TWh	0,028	***	-0,020	***	0,052	***
Temperature	-0,037	***	-0,011	***	-0,023	***
ln Inflow TWh	-0,340	***	-0,012		-0,292	***
ln SRMC coal NOK/MWh	-0,002		0,348	***	-0,860	***
Price Expectations	0,001	***	-0,001	***	0,003	***
ln German Power Price			0,293	***		
Constant	0,529	*	1,949	***	-1,783	**
R^2	88,3%		75,9%			

Significant at *p<0,10, **p<0,05, ***p<0,01

4. Results:
National supply - Seasonal models

OLS regression model result for all regions divided in different seasons:

	Regression coefficients							
Variable	Winter		Spring		Summer		Fall	
ln Power Price, NOK/MWh	0,973	***	0,569	***	0,248	***	0,153	**
Hydrological Balance, TWh	0,035	***	0,030	***	0,031	***	0,021	***
Temperature, Deg C.	-0,047	***	-0,020	***	-0,025	***	-0,045	***
ln Inflow, TWh	-0,251	***	-0,323	***	-0,471	***	-0,305	***
ln SRMC coal, NOK/MWh	-0,309	**	-0,095		-0,057		0,459	***
Price Expectations, NOK/MWh	0,002	***	0,000		0,000		0,001	*
Constant	-0,939	**	-0,165		1,763	***	-0,620	
N	129		132		130		131	
R^2	81,2%		85,7%		64,6%		75,6%	

Significant at *p<0,10, **p<0,05, ***p<0,01

4. Results – Regional models

2SLS regression model result for regions divided in different seasons:

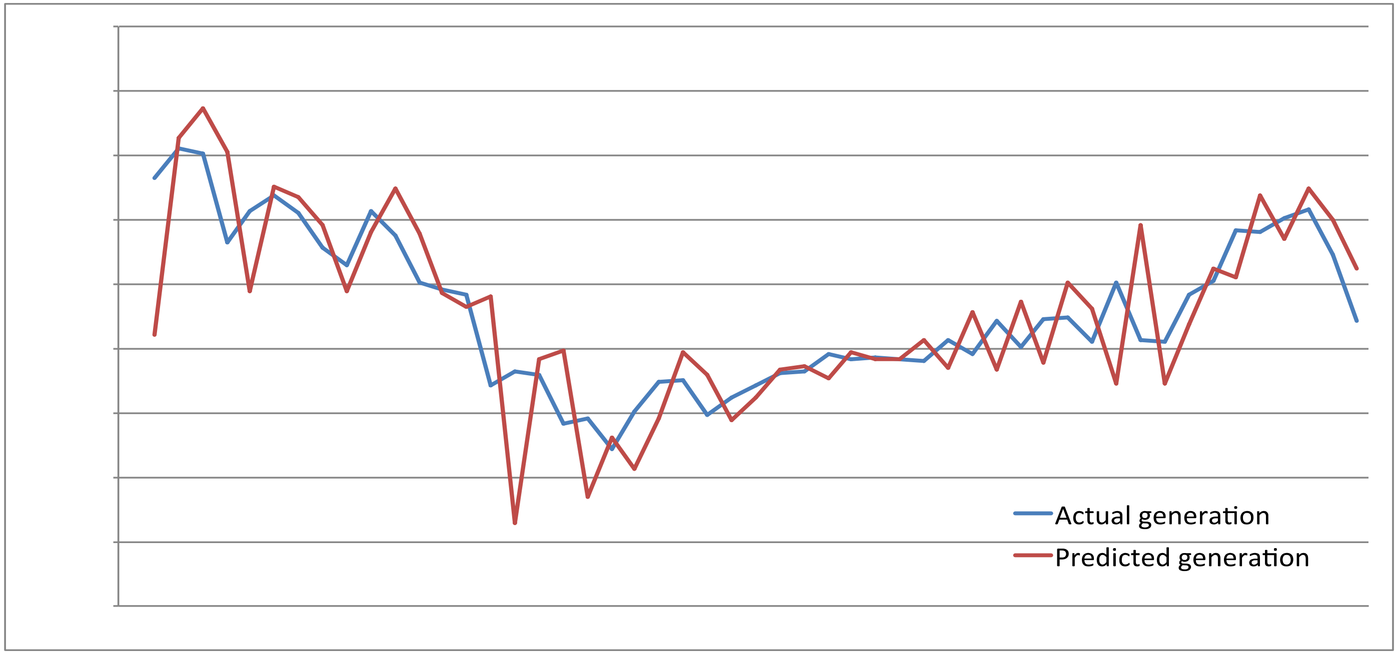
Variable	Southern Norway		Mid-Norway		Northern Norway	
ln Power Price NOK/MWh	0,884	***	0,340	***	0,453	***
Hydrological Balance TWh	0,035	***	0,008	***	0,008	***
Temperature	-0,020	***	-0,004	***	-0,006	***
ln Inflow TWh	-0,206	***	-0,007		-0,019	**
ln SRMC coal NOK/MWh	-0,411	***	-0,199	***	-0,288	***
Price Expectations	0,002	***	0,000	***	0,001	***
Constant	-0,654		-0,502	***	-0,535	***

Significant at *p<0,10, **p<0,05, ***p<0,01

4. Results – Prediction accuracy

Out of sample prediction

- OLS-model based on data spanning 2004-2012
- Observed values for 2013



- Average absolute deviation: 313 GWh / 13,6 %

5. Conclusions

- Explanatory variables like hydrological balance, inflow, temperature, SRMC coal and power prices have significantly affected the supply of national and regional supply in the years 2004-2013
- Main reasons for the differences seen in the regional models are the storage and regulation capacity in the three regions
- The estimated models have, in general, a good ability to predict the hydro power generation

Thank you for your attention! ☺

Changes in the supply of regulated hydro power (GWh) as a result of unit and percentage changes in explanatory variables:

Norge - produksjonstall i GWh	**Årsbasis** OLS	2SLS	**Vinter** OLS	**Vår** OLS	**Sommer** OLS	**Høst** OLS
%endring lnKraftpris	3,99	16,72	9,68	5,66	2,47	1,52
Enhetsendr. HydBal	28,22	52,37	34,78	30,37	31,36	20,90
Enhetsendr. Temp.	-37,07	-22,65	-47,41	-20,25	-25,05	-44,92
%endring lnTilsig	-3,38	-2,91	-2,49	-3,21	-4,69	-3,04
%endring lnSRMCkull	-0,02	-8,56	-3,08	-0,94	-0,57	4,57
Enhetsendr. Prisforv.	1,03	2,98	1,92	0,14	0,30	0,56

Regionale modeller - produksjonstall i GWh	**Sør-Norge** OLS	**Midt-Norge** OLS	**Nord-Norge** OLS
%endring lnKraftpris	1,46	0,18	1,31
Enhetsendr. HydBal	19,00	2,96	3,10
Enhetsendr. Temp.	-31,00	-4,47	-7,52
%endring lnTilsig	-2,16	-0,33	-0,33
%endring lnSRMCkull	0,89	0,14	-0,47
Enhetsendr. Prisforv.	1,00	0,08	0,16

Changes in the supply of regulated hydro power as a result of unit and percentage changes in explanatory variables:

Norge - produksjonstall i GWh	**Årsbasis**		**Vinter**		**Vår**		**Sommer**		**Høst**	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
%endring lnKraftpris	3,99	16,72	9,68	54,10	5,66	6,85	2,47	10,63	1,52	19,62
Enhetsendr. HydBal	28,22	52,37	34,78	103,71	30,37	32,39	31,36	54,77	20,90	47,81
Enhetsendr. Temp.	-37,07	-22,65	-47,41	64,38	-20,25	-22,28	-25,05	-18,11	-44,92	-29,14
%endring lnTilsig	-3,38	-2,91	-2,49	-4,30	-3,21	-2,86	-4,69	-2,49	-3,04	-2,22
%endring lnSRMCkull	-0,02	-8,56	-3,08	-21,51	-0,94	-2,00	-0,57	-8,69	4,57	-8,70
Enhetsendr. Prisforv.	1,03	2,98	1,92	7,73	0,14	0,47	0,30	1,88	0,56	3,13

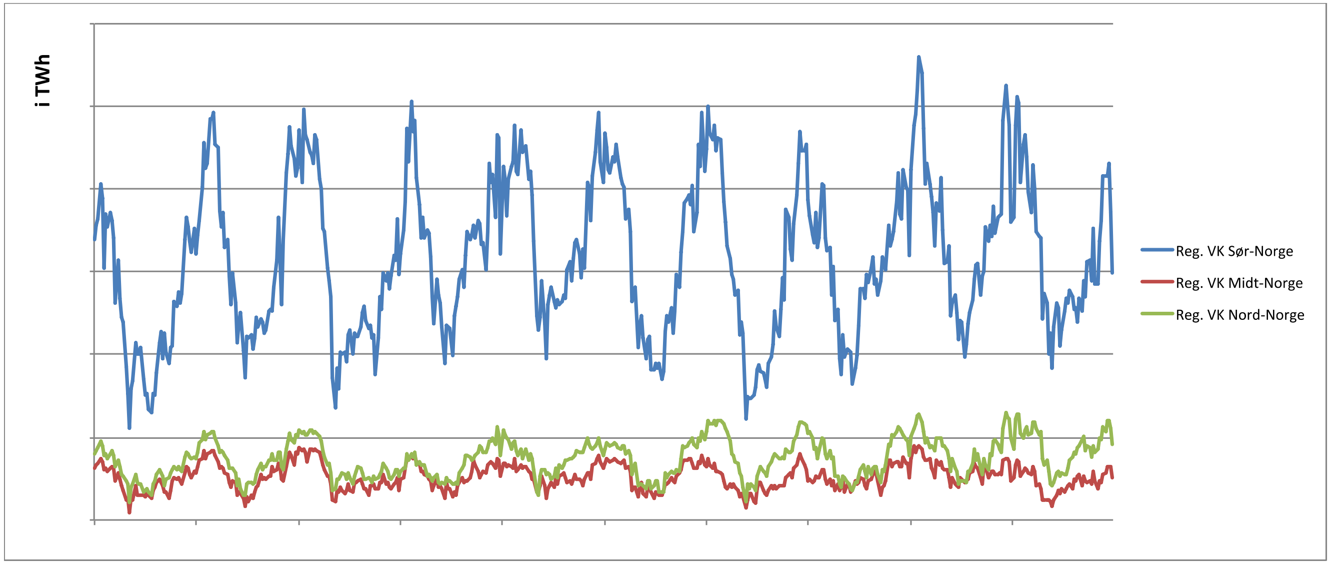
4. Results – All-year model

OLS regression model result for all regions and seasons aggregated:

Variable	Coefficient		Newey-West std.error	t	P>|t|	[95 % Confidence Interval]	
ln Power Price NOK/MWh	0,401	***	0,073	5,52	0,000	0,259	0,544
Hydrological Balance TWh	0,028	***	0,002	16,66	0,000	0,025	0,032
Temperature	-0,037	***	0,003	-10,89	0,000	-0,044	-0,030
ln Inflow TWh	-0,340	***	0,027	-12,81	0,000	-0,392	-0,288
ln SRMC coal NOK/MWh	-0,002		0,070	-0,02	0,982	-0,139	0,135
Price Expectations	0,001	***	0,000	4,97	0,000	0,001	0,001
Constant	0,529	*	0,313	1,69	0,091	-0,085	1,143
N	522						
R^2	88,3%						

Significant at *p<0,10, **p<0,05, ***p<0,01

SETNING om test + resultater. AVSLUTNINGSVIS: hva resultatene kan brukes til + hvilke implikasjoner



i TWh
Reg. VK Sør-Norge
Reg. VK Midt-Norge
Reg. VK Nord-Norge