Competition and substitution in energy: old scenarios and emerging technologies

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CENTRO STUDI DI ECONOMIA E TECNICA DELL'ENERGIA "GIORGIO LEVI CASES"

UNIVERSITÀ DEGLI STUDI DI PADOVA

Overview

PhD in Statistical Sciences

1st year: courses for theoretical deepening of important mathematical and statistical topics

Original project (started in October 2016)

- ✓ Dataset (Belgium, China, Finland, France, Germany, India, Japan, Spain, Sweden, Switzerland, UK, USA)
- ■ Univariate diffusion models (unnecessary)
- ✓ UCRCD and CRCD models: 2 competitors
- ■ Dynamic market potential (to be done in the next months)
- ✓ Incorporate intervention functions
- ✓ Extend the competition models: 3 competitors

Competition among energy sources?

- Still, most of electricity produced with depleting energy sources (e.g., coal, gas, oil, nuclear).
- Beside the problem of fuel depletion, climate change and pollution produced by fossil fuels.
- Renewable sources of energy appear a viable option to deal with all these problem
  $\Rightarrow$ solar technology has already made significant progress in a short amount of time (The Economist, June 6, 2015).

Renewable energy sources is gaining market share against other sources.

Models for competition

Two versions

Balanced model

A model where the word-of-mouth (w.o.m) affects only at the category level instead of brand level, i.e. the w.o.m effect does not separate the adoptions of each brand from those of competitors.

Unbalanced model

A model where the w.o.m affects at the brand level, i.e. separating the within-brand from the cross-brand w.o.m effects.

2 types of competitions

Synchronic competition

It means there are simultaneous market entries for the competing brands (products).

Diachronic competition

It means there are sequential market entries of the competing brands (products). Diachronic competition creates the 'regime change' problem for the previously entered pioneers.

Sources of energy

Usually, feasible competition models deal with 2 products due to parameters' complexity

Renewable

Renewable sources of energy are those that are replenished by the environment over relatively short periods of time. Solar, wind, water, biomass, etc.

Non-renewable

Non-renewable energy comes from sources that will run out or will not be replenished in our lifetimes. Coal, gas, oil and nuclear.

UCRCD model (Guseo and Mortarino, 2012; 2014)

$$z_1'(t) = m\Bigg[\left(p_{1a} + q_{1a}\frac{z(t)}{m}\right)(1 - I_{t>c_2}) +$$

$$+\left(p_{1c} + (q_{1c}+\delta)\frac{z_1(t)}{m} + q_{1c}\frac{z_2(t)}{m}\right) I_{t>c_2}\Bigg]\left(1 - \frac{z(t)}{m}\right)$$

$$z_2'(t) = m\left(p_2 + (q_2-\gamma)\frac{z_1(t)}{m} + q_2\frac{z_2(t)}{m}\right)\left(1 - \frac{z(t)}{m}\right) I_{t>c_2}$$

$$m = m_a(1 - I_{t>c_2}) + m_c I_{t>c_2}$$

$$z(t) = z_1(t) + z_2(t) I_{t>c_2}$$

Model fitted for 2 competitors

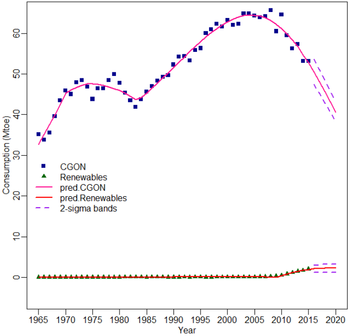
Non-renewable (CGON): coal, gas, oil, nuclear
Renewable : hydro, solar, wind

CRCS model with 3 exp. shock for 2 competitors, Belgium

Parameter	Estimate	Standard Error	95% Confidence interval
m	3346.41	84.6301	(3178.22, 3514.59)
p1	0.07208	0.21886	(-0.36286, 0.50704)
q1	0.60419	1.79455	(-2.9621, 4.17049)
a1	5.97378	0.84601	(4.29251, 7.65504)
b1	-0.04530	0.02514	(-0.09528, 0.00466)
c1	0.12536	0.35290	(-0.57595, 0.826682)
a2	19.28340	0.51744	(18.25510, 20.31170)
b2	-0.00364	0.01091	(-0.02533, 0.01805)
c2	-0.99004	0.06914	(-1.12745, -0.85264)
p2	0.00025	0.01091	(-0.02143, 0.021947)
q2	0.01147	0.15821	(-0.30293, 0.32588)
a3	45.28640	3.61224	(38.10790, 52.46500)
b3	-0.05964	0.99596	(-2.03893, 1.91963)
c3	-0.98898	0.15527	(-1.29756, -0.680406)
R^2=0.99855	F test=7.42487		

2 competitors

Non-renewable (CGON): coal, gas, oil, nuclear
Renewable : hydro, solar, wind



Fitted CRCS model with 3 exp. shocks (for confidence bands see, Guseo and Mortarino, 2015)

Increasing competitors

⇒ Not feasible for 7 products (coal, gas, oil, nuclear, hydro, solar, wind).

⇒ Nuclear energy might be defined as renewable (controversial in the literature)

- **CGO:** coal, gas, oil
- **Nuclear**
- **Renewable:** hydro, solar, wind

Balanced model for 3 competitors

$$z_1'(t) = m\left\{ \left[p_{1\alpha} + q_{1\alpha}\frac{z(t)}{m}\right] I_{t\le c_2} + \left[p_{1\beta} + q_{1\beta}\frac{z(t)}{m}\right] I_{c_2<t\le c_2} + \right.$$
$$\left. + \left[p_{1\gamma} + q_{1\gamma}\frac{z(t)}{m}\right] I_{t>c_3} \right\} \left[1 - \frac{z(t)}{m}\right]$$
$$z_2'(t) = m\left\{ \left[p_{2\beta} + q_{2\beta}\frac{z(t)}{m}\right] I_{c_2<t\le c_2} + \left[p_{2\gamma} + q_{2\gamma}\frac{z(t)}{m}\right] I_{t>c_3} \right\} \times$$
$$\times \left[1 - \frac{z(t)}{m}\right]$$
$$z_3'(t) = m\left[\left(p_{3\gamma} + q_{3\gamma}\frac{z(t)}{m}\right)\right]\left[1 - \frac{z(t)}{m}\right] I_{t>c_3}$$
$$m = m_\alpha I_{t\le c_2} + m_\beta I_{c_2<t\le c_3} + m_\gamma I_{t>c_3}$$
$$z(t) = z_1(t) + z_2(t) I_{t>c_2} + z_3(t) I_{t>c_3}$$

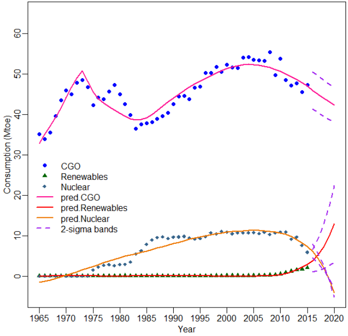
Model fitted for 3 competitors

CGO : coal, gas, oil
Nuclear
Renewable: hydro, solar, wind

UCRCS model with 1 exp. shock for 3 competitors, Belgium

Parameter	Estimate	Standard Error	95% Confidence interval
m	3849.24	72.5341	(3705.82, 3992.65)
p1	0.00256	0.00103	(0.00052, 0.00460)
δ	-0.23442	0.08316	(-0.39885, -0.07000)
η	0.25708	0.08544	(0.08814, 0.42603)
q1	0.2553	0.07444	(0.10810, 0.40250)
a1	8.86723	0.29263	(8.28864, 9.44581)
b1	-0.14734	0.02204	(-0.19092, -0.10376)
c1	2.32784	1.33721	(-0.31606, 4.97175)
p2	-0.00001	0.00016	(-0.00034, 0.00031)
θ	0.00415	0.01184	(-0.01926, 0.0275731)
ξ	1.56074	0.44188	(0.68705, 2.43443)
q2	-0.00572	0.01063	(-0.02674, 0.01529)
p3	-0.00040	0.00016	(-0.00073, -0.00007)
q3	0.03467	0.01109	(0.01272, 0.05661)
R^2=0.99550	F test=43.20186		

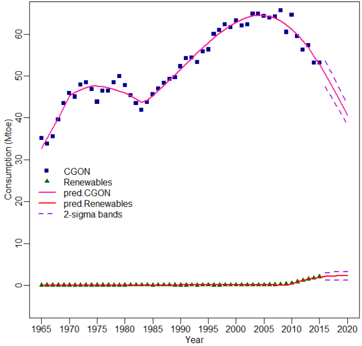
CGO : coal, gas, oil
Nuclear
Renewable: hydro, solar, wind



Fitted UCRCS model with 1 exp. shock; for confidence bands (see, Guseo and Mortarino, 2015)

Comparison

CGON: coal, gas, oil, nuclear
Renewable: hydro, solar, wind



CGO: coal, gas, oil
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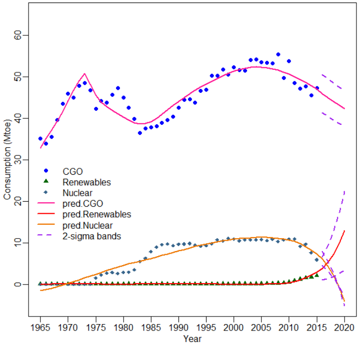
Renewable: hydro, solar, wind



Concluding remarks

- For almost all 12 countries analyzed our extended models for 3 competitors give narrower confidence bands than the existing models for 2 competitors.
- Narrower confidence bands correspond to a reduced forecasting uncertainty
  $\Rightarrow$ the new model allows more precise forecasting.

Future plans

- Complete comparisons between 2-product models and 3-product models.
- Improve model accuracy with a more flexible market potential definition (in the analyzed models a fixed market potential was assumed).
- Evaluate feasibility of 4-product models

References

1. Guseo, R. and Mortarino, C. (2012). Sequential market entries and competition modeling in multi-innovation diffusions. *European Journal of Operation Research* 216:658-667.
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3. Guseo, R. and Mortarino, C. (2015). Modeling competition between two pharmaceutical drugs using innovation diffusion model. *The Annals of Applied Statistics* 9(4):2073-2089.
4. Savin, S. and Terwiesch, C. (2005). Optimal product launch times in a duopoly: balancing life-cycle reveneues with product cost. *Operation Research* 53:26-47.

Thank you for your kind attention!