Energy and Fuel-Switching Pricing Using Levy Processes - An Application to Canadian Data

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Abstract

The Goal of this paper is to put a price on carbon following the introduction of the carbon price by the federal government of Canada. We use energy-switching to define a theorical carbon price. In order to model the prices, we consider three types of stochastic models: Levy Normal Inverse Gaussian (NIG) process, Levy Normal, and the Heston model.

Introduction

This paper focuses on Alberta who introduced the carbon tax in 2017. Alberta is currently the biggest coal producer alongside British Columbia as they provide 85% of Canadian coal. The use of this fossil fuel currently generates 10% of the country's electricity. Moreover, the province supplies 71% of Canada's natural gas (NRCAN, 2018). In 2018, the carbon tax increased by 50% to reach 30$ per tonne. The main concern raised by economists is that the tax is going to affect poor households, and this, in turn, could lead to an increase in inequalities (Ambasta and Buonocore, 2018). Hence, a correct approach to carbon pricing is essential for the Albertan economy and its residents.

We introduce an approach to carbon pricing based on the European energy market experience. Following the method introduced by Goutte and Chevallier (2015), we define the carbon price as the necessary price to incite companies to switch from coal to natural gas. Since the latter is less carbon intensive, this measure would considerably reduce GHG emissions. Besides, we also examine the case of switching from natural gas to wind. Moreover, we intend to generalize our statistical approach to the North American market and other energy indicators. In addition to the fuel-switching and energy-switching prices, we look at coal, natural gas, and oil individually. In order to model the prices, we consider three types of stochastic models: Levy Normal Inverse Gaussian (NIG) process, Levy Normal, and the Heston model.

Energy Economics and Energy Switching

Energy Prices depend on microeconomic and macroeconomic factors:

- National Allocation Plans
- Competition
- Weather Conditions
- Economic Growth

Energy-switching happens when the marginal cost of one source of electricity is greater than the other and can be expressed mathematically as:

$$MC = \frac{FC}{\eta} + \frac{EF}{\eta} EC$$

$$EC_{switch} = \frac{\eta_{coal} FC_{gas} - \eta_{gas} FC_{coal}}{\eta_{gas} EF_{coal} - \eta_{coal} EF_{gas}}$$

where, MC represents the marginal cost, EF, the emission factor, η, the plant's efficiency and EC, the carbon cost

Stochastic Model

Continuous mean-reverting process with Brownian motion is the solution to the stochastic defferential equation:

$$dX_t = (\theta - X_t)dt + \sigma dW_t$$

where W_t is a standard Brownian motion.

Lévy-driven Ornstein-Uhlenbeck Processes is the solution to the stochastic defferential equation:

$$dX_t^L = (\theta - X_t)dt + \sigma_L dL_t$$

where L_t is a Lévy process.

Heston Model Under the risk-neutural probability measure Q the Heston model is given by

$$dS(t) = rS(t)dt + \sqrt{V(t)}S(t)dW_s(t)$$
$$dV(t) = \kappa(\theta - V(t))dt + \sigma\sqrt{V(t)}dW_v(t)$$

where $W_s(t)$ and $W_v(t)$ are two Brownian motions with correlation coefficient ρ.

Data

The data used in this project were gathered from various sources, such as NRG Stream, Bloomberg, Energy Information Association (EIA), Market Insider, Jem Energy, the city of Winnipeg and CanWea. We obtain data ranging from 2000-2018 and chose to model prices using weekly frequencies.

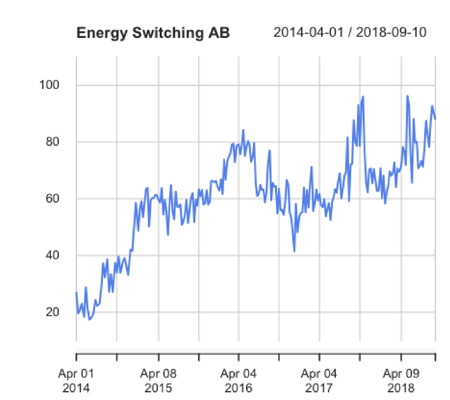


Figure 1:

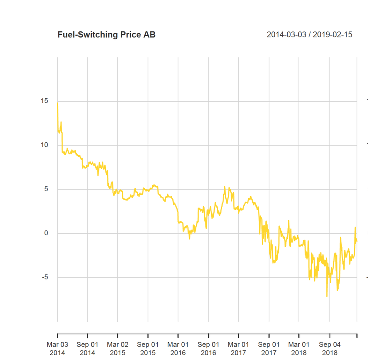
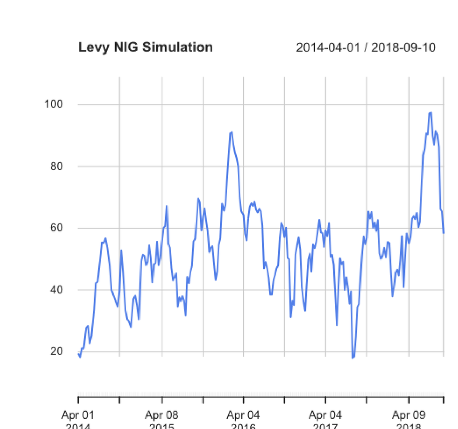
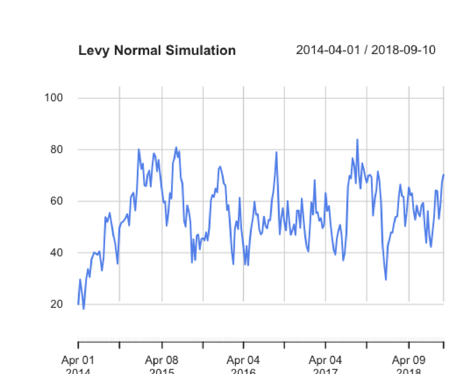


Figure 2: Fuel Switching price on Alberta

Simulations Results





Conclusion and future enhancement

The recent changes in the coal and natural gas prices have made fuel-switching an obsolete method to price carbon. Indeed, the fuel-switching price appears to be negative for several periods. Energy-switching, on the other hand, relies on the use of renewable energies, such as wind. This approach is hard to implement due to the lack of existing infrastructure, which does not allow to switch from one energy to the other. Nonetheless, as the use of renewable increases, a policy maker could define a carbon price based on this approach. Future research could consider alternative sources of energies, such as hydro and solar energies.

The three types of stochastic procedures yield different results. Overall, the Levy NIG outperforms both, the Levy Normal and Heston model. Moreover, it seems that the Heston model is not suitable for energy prices. Future research should focus on Hawkes processes and Markov-switching models. Additionally, different frequencies could be used such as daily or even high-frequency data. We chose weekly due to the difficulties to switch from one energy to another on a daily basis.

References

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[2] Barndorff-Nielsen, O. E., 1998, *Processes of normal inverse Gaussian type.*, Finance and Stochastics, 2, 41-68.

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