Modeling Canadian Heavy Crude Congestion Pricing

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Model - Price decomposition of the spread

This model is based off of the work of Birge et al., *Spatial price integration in commodity markets with capacitated transportation networks*, 2020.

For a network with fixed costs and fixed network structure, we decompose the equilibrium of the WTI–WCS price spread λ^t as follows:

$$\lambda^t = \rho + \varepsilon^t + \omega^t$$

where

1. λ^t: the WTI–WCS price spread at time t;
2. ρ: the transportation cost;
3. ε^t: a baseline equilibrium value;
4. ω^t: the congestion surcharge at time t.

Model - The neutral band

Uniqueness

In general, equilibrium prices are NOT unique in a transportation network.

Example

The price of a bottle of olive oil is \$15 in Vancouver (YVR) and \$20 in Calgary (YYC). It costs \$8 to transport each bottle between YVR and YYC.

Is there arbitrage?

Model - The neutral band

Uniqueness

In general, equilibrium prices are NOT unique in a transportation network.

Example

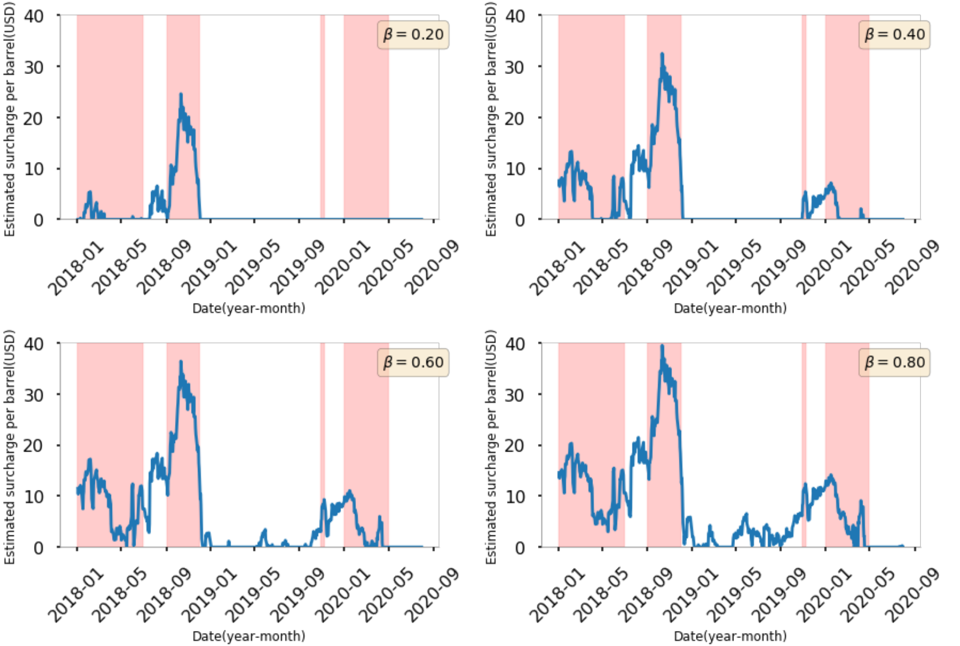
The price of a bottle of olive oil is $15 in Vancouver (YVR) and $20 in Calgary (YYC). It costs $8 to transport each bottle between YVR and YYC.

Is there arbitrage?
No. For any price at YVR in the interval [$12, $28] and there will be no arbitrage. We call this the *neutral band*.

Model - A one node model

$$
\begin{aligned}
\text{minimize: } & \alpha \\
\text{subject to: } & \lambda^t = \rho + \varepsilon^t + \omega^t, \quad \forall t \in \mathcal{T}, \\
& -\alpha \leq \varepsilon^t \leq \alpha, \quad \forall t \in \mathcal{T} \\
& 0 \leq \omega^t \leq \psi^t M, \quad \forall t \in \mathcal{T} \\
& \varepsilon^t \geq \alpha - (1 - \psi^t) M, \quad \forall t \in \mathcal{T} \\
& \sum_t \psi^t \leq \beta T, \\
& \psi^t \in \{0, 1\}, \quad \forall t \in \mathcal{T}.
\end{aligned}
$$

Here β and M are constants where $\beta \in [0, 1]$ and M is a sufficiently large upper bound for congestion.


$\beta = 0.20$
$\beta = 0.40$
$\beta = 0.60$
$\beta = 0.80$
Estimated surcharge per barrel(USD)
Date(year-month)
0
10
20
30
40
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05
2020-09

Model - A multi-node model

$$
\begin{aligned}
\text{minimize: } & \sum_{s\in\mathcal{S}} \alpha_s \\
\text{subject to: } & \lambda_s^t = \rho_s + \varepsilon_s^t + \omega_s^t, \quad \forall s \in \mathcal{S},\ \forall t \in \mathcal{T}, \\
& -\alpha_s \le \varepsilon_s^t \le \alpha_s, \\
& 0 \le \omega_s^t \le \psi^t M, \\
& \varepsilon_s^t \ge \alpha_s - (1-\gamma_s^t)M, \\
& \psi^t \le \sum_s \gamma_s^t \le |S|\,\psi^t, \\
& \sum_t \psi^t \le \beta T, \\
& \psi^t, \gamma_s^t \in \{0,1\},
\end{aligned}
$$

Here β and M are constants where $\beta \in [0,1]$ and M is a sufficiently large upper bound for congestion, and $|\cdot|$ denotes the cardinality of a set.

Model - Ornstein–Uhlenbeck process

$$\mathrm{d}S_t = \alpha(\mu - S_t)\,\mathrm{d}t + \sigma\,\mathrm{d}W_t$$

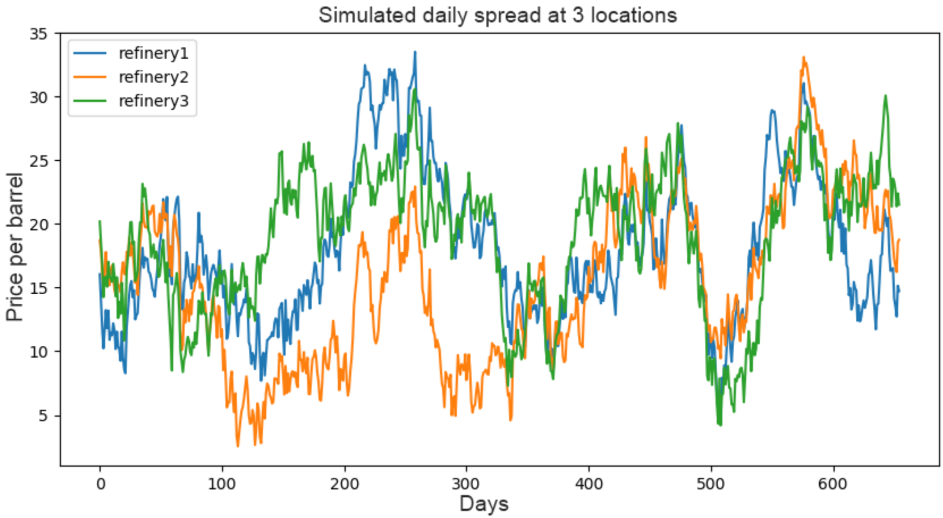
The SDE is calibrated to the WTI/WCS spread with parameters:

$$\alpha = 0.0119, \quad \mu = 16.3, \quad \sigma = 1.45.$$

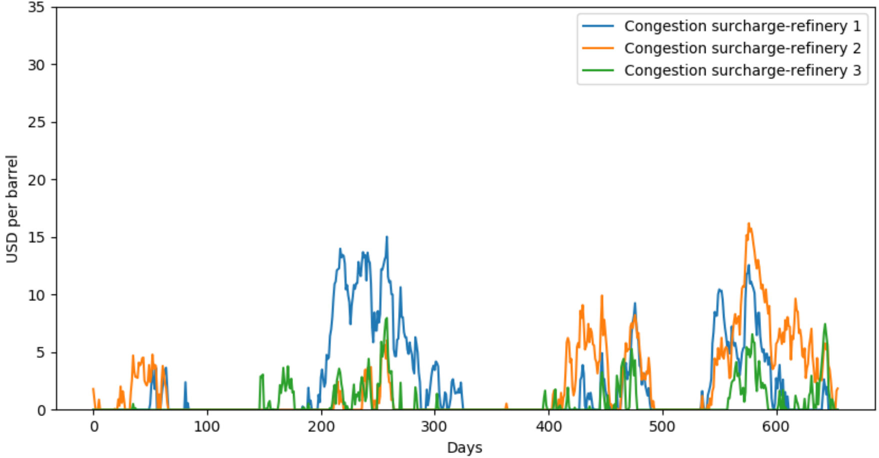
We simulate three paths using the correlation matrix:

$$\mathrm{corr} = \begin{bmatrix} 1 & 0.8 & 0.7 \\ 0.8 & 1 & 0.56 \\ 0.7 & 0.56 & 1 \end{bmatrix}$$

Simulated paths of the spread



Estimated congestion surcharge for $\beta = 0.6$



Thank you for your attention.