

Modeling Canadian Heavy Crude Congestion Pricing

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Introduction-Spatial price integration

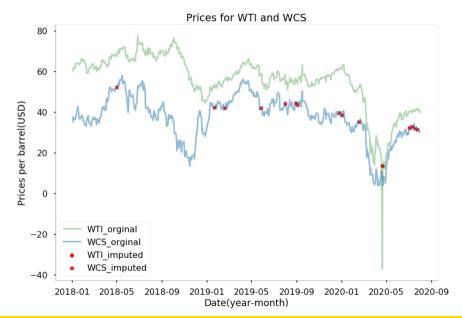
- Crude oil classification:Lighter oils are higher in price due to an easier cheaper process in refineries rather than heavy oils
- Location of extraction: It needs to be transported to the point of refinery
- Transportation capacity: Type of transportation and their capacitance, either pipelines or trains

Introduction - Oil price benchmarks

- West Texas Intermediate(WTI)
- West Canada Select (WCS)

- Alberta produces 4MM barrels per day. Two-thirds of the WCS production is consumed in United States.
- The spread between WTI and WCS is estimated about \$5 US due to the different oil classification

CANADIAN AND U.S. CRUDE OIL PIPELINES AND REFINERIES - 2019 CANADA'S OIL & NATURAL GAS PRODUCERS THE RESERVE lde Perining (Starpeon C LLD*Grand IEA Husky sophisk plant (AB) Husky Sppraker (SK) BP (Charry Point) Shell (Associated) Andescor (Associated) Philips SE (Farnishi) Traditions (Tacoma) MONTHÉR, QUÉBEC Voiero (Sarbino City) 235 Sarana Monteiro 137 PADD IV PADD V SAN PRAMERSON Outcome (Filchmand) 257 Andexore (Filchmand) 165 Shall (Startinas) 165 Water (Startinas) 165 Philips 66 (Footoo & Santa Markel 130 **PADD II** PENSPISANIA Pri Dwgs Solders (NE) NEW JERSEY Politip III (Bayway) THE Chalaters) PELME TOLLS FOR HEAVY OIL ONE or hand OLARAGE ST. CALBURY Member Philips 65 (Carson/W Volum (Wilminster) PADD I State of Contract Contract (Service Contract Contract (Service) Andrews (Service) Crude Refining Capacities as at June 1, 2019 Seusand barrats per ded Marathur (Sarpella) Coundhild (Balon Rouge) Philips SI (Belle Chasse) Shell (Narra) Petroleum Administration for Defense District SAN ANTENNO Columns THREE RIMERS Mandron Eintwester) 585 Excellibid Saytones 581 Shall-Exer Fark) 340 LyandelSaset 260 Major Existing Crude Oil Picelines Carrylon Viters CHREST Canadian Crude Oil 600 LARE CHAR 560 CITGO 300 Philips 66 Value (II. Charles) PM (Chalmete) Value (Mirzus) Date (Kndr Springs) Pauld (Part Klari) Selected other Crude Oil Pipelines



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;
- ρ : the transportation cost;
- ε^t : a baseline equilibrium value;
- 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

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Example

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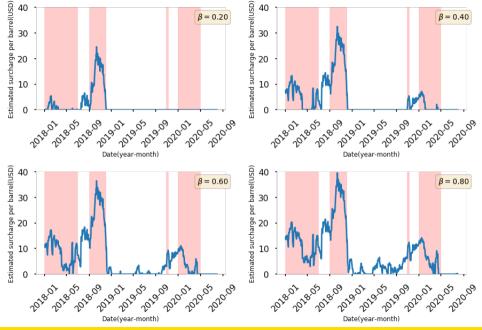
Is there arbitrage?

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

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

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



Model - A multi-node model

minimize:
$$\sum_{s \in \mathcal{S}} \alpha_s$$
 subject to: $\lambda_s^t = \rho_s + \varepsilon_s^t + \omega_s^t$, $\forall s \in \mathcal{S}, \ \forall t \in \mathcal{T},$ $-\alpha_s \leq \varepsilon_s^t \leq \alpha_s,$ $0 \leq \omega_s^t \leq \psi^t M,$ $\varepsilon_s^t \geq \alpha_s - (1 - \gamma_s^t) M,$ $\psi^t \leq \sum_s \gamma_s^t \leq |S| \ \psi^t,$ $\sum_t \psi^t \leq \beta T,$ $\psi^t, \gamma_s^t \in \{0,1\},$

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

$$\mathsf{d} \mathcal{S}_t = \alpha (\mu - \mathcal{S}_t) \; \mathsf{d} t + \sigma \; \mathsf{d} W_t$$

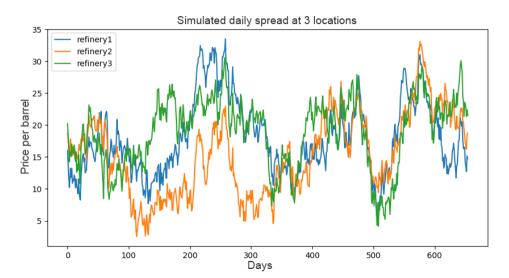
The SDE is calibrated to the WTI/WCS spread with parameters:

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

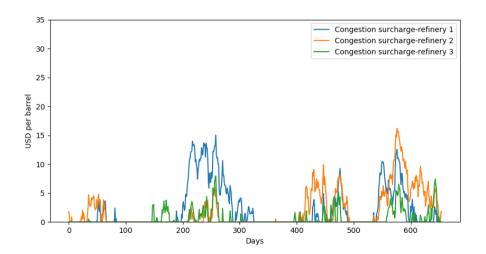
We simulate three paths using the correlation matrix:

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

Simulated paths of the spread



Estimated congestion surcharge for $\beta = 0.6$



Thank you for your attention.