Lower-level problem

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SETS

$e \in \mathcal{E} = \{1, \dots E\}$ (exporters)

$e' \in \mathcal{E}' = \{2, \dots E\}$ (fringe exporters/suppliers)

$\underline{e} \in \underline{\mathcal{E}} \subset \mathcal{E}$ (exporters subject to embargoes)

$m \in \mathcal{M} = \{M1, M2\}$ (set of markets)

$t \in \mathcal{T} = \{2025, \dots 2040\}$ (time steps)

$t' \in \mathcal{T}' \subseteq \mathcal{T}$ (time steps without the initial one)

DECISION VARIABLES

$q_{e,m,t} \quad : \forall e, m, t$

$\bar{q}_{e',t} \quad : \forall e', t$

$q^{arb}_{M1,M2,t} \quad : \forall t$

$q^{del}_{1,m,t} \quad : \forall m, t$

$q^{arb}_{1,m,t} \quad : \forall m, t$

$q^{stock,in/out}_{M1,t} \quad : \forall t$

$q^{stock,stored}_{M1,t} \quad : \forall t$

$$x = \left[q_{e,m,t},\ \bar{q}_{e,t},\ q^{arb}_{M1,M2,t},\ q^{del}_{1,m,t},\ q^{arb}_{1,m,t},\ q^{stock,in,out}_{M1,t},\ q^{stock,stored}_{M1,t} \right] \quad (1)$$

OBJECTIVE FUNCTION

$$\min_{x} \underbrace{\sum_{e} \sum_{m} \sum_{t} c^{gen}_{e} \times q_{e,m,t}}_{\text{Market cleaning}} + \underbrace{\sum_{e'} \sum_{t} c^{main}_{e'} \times \bar{q}_{e',t}}_{\text{Maintenance cost of finge supplier}} + \underbrace{\sum_{t} c^{stockpiling} \times q^{stock,stored}_{M1,t}}_{\text{Stockpiling cost of the European market M1}}$$

CONSTRAINTS

Equality Inequality

$$\left[\sum_{m} q_{e,m,t}\right] - \bar{q}_{e,t} \leq 0 \quad : \forall e, t \quad (\mu^{3}_{e,t}) \quad (3)$$

$$q^{del}_{1,m,t} + q^{arb}_{1,m,t} - q_{1,m,t} = 0 : \forall m, t \quad (\lambda^{4}_{m,t}) \quad (4)$$

$$\left[\sum_{e'} q_{e',M1,t}\right] - q^{arb}_{M1,M2,t} + q^{del}_{1,M1,t} + q^{arb}_{1,M2,t} - d_{M1,t} + q^{stock,in/out}_{M1,t} = 0 \quad : \forall t \quad (\lambda^{5}_{t}) \quad (5)$$

$$\left[\sum_{e'} q_{e',M2,t}\right] + q^{arb}_{M1,M2,t} + q^{del}_{1,M2,t} + q^{arb}_{1,M1,t} - d_{M2,t} = 0 : \forall t \quad (\lambda^{6}_{t}) \quad (6)$$

$$q_{e,M1,t} = 0 \quad : \forall \underbrace{e \in \mathcal{E}_{embargo}}_{\underline{e}} \quad (\lambda^{7}_{e,t}) \quad (7)$$

$$q^{del}_{1,M1,t} + q^{arb}_{1,M2,t} - \ell \cdot d_{M1,t} \leq 0 \quad : \forall t \quad (\mu^{8}_{t}) \quad (8)$$

$q^{stock,stored}$ ... 0 ... (λ^{9}) (9)

$$q_{1,M1,t} + q_{1,M2,t} - \mathcal{L} \cdot d_{M1,t} \leq 0 \; : \; \forall t \quad (\nu_t^{8}) \quad (8)$$

$$q_{M1,0}^{stock,stored} = 0 \; : \quad (\lambda^{9}) \quad (9)$$

$$q_{m,t}^{stock,stored} - q_{,t-1}^{stock,stored} + q_{,t}^{stock,in/out} = 0 \; : \; \forall \underbrace{t'}_{t \setminus \{0\}} \quad (\lambda_{t'}^{10}) \quad (10)$$

$$-q_{e,m,t} \leq 0 \; : \; \forall e,m,t \quad (\nu_{e,m,t}^{11}) \quad (11)$$

$$-\bar{q}_{e',t} \leq 0 \; : \; \forall e',t \quad (\nu_{e',t}^{12}) \quad (12)$$

$$-q_{1,m,t}^{del} \leq 0 \; : \; \forall m,t \quad (\nu_{m,t}^{13}) \quad (13)$$

$$-q_{1,m,t}^{arb} \leq 0 \; : \; \forall m,t \quad (\nu_{m,t}^{14}) \quad (14)$$

$$-q_{m,t}^{stock,stored} \leq 0 \; : \; \forall t \quad (\nu_{,t}^{15}) \quad (15)$$

DUAL VARIABLES

$$\lambda = [\lambda_{m,t}^{4}, \lambda_t^{5}, \lambda_t^{6}, \lambda_{e,t}^{7}, \lambda^{9}, \lambda_{t'}^{10}]$$

$$\nu = [\nu_{e,t}^{3}, \nu_t^{8}, \nu_{e,m,t}^{11}, \nu_{e',t}^{12}, \nu_{m,t}^{13}, \nu_{m,t}^{14}, \nu_t^{15}]$$

LANGRANGIAN FUNCTION

$$\mathcal{L}(x,\lambda,\nu) = f(x) + \lambda^T h(x) + \nu^T g(x)$$

$$\mathcal{L}(x,\lambda,\nu) = \sum_e \sum_m \sum_t c_e^{gen}$$