The Costs of Counterparty Risk in Long-Term Contracts: Notes for Numerical Exercise

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Overview

This project investigates the investment behavior of wind and solar producers under different energy market designs using real project-level data from Spain (2022). We model outcomes under:

Spot markets without counterparty risk

Contracts with counterparty risk (CPR) - Baseline

Contracts with CPR with some interventions, in particular:

1. Public guarantees
2. Public subsidies
3. Regulator-backed contracts (RBC)

Using numerical techniques, we estimate equilibrium prices, quantities, and welfare metrics across scenarios.

Section 1: Dataset Construction

This section prepares the core dataset used throughout the analysis, based on real project-level data for wind and solar installations in Spain (2022). The steps are as follows:

1. **Parameter Initialization:** Key constants are defined, including:

   Exchange rate (USD to EUR)

   Investment, Maintenance and Operation (M&O) costs (converted from USD/kW to EUR/kW)

   Technical and economic parameters: plant lifetime (25 years), *etc.*

2. **Data Import:** The project dataset is loaded from a CSV file. Each entry includes project name, capacity (MW), average capacity factor, and technology type (Solar or Wind).

3. **Splitting Large Projects:** Projects with total capacity above 50 MW are split into smaller sub-projects.

4. **Variable Computation:** For each project:

   We study a set of electricity production units (solar or wind) in Spain that began operation in 2022. Each unit i is defined by its **technology** t, **capacity** k_i (kW), and **location** l. Data source: Global Energy Monitor.

   Each plant i has a *total cost* $C(k_i)$. The *average cost* $c(k_i)$ is given by:

   $$c(k_i) = \frac{C(k_i)}{Q_{itl}},$$

   where Q_{itl} is the plant's total lifetime production.

   Lifetime production is computed as:

   $$Q_{itl} = h_{tl} \times \text{life} \times k_i,$$

   where h_{tl} is the location-specific capacity factor from `renewable.ninja`, and life $= 25$ years.

   Total cost is given by:

   $$C(k_i) = \left(c_{it}^{INV} + c_{it}^{OM} \times \text{life} + \epsilon_t\right) \times \left[k_i + (1000 - k_i)\omega\right],$$

   where:

   c_{it}^{INV}: investment cost (EUR/kW),
   c_{it}^{OM}: fixed operation and maintenance cost (EUR/kW),
   ω: parameter for economies of scale (for now, $\omega = 0.01$),
   ϵ_t: technology-specific cost shock (for now, $\epsilon_t = 0$).

   Parameter values (from IRENA 2022 Report). Those values are fixed and are computed as:

   Solar: $c_{it}^{INV} = \frac{778}{0.94895}$ USD$\to$EUR, $c_{it}^{OM} = \frac{7.36}{0.94895}$ USD$\to$EUR
   Wind: $c_{it}^{INV} = \frac{1159}{0.94895}$ USD$\to$EUR, $c_{it}^{OM} = \frac{29.9}{0.94895}$ USD$\to$EUR

   We convert the initial USD values into EUR values, which are suited to Spain.

Section 2: Cumulative Capacity and Cost Curve Construction

In this section, we construct empirical cumulative functions that relate renewable project costs to available capacity and production. These are not distribution functions in a probabilistic sense but represent aggregate quantities sorted by cost.

Cumulative Capacity Function $\mathbf{G_k}$: We sort all wind and solar projects by their average cost per MWh and compute the cumulative installed capacity (in MW) for all projects with cost less than or equal to f. This results in a stepwise function mapping costs to aggregate capacity.

Cumulative Production Function $\mathbf{G_Q}$: Analogously, we compute the cumulative expected lifetime production (in MWh) for all projects with costs up to f.

We then visualize the function $f \mapsto G_k(f)$ in the form of an *empirical supply curve*, plotting average cost (€/MWh) on the vertical axis against cumulative capacity (MW) on the horizontal axis. Each point represents a project or cost step, and the resulting graph illustrates how capacity expands as projects with higher costs are incorporated.

Finally, in this section, we also define the key parameters that we will use for much of the subsequent analysis.

Section 3: Market Modelling without CPR

Modelling Prices We assume that $p \in (0,1)$ and $f \in (0,1)$. To scale them up, they are both multiplied by a parameter x, which we set at $x = 60$ but could consider alternative values. Spot prices and contract prices are thus px and fx. We assume that spot prices p follow a **beta distribution**[1] with $\alpha = 4$ and $\beta = 2$. Since this function takes values in $[0,1]$, spot prices px take value in $[0,60]$:

$$\mathbb{E}(p) = \frac{\alpha}{\alpha+\beta} = \frac{2}{3}, \quad \mathrm{Var}(p) = \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)} = \frac{2}{63}.$$

This is useful for subsequent sections.

Spot market profits Sellers get the following utilities when trading in the spot market:

$$\Pi_S^0(c) = q_i x \mathbb{E}(p) - C(k_i) - r_i, \tag{1}$$

where:

q_i is the total production of plant i, in MWh;

x represents the scaling factor;

$\mathbb{E}(p)$ displays the expected price;

$C(k_i)$ shows total costs of plant i;

$r_i = r_0(xq_i)^2 Var(p)$.

(i) We compute spot profits for all plants.

(ii) We want to make sure that some plants find it optimal to trade in the spot market, so we choose r_0 sufficiently small so that, for at least some plants, $\Pi_S^0(c) > 0$.

(iii) To do this, we choose a sufficiently low value for r_0 such that a subset of the plants have positive spot market profits. The sum of their production is q_0.

Contracts with no CPR With contracts, sellers make profits:

$$\Pi_S(f) = q_i x f - C(k_i). \tag{2}$$

Contract prices need to satisfy two constraints:

1. Break-even constraint: contract profits (2) have to be non-zero, i.e., xf has to be above average cost. Hence, for each plant, compute

   $$xf^c \geq \frac{C(k_i)}{q_i} \tag{3}$$

   which is equal to the plant's average cost.

2. Spot market constraint: xf has to such that the contract is more profitable than trading in the spot market, i.e., contract profits (2) have to be greater or equal than (1). Hence, for each plant, we compute:

   $$xf^{spot} \geq xE(p) - r_0 Var(p) q_i x^2 \tag{4}$$

[1] For shape parameters $\alpha = 4$ and $\beta = 2$, the hazard rate is strictly increasing.

(a) For each plant, we find the max between xf^c and xf^{spot}. *Note:* that all those plants with positive spot market profits have $xf^{spot} > xf^c$;

(b) We rank plants in increasing order according to the maximum between xf^c, xf^{spot} and plot the cumulative curve using the plant's production (contract supply curve). For instance, suppose that we have two plants: plant A has $xf^c = 10, xf^{spot} = 20$ and production 100 and plant B has $xf^c = 30, xf^{spot} = 10$ and production 50. Then, the curve is $p = 20$ up to quantity 100 and $p = 30$ from 100 to 150.

Contract Demand

Contract demand is θ for prices at or below $xE(p)$, and zero for prices above.

We choose a value for contract demand θ above q_0.

Equilibrium

The intersection between the contract supply curve and contract demand θ gives the contract price f^* that clears the market in the absence of counterparty risk.

If the two curves do not intersect, the equilibrium is a price equal to $xE(p)$ and all the quantity that can be produced with average costs below that level.

Section 4: Market Modelling with CPR - Baseline

In this section, we model a competitive electricity market with long-term contracts, where sellers face **counterparty risk** due to opportunistic buyers. The model is consistent with the framework presented in the reference paper.

4.1 Overview

Each seller decides to invest based on expected profits from either:

Trading in the spot market, where prices are uncertain, or

Entering a bilateral contract with a buyer, who may default with some probability.

Counterparty risk is introduced through a proportion $\gamma \in [0,1]$ of *opportunistic buyers*, who default if the spot price falls below the contract price.

4.2 Key Parameters

$\alpha = 4$, $\beta = 2$: shape parameters of the Beta distribution for spot price $p \sim \text{Beta}(\alpha, \beta)$.

$x = 60$: scaling factor converting normalized price $p \in (0,1)$ into Euros/MWh.

γ: share of opportunistic buyers, increasing CPR as $\gamma \to 1$. We have $\gamma \in [0, 0.5]$.

$\theta \in \{2500, 3500, 4500\}$: different contract demand (MW) values.

r_0: risk aversion parameter determining seller's exposure to price variance. r_0 should be sufficiently low in order to allow some plants make positive profits in the spot market.

4.3 Seller Profits under CPR

Sellers who enter a contract at price $f \in (0,1)$ earn profits:

$$\Pi_S(f;\gamma;C) = q_i x \left[\gamma \int_0^f p\phi(p)\, dp + f \cdot \Big(1 - \gamma\Phi(f)\Big)\right] - R_i(f,\gamma) - C(k_i). \tag{5}$$

where:

q_i: is the total production of plant i, in MWh.

$\phi(p)$, $\Phi(p)$: represent respectively the PDF and CDF of the Beta distribution.

$R_i(f,\gamma)$ displays the risk premium for each plant:

$$R_i(f,\gamma) = r_0\, \gamma\, q_i^2\, x^2 \left[Var(\tilde{p}) + (1-\gamma) \times \Big(f - \mathbb{E}(\tilde{p})\Big)^2\right].$$

$C(k_i)$: total costs of plant i with capacity k_i.

4.4 Spot Market Profits

For comparison, profits from participating in the spot market are given by:

$$\Pi_S^0 = q_i x \cdot \mathbb{E}(p) - C(k_i) - r_i, \tag{6}$$

where $r_i = r_0 (q_i x)^2 \cdot Var(p)$.

4.5 Constraints

Contract prices f_c^* need to satisfy two constraints:

1. **Break-even constraint**: Contract profits (5) have to be non-zero. For each plant, we compute the f^c that equates (5) to zero.

$$\Pi_S(f;\gamma;c) = 0.$$

2. **Spot market constraint**: f_c has to such that the contract is more profitable than trading in the spot market. For each plant, we compute the f_{spot} that equates (5) and (6).

$$\Pi_S(f;\gamma;c) = \Pi_S^0(c).$$

3. For each plant, the chosen price is:

$$f_i = \max\{f_c, f_{spot}\}.$$

4.6 Equilibrium and Welfare

Welfare without CPR in the Spot Market. We compute the welfare W^0 under no counterparty risk as the total surplus from all plants that are profitable in the spot market:

$$W^0 = \sum_{i \in \mathcal{I}_0} (x \cdot \mathbb{E}(p) \cdot q_i - C(k_i) - r_i) \tag{7}$$

where:

$\mathcal{I}_0$ is the set of plants with $\Pi_S^0 > 0$ for $\gamma = 0$,

q_i is the production of plant i,

$C(k_i)$ is the total cost of plant i with capacity k_i,

$r_i = r_0 \cdot (xq_i)^2 \cdot \mathrm{Var}(p)$ is the risk premium in the spot market of plant i.

Welfare with CPR. We compute welfare $W^B(\gamma, \theta)$ for baseline (B) results under counterparty risk as the total surplus of sellers under contracts, for those included in the market-clearing allocation:

$$W^B(\gamma, \theta) = \sum_{i \in \mathcal{I}_\gamma^B(\theta)} (x \cdot \mathbb{E}(p) \cdot q_i - C(k_i) - R_i(f^*, \gamma)) \tag{8}$$

where:

$W^B(\gamma, \theta)$ represents the total welfare results, given a γ, θ combination;

$\mathcal{I}_\gamma^B(\theta) = \{i : f_i \leq f^*\}$, the set of plants i that have a $f_i \leq f^*$ that clear the market under γ and θ;

f^* represents the equilibrium price for a given γ and θ;

$R_i(f^*, \gamma)$ is the CPR-related risk premium for plant i at equilibrium price f^*.

4.7 Profits

Seller Profits For each combination of γ and θ, we compute the total seller profits under contracts as:

$$\Pi_S^B(\gamma,\theta) = \sum_{i \in \mathcal{I}_\gamma^B(\theta)} \pi_i^{\mathrm{B}}, \tag{9}$$

where each plant's profit π_i^B is defined at the equilibrium price f^*:

$$\pi_i^{\mathrm{B}} \equiv q_i x \left[\gamma \int_0^{f^*} p\,\phi(p)\,dp + f^* \cdot \Big(1 - \gamma \Phi(f^*)\Big) \right] - R_i(f^*,\gamma) - C(k_i).$$

Buyer Profits Given total welfare under CPR, $W(\gamma,\theta)$, and total seller profits $\Pi_S(\gamma,\theta)$, we compute buyer profits as follows:

$$\Pi_{Buyers}^B(\gamma,\theta) = W^B(\gamma,\theta) - \Pi_S^B(\gamma,\theta), \tag{10}$$

where:

$\Pi_{Buyers}(\gamma,\theta)$ is the total profit of buyers under baseline CPR;

$W(\gamma,\theta)^B$, defined in (8);

$\Pi_S(\gamma,\theta)^B$ is the seller profit, as defined in (9).

4.8 Steps

For each combination of γ and θ:

1. Compute equilibrium contract price f^* where cumulative capacity offered equals θ.
2. Calculate welfare $W(\gamma)$.
3. Compare $W(\gamma)$ to assess efficiency losses/gains:

   W^0**:** Welfare in the absence of counterparty risk, calculated as the total surplus generated by all plants that earn positive profits in the spot market.

   $W(\gamma,\theta)$**:** Welfare under a given level of counterparty risk ($\gamma > 0$), reflecting efficiency losses due to strategic default and sellers opting out of contracts.

   $\frac{W(\gamma,\theta)}{W(0,\theta)}$**:** Relative efficiency with CPR. Measures the proportion of welfare retained compared to the CPR-free case.

   $W(0,\theta) - W(\gamma,\theta)$**:** Absolute welfare gain or loss due to CPR. Quantifies the social cost of counterparty risk relative to the ideal contracting scenario.

   $W(\gamma,\theta) - W^0$**:** Net gain or loss from using contracts under CPR versus relying only on the spot market.

4. Evaluate profit shares:

   Seller profits

   Buyer profits

Section 5: Market Modelling with CPR - Public Guarantees

In this section, we study the impact of introducing **public guarantees** as a policy intervention to mitigate the negative effects of counterparty risk (CPR). The mechanism assumes that contracts are partially backed by the regulator, reducing seller exposure to default risk.

5.1 Mechanism and Modelling Approach

Public guarantees do not alter the market structure but modify the seller's expected payoff under CPR by compensating for potential buyer default. The core model structure remains intact. The key change is the addition of a government-backed transfer component indexed to buyer default scenarios.
We use a similar simulation environment as in the baseline CPR setting, but compute a new welfare metric and equilibrium outcomes under this new risk allocation.

5.2 Equilibrium Computation under Public Guarantees

To simulate this environment:

1. For each value of γ and contract demand θ, we replicate the equilibrium price and quantity observed under $\gamma = 0$ as those observed in the baseline results.
2. We hold this reference price f^* fixed, and compute adjusted outcomes assuming public guarantees restore seller expectations to this no-CPR benchmark.
3. The equilibrium quantity q^* and price f^* are therefore consistent across all γ, simulating a "guaranteed market" scenario.

5.3 Welfare Metrics

The total welfare under public guarantees, $W^{\text{PG}}(\gamma, \theta)$, is defined as:

$$W^{\text{PG}}(\gamma,\theta) = \sum_{i \in \mathcal{I}_{\gamma}^{\text{PG}}(\theta)} \Big(x \cdot \mathbb{E}(p) \cdot q_i - C(k_i) - R_i(f^*, \gamma) \\ - \lambda \cdot \gamma \cdot q_i \cdot x \cdot \int_0^{f^*} (f^* - p) \cdot \phi(p)\, dp \Big). \tag{11}$$

where:

$\lambda \geq 0$ is a per-unit social cost of public funds. It reflects the real cost to society of funding the guarantee, beyond just the transfer amount. λ is a fixed parameter and kept to 0.3.

$\lambda \cdot \gamma \cdot q_i \cdot x \cdot \int_0^{f^*} (f^* - p) \cdot \phi(p)\, dp$ is an expected loss term. It acts as a fiscal transfer, reducing the effective costs faced by sellers under CPR.

We then compute relative metrics:

$\frac{W^{\text{PG}}(\gamma,\theta)}{W^{\text{PG}}(0,\theta)}$: efficiency of public guarantees when $\gamma > 0$ relative to the case without CPR (*i.e.* when $\gamma = 0$);

$\frac{W^{\text{PG}}(\gamma,\theta)}{W^{0}}$: welfare under public guarantees relative to the no-CPR benchmark;

$\frac{W^{\mathrm{PG}}(\gamma,\theta)}{W^{\mathrm{B}}(\gamma,\theta)}$: efficiency gain of public guarantees over CPR without intervention;

$W^{\mathrm{PG}}(\gamma) - W^0$: net welfare gain/loss from moving from no-CPR to CPR, under public guarantees.

5.4 Profits

Sellers Profits Sellers benefit from the guarantee by receiving higher expected profits due to reduced exposure to default risk. Aggregate profits under public guarantees are computed as:

$$\Pi_S^{\mathrm{PG}}(\gamma,\theta) = \sum_{i \in \mathcal{I}_\gamma^{\mathrm{PG}}(\theta)} \pi_i^{\mathrm{PG}}, \tag{12}$$

where each plant's profit π_i^{CPR} is defined at the equilibrium price f^*:

$$\pi_i^{\mathrm{PG}} \equiv q_i x \left[\gamma \int_0^{f^*} p\,\phi(p)\,dp + f^* \cdot \Big(1 - \gamma \Phi(f^*)\Big) \right] - R_i(f^*,\gamma) - C(k_i).$$

Buyer Profits Given total welfare under public guarantees, $W^{PG}(\gamma,\theta)$, and total seller profits $\Pi_S^{PG}(\gamma,\theta)$, we compute buyer profits as follows:

$$\Pi_{Buyers}^{PG}(\gamma,\theta) = W^{PG}(\gamma,\theta) - \Pi_S^{PG}(\gamma,\theta), \tag{13}$$

where:

$\Pi_{Buyers}^{PG}(\gamma,\theta)$ is the total profit of buyers under public guarantees;

$W^{PG}(\gamma,\theta)$, defined in (11);

$\Pi_S^{PG}(\gamma,\theta)$ is the seller profit, as defined in (12).

Section 6: Market Modelling with CPR - Public Subsidies

This section introduces **public subsidies** as a policy intervention to mitigate the impact of counterparty risk (CPR). The government offers a fixed per-unit subsidy $T$to all sellers who sign long-term contracts.

6.1 Overview

As in the baseline, sellers decide between trading in the spot market or entering into a bilateral contract. However, now the government subsidizes contracted electricity with a public subsidy T multiplied by the total production of a plant i, q_i.

6.2 Seller Profits under Subsidies

Sellers' profits under CPR and public subsidies are defined as:

$$\Pi_S^T(f;\gamma;C) = q_i x \left[\gamma \int_0^f p\phi(p)\,dp + f \cdot (1-\gamma\Phi(f))\right] - R_i(f,\gamma) - C(k_i) + Tq_i, \qquad (14)$$

where:

T: per-unit public subsidy for contracted energy;

All other terms match those in the baseline CPR model (see 4.3 Seller Profits under CPR).

6.3 Implementation and Simulation Procedure

To simulate the impact of public subsidies on equilibrium outcomes under CPR, we proceed in several computational steps:

1. For each plant, we solve numerically:

   The contract breakeven price f_c, where $\Pi_S^T(f_c) = 0$;

   The spot price f_{spot}, where $\Pi_S^T(f_{\text{spot}}) = \Pi_S^0$;

   The plant-specific price $f_i = \max\{f_c, f_{\text{spot}}\}$.

2. For each $T \in \{0, 0.01, 0.02, \ldots, 0.05\}$: We determine the market-clearing contract price f^* and corresponding equilibrium allocations given the share of opportunistic buyers γ and contract demand θ.

3. Once equilibrium prices are computed for each subsidy level:

   We derive equilibrium quantities and compute welfare, seller and buyer profits.

   We compare baseline welfare with welfare with subsidies for each level of γ and θ.

6.4 Numerical Computation of Equilibrium and Welfare

To implement the theoretical welfare and profit formulas described above, we proceed as follows:

Computing Welfare As before, we have:

1. W^0, which represents the total surplus from all plants that are profitable in the spot market (given by equation (7)).

2. We compute welfare $W^T(\gamma, \theta)$ results under counterparty risk as the total surplus of sellers under contracts, for those included in the market-clearing allocation: we compute total surplus for all plants that participate in contracts at f^* (i.e., those for which $f_i \leq f^*$), accounting for CPR and subsidy:

$$W^T(\gamma, \theta) = \sum_{i \in \mathcal{I}_\gamma^T(\theta)} \left(x \cdot \mathbb{E}(p) \cdot q_i - C(k_i) - R_i(f^*, \gamma) \right) - \lambda T \sum q_i, \tag{15}$$

where:

$\lambda \geq 0$ is again the marginal cost of public funds (see equation (11)). It reflects the real cost to society of funding the subsidy, beyond just the transfer amount. λ is a fixed parameter and kept to 0.3.

$\lambda T \sum q_i$ is the social cost of the public subsidy.

We then compare the resulting welfare $W^T(\gamma, \theta)$ under subsidies to the baseline welfare without subsidies, denoted $W^B(\gamma, \theta)$.

Computing Seller and Buyer Profits

Seller profits are computed as:

$$\Pi_S^T(\gamma, \theta) = \sum_{i \in \mathcal{I}_\gamma^T(\theta)} \pi_i^T, \tag{16}$$

where each plant's profit π_i^T is defined at the equilibrium price f^*:

$$\pi_i^T \equiv q_i x \left[\gamma \int_0^{f^*} p\, \phi(p)\, dp + f^* \cdot \left(1 - \gamma \Phi(f^*)\right) \right] - R_i(f^*, \gamma) - C(k_i) + T q_i.$$

Buyer profits are computed as follows:

$$\Pi_{Buyers}^T(\gamma, \theta) = W^T(\gamma, \theta) - \Pi_S^T(\gamma, \theta),$$

where:

$\Pi_{Buyers}^T(\gamma, \theta)$ is the total profit of buyers under public guarantees;

$W^T(\gamma, \theta)$, defined in (15);

$\Pi_S^T(\gamma, \theta)$ is the seller profit, as defined in (16).

Section 7: Market Modelling with CPR — Matching Public Expenditures (G = T)

In this section, we evaluate a scenario in which the government uses a public subsidy T^* to replicate the same public expenditure it would have incurred under a public guarantee scheme (*cf.* Section 5: Market Modelling with CPR - Public Guarantees).

The idea is to find, for each pair (γ, θ), the subsidy T^* such that total public expenditure under the subsidy scheme matches that under the guarantee scheme. This allows fair policy comparisons.

7.1 Calibration of T^*

For each (γ, θ) pair, we use numerical root-finding techniques to identify the value of T^* that satisfies:

$$T^* \cdot \sum_{i \in \mathcal{I}_{\gamma}^{G=T}(\theta)} q_i = \sum_{i \in \mathcal{I}_{\gamma}^{G=T}(\theta)} \left(q_i \cdot \gamma \cdot x \cdot \int_0^{f^*} (f^* - p) \phi(p) dp \right) \tag{17}$$

This ensures that public spending under the subsidy scheme is equivalent to the fiscal cost of guarantees for each (γ, θ) combination, taking into account the per-unit cost of public funds λ.

We denote the calibrated subsidy as $T^*(\gamma, \theta)$, and recompute all equilibrium outcomes accordingly.

7.2 Equilibrium and Welfare under T^*

Once the subsidy T^* is found, we rerun the market equilibrium algorithm:

1. Derive equilibrium prices f^* and quantities q^* given plant participation.
2. Compute welfare, using the following formula:

$$W^{G=T}(\gamma, \theta) = \sum_{i \in \mathcal{I}_{\gamma}^{G=T}(\theta)} (x \cdot \mathbb{E}(p) \cdot q_i - C(k_i) - R_i(f^*, \gamma)) - \lambda \cdot T^* \cdot \sum q_i,$$

3. Break down profits into seller and buyer components as in previous sections.

7.3 Comparison with Public Guarantees and Public Subsidies

We perform a comparative analysis between the results of the calibrated subsidy scheme ($G = T$), and the public guarantee scheme (PG). This includes:

Welfare Comparison: We compute and plot ratios such as $W^{G=T}/W^{PG}$ to assess efficiency, and other metrics similar to those in previous sections.

Buyer vs Seller Profit Shares: We compare how the composition of welfare changes across interventions and evaluate whether buyers/sellers do better or worse under public subsidies versus public guarantees.

This allows for investigating whether direct public subsidies—when calibrated to match the fiscal effort of public guarantees—are more or less effective in restoring market efficiency and balancing profit distribution.

Section 8: Market Modelling with CPR - Regulator-backed Contracts

In this section, we extend the market framework to include Regulator-Backed Contracts (RBCs) that aim to mitigate the impact of counterparty risk on investment and welfare.

The regulator participates in the market by guaranteeing a portion of long-term contracts. This intervention is intended to restore confidence among sellers who would otherwise avoid contracts due to opportunistic buyer behavior. The analysis compares market outcomes:

Without RBCs (pure private contracts subject to CPR),

With RBCs, where a fixed share of demand is secured by a public regulator.

8.1 Policy Design

Let θ denote the total long-term contract demand, decomposed as:

$$\theta = \theta_P + \theta_R,$$

where:

θ_P is demand from private buyers (here: 2,500);

θ_R displays regulator-backed demand (here: 2,500);

θ represents the total demand, so 5,000.

8.2 RBC Setting: Equilibrium Prices, Quantities and Profits

To simulate regulator-backed contracting, we proceed in two stages:

Step 1: Solve Baseline Equilibrium for $\theta = 5000$ We begin by computing equilibrium outcomes for the private-only market (no RBC) where total long-term contract demand is $\theta = 5000$. For each plant i, given γ, we determine:

The equilibrium price f^* that clears the aggregate demand θ.

We do this in the same vein as in previous sections, with equilibrium prices & quantities, welfare and profits for every gamma.
From this, we identify the subset of winning plants for each γ, *i.e.*:

$$\text{winning plant} = \{i : f_i \leq f^*, \text{ cumulative capacity} \leq \theta\}.$$

In other terms, winning plants are defined as projects that have a contract price $f_i \leq f^*$ and a cumulative capacity lower than 5,000. Those projects that do not satisfy these requirements are not selected for the rest.

Step 2: Construct RBC Prices Using the baseline profits obtained in Step 1, we construct the price that the regulator must offer to induce plant i to accept a regulator-backed contract, denoted f_i^R. This is calculated by ensuring indifference between private and RBC participation:

$$f_i^R = \frac{\Pi_i^{\text{Private}} + C(k_i)}{q_i x}, \tag{18}$$

where $\Pi_i^{\text{Private}} = q_i x \left[\gamma \int_0^{f^*} p\phi(p)\, dp + f^* \cdot \left(1 - \gamma\Phi(f^*)\right)\right] - R_i(f^*, \gamma) - C(k_i)$.
We used f^* computed in Step 1 above, *i.e.* for $\theta = 5000$ without RBC. Profits under RBC are given by:

$$\begin{aligned} \Pi_i^R &= x f_i^R \cdot q_i - C(k_i) \\ &= \cancel{q_i x} \cdot \frac{\Pi_i^{\text{Private}} + \cancel{C(k_i)}}{\cancel{q_i x}} - \cancel{C(k_i)} \\ &\Rightarrow \Pi_i^R = \Pi_i^{\text{Private}} \end{aligned} \tag{19}$$

So, we computed the contract price f_i^R for each project such that the seller is indifferent between accepting a private contract or a regulator-backed contract (*i.e.* the profits are the same).

Step 3: Identify Winning Plants We then identify winning plants that:

1. are selected under private market conditions, i.e., $x f_i^{\max} \leq x f^*$,
2. fall within the cumulative capacity that meets total contract demand θ.

These plants are said to have "won" the private market and form the pool for RBC pricing.

Step 4: Reordering and Aggregation In this step, we determine the equilibrium contract price and total investment quantity associated with the regulator-backed demand level θ_R for each risk aversion level γ.

We sort all eligible projects in ascending order of their regulator-backed price f_i^R, within each γ group. We then compute the cumulative capacity.

Step 5: Identify Equilibrium Quantity and Price To determine the equilibrium under the regulator-backed scheme, we simulate how projects are selected to meet the target demand θ_R. For each γ. This allows us to extract the equilibrium quantity q_*^R and the corresponding contract price f_*^R under the RBC mechanism for each γ.

Step 6: Profits and Contract Type Assignment under the RBC Equilibrium After determining the equilibrium price and quantity under the regulator-backed scheme, we simulate how each plant would participate in the market and compute its profits accordingly. The key goal is to assign each plant to one of the following contract types:

i. **Regulated (RBC)**,

ii. **Private**

We assign each project to one of two contract types (Private vs. RBC) based on its price and its position relative to the regulator's capacity threshold θ_R.
To do this, we proceed as follows:

1. **Tag the Marginal Project**:

   For each value of γ, we identify the project that exactly reaches the cumulative capacity target θ_R and is priced at the RBC equilibrium price xf_*^R.

   All projects with:

$$xf_i^R \leq xf_*^R \quad \text{and} \quad \text{Cumulative Capacity}_i \leq \theta_R$$

   are selected under the RBC scheme.

2. **Assign Contract Types**:

   Each project is then assigned a contract type using the following rules:

   Regulated Contract (RBC): A plant receives a regulated contract if:

$$xf_i^R \leq xf^* \quad \text{(eligible under private equilibrium)}$$

   and

$$xf_i^R \leq xf_*^R, \quad \text{Cumulative Capacity}_i \leq 2500,$$

   Its profit is:

$$\Pi_i^R = xf^{R*} \cdot q_i - C(k_i)$$

   Private Contract: If the plant is:

$$xf_i^{\max} \leq xf^*, \quad xf_i^R > xf_*^R, \quad \text{Cumulative Capacity}_i \leq 5000,$$

   then the project would be selected under the private market but is not chosen under the RBC scheme. It earns:

$$\Pi_i^{\text{Private}} = xf^* \cdot q_i - C(k_i) - R(f^*, \gamma)$$

8.3 Welfare Computation under RBC and Comparison with Benchmarks

We now compute and compare welfare outcomes under three market settings:

1. A market with counterparty risk and Regulator-Backed Contracts (RBC),
2. A market with counterparty risk and no RBC (for comparison).

We will then compare those two markets

Step 1: Compute W^0 We compute W^0 as in other scenarios, so:

$$W^0 = \sum_{i \in \mathcal{I}_0} (x \cdot \mathbb{E}(p) \cdot q_i - r_i - C(k_i)) \tag{20}$$

where:

$\mathcal{I}_0$ is the set of plants with $\Pi_S^0 > 0$ for $\gamma = 0$,

q_i is the production of plant i,

$C(k_i)$ is the total cost of plant i with capacity k_i,

$r_i = r_0 \cdot (xq_i)^2 \cdot \mathrm{Var}(p)$ is the risk premium in the spot market of plant i.

Step 2: Compute $W^R(\gamma)$ We then compute welfare for each risk level γ when RBCs are available.
We break this into:

$W^{\text{Private}}(\gamma)$: welfare from projects operating under private contracts,

$W^{\text{RBC}}(\gamma)$: welfare contribution from regulator-backed contracts.

Total welfare under RBC is then:

$$W^R(\gamma) = W^{\text{Private}}(\gamma) + W^{\text{RBC}}(\gamma)$$

Private welfare $W^{\text{Private}}(\gamma)$: This measures the net value generated by plants that receive private contracts (*i.e.*, not selected under RBC but still viable under private equilibrium conditions). For each such project i, the contribution is:

We sum these across all projects assigned to private contracts:

$$W^{\text{Private}}(\gamma) = \sum_{i \in \mathcal{I}_\gamma^{\text{Private}}} (x \cdot \mathbb{E}(p) \cdot q_i - C(k_i) - R_i(f^*, \gamma))$$

Regulated welfare $W^{\text{RBC}}(\gamma)$: This captures the value of public intervention through RBCs. For projects selected under the RBC, the welfare is:

$$W^{\text{RBC}}(\gamma) = \sum_{i \in \mathcal{I}_\gamma^{\text{RBC}}} (x \cdot \mathbb{E}(p) \cdot q_i - C(k_i))$$

Step 3: Compare RBC Outcomes to the Baseline Without Regulation In this final step, we compare the outcomes under the Regulator-Backed Contract (RBC) scheme to the baseline results without RBC with $\theta = 5000$.

Profits and Welfare Comparison Across Policy Scenarios

We enrich the welfare analysis by incorporating the distributional effects between market participants. Specifically, we focus on comparing these values across four policy settings:

1. **RBC mechanism**,
2. **Public Guarantees where the guarantee threshold equals the transfer level** ($T = G$),
3. **Public Subsidies**,
4. **Baseline**.

Profits Under RBC We calculate:

Total seller profits under private and regulated contracts,

Total welfare under RBC (previously computed),

Buyer profits as:

$$\Pi(\gamma)^{R}_{\text{Buyers}} = W(\gamma)^{R} - \Pi(\gamma)^{R}_{\text{Sellers}}$$

Compile Profits and Welfare from Other Scenarios We collect equivalent metrics from the other scenarios (Guarantees, Subsidies, Baseline), always for the same demand level (2500), and ensure consistency across groups by keeping only comparable variables: total welfare, seller profits, buyer surplus.

Compute Relative Ratios For each scenario and level of risk aversion γ and $\theta = 2500$, we compute the relative performance of RBC compared to:

Welfare ratios:

$$\frac{W(\gamma)^{R}}{W(\gamma)^{\text{Scenario}}}$$

Seller profit ratios:

$$\frac{\Pi(\gamma)^{R}_{S}}{\Pi(\gamma)^{\text{Scenario}}_{S}}$$

Buyer surplus ratios:

$$\frac{\Pi(\gamma)^{R}_{\text{Buyers}}}{\Pi(\gamma)^{\text{Scenario}}_{\text{Buyers}}}$$

These indicators allow us to assess not only the efficiency (total welfare), but also the distributional consequences of each policy option, under varying levels of counterparty risk.