



Project 4:

Electricity markets with 100% renewables

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1. Bertrand and Bertrand-Edgeworth competition

- a. Describe Bertrand competition between two firms and solve the problem for the case of two firms with symmetric costs.
- b. Define the Bertrand-Edgeworth paradox and explain it through an example.
- c. Show that in a market where two firms choose simultaneously their capacity c_i and price p_i (assuming a cost of expanding capacity γ_i and a reservation price R) there is no pure strategy Nash equilibrium.

2. Electricity markets with 100% renewables

In a (very) near future where 100% of the electricity demand is satisfied by renewable sources of energy with zero marginal costs, suppliers are only asked to bid their asking price when participating in the electricity market. As their production¹ materialises, the supplier with the lower price satisfies the demand up to his realised capacity, followed by the second lowest price and so on, till there is no demand left. Given the model and market described in detail [2] (e.g. do not forget that one producer is larger than the other – section IV in [2]) address the following questions:

- a. Under the assumption that there is uncertainty for both the suppliers and the demand identify the mixed strategy Nash equilibria.
- b. Provide a **sketch of the proof** (not the full mathematical proof) and discuss the **intuition** behind the mixed strategy Nash equilibria in this specific case.
- c. Based on a simplified version of the example in Section IV from [2], let a conceptual market with two wind farms with their capacity modelled by uniform distribution $U(0.9, 1.0)$ and $U(0.3, 0.4)$ respectively with demand modelled by $U(1.1, 1.2)$. Simulate the mixed strategy equilibrium and compute the equilibrium prices and profits as the capacity of wind farm 2 increases up to 200%.

Literature supplements²:

- [1] Price and Capacity Competition (section 9), D. Acemoglu, K. Bimpikis, A. Ozdaglar.
 [2] Strategic Bidding in Electricity Markets with Only Renewables. J. A. Taylor and J. L. Mathieu.
 [3] Price and capacity competition in balancing markets with energy storage. J. A. Taylor, J. L. Mathieu, D. S. Callaway, K. Poolla.

¹ Production is referred from now on as capacity to maintain consistency with Bertrand competition terms introduced in the lecture and in Question 1.

² The proposed literature is given as supplementary material. Use it freely for the assignment but reference it in your report.