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Carbon tax or carbon permits: the impact on generators' risks

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The Issue

- Fuel prices are volatile
- Costs of fossil fuelled generators are risky
- Nuclear generators have stable costs
- So build nuclear for insurance?
- Social and corporate answers differ!
  - Roques *et al.*, Energy Journal 2006

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This paper

- Carbon prices correlated with gas and coal
  - Adds to risk of nuclear stations
- Will a carbon tax reduce nuclear risks?
- Detailed electricity model to calculate profits
- Consider risks and returns for single plants
- Consider optimal portfolio of plants, with and without long-term contracts

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Supply function model

- Firms offer schedules of prices and quantities to meet varying demand
- Klemperer and Meyer (Eta, 1989)
- Green and Newbery (JPE, 1992)
- Evans and Green (U.Bham, 2005)

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The Model

- Profits are a function of price
- Your sales are demand less others' supply

$$\pi_i(\ p\ ,t\ ) = p\left(D(p,t) - \sum_{j\neq i} q_j(p)\right) - C_i\left(D(p,t) - \sum_{j\neq i} q_j(p)\right)$$

- Maximise for any level of demand

$$\frac{\partial\,\pi_i(t)}{\partial p} = D(p,t) - \sum_{j\neq i} q_j(p) + \left(p - C_i'\left(D(p,t) - \sum_{j\neq i} q_j(p)\right)\right)\left(\frac{\partial D(p,t)}{\partial p} - \sum_{j\neq i}\frac{\partial\, q_j}{\partial p}\right)$$

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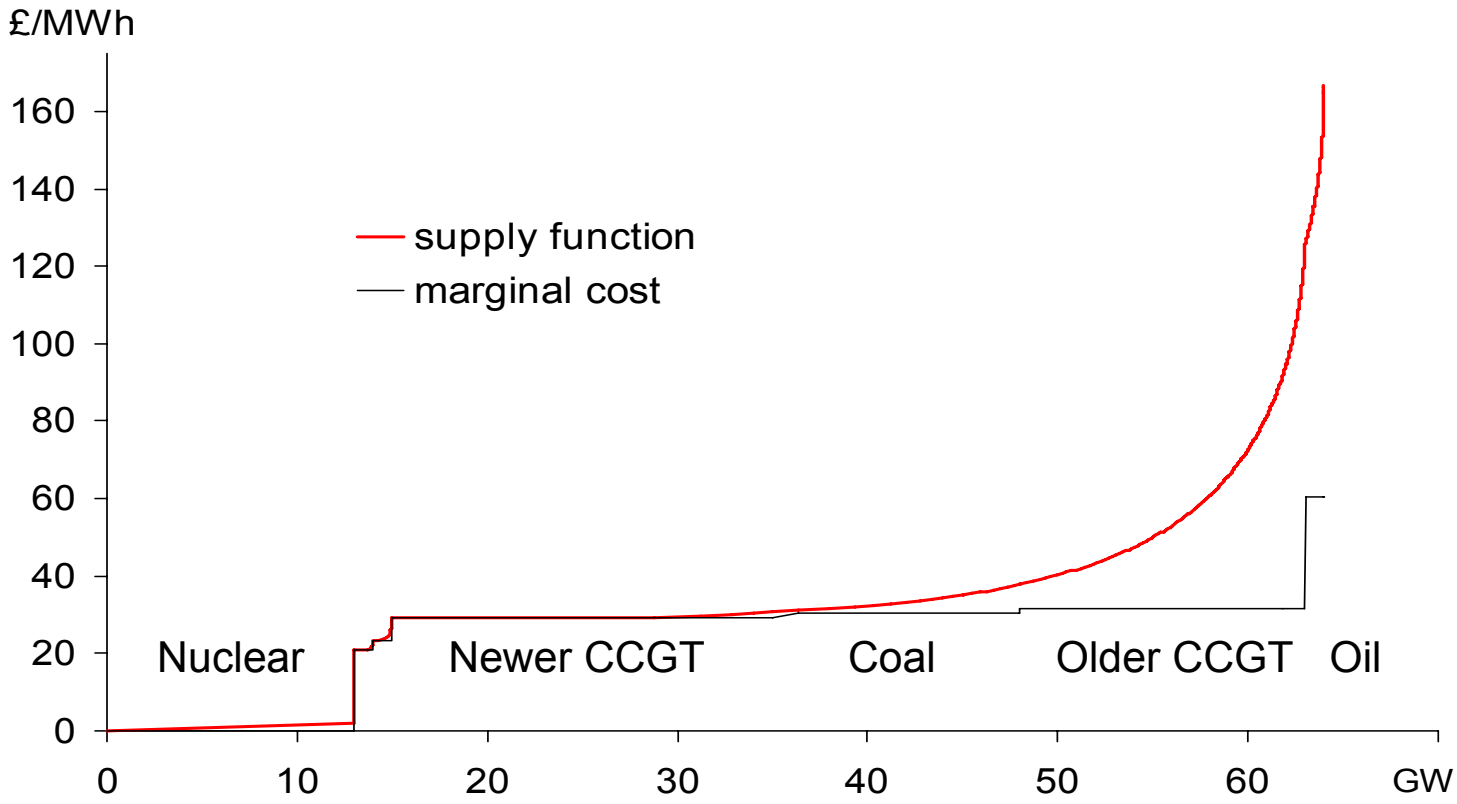
The Model

- Treat industry "as if" firms are symmetric
- Number is inverse of Herfindahl index
  - Squared market shares

$$q_i(p) = \left(p - C_i'\left(q_i(p)\right)\right)\left(-\frac{\partial D}{\partial p} + (\hat{n} - 1)\frac{\partial q_i}{\partial p}\right)$$

- In this case, treat as if 6 symmetric firms

Figure 1: Industry supply function - DTI Base Case



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Generation

- Costs from DTI Energy Review, 2006
  - O&M costs, thermal efficiencies
  - Capital costs discounted at 10%
- Capacities from SUPERGen FUTURENet Scenarios for 2020 (Elders et *al.*)
  - 35 GW gas, 12 GW coal, 13 GW nuclear
  - 22 GW renewable with random output

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Fuel Prices

- Mean values are DTI base case
- Log-normal distributions: DTI high and low ≈ ± 2 s.d.
- Correlation between oil and gas ≈ 0.87, and coal ≈ 0.7

£/MWh	Coal	Gas	Oil
Mean	3.98	12.45	16.00
Standard Deviation	1.09	3.38	5.46

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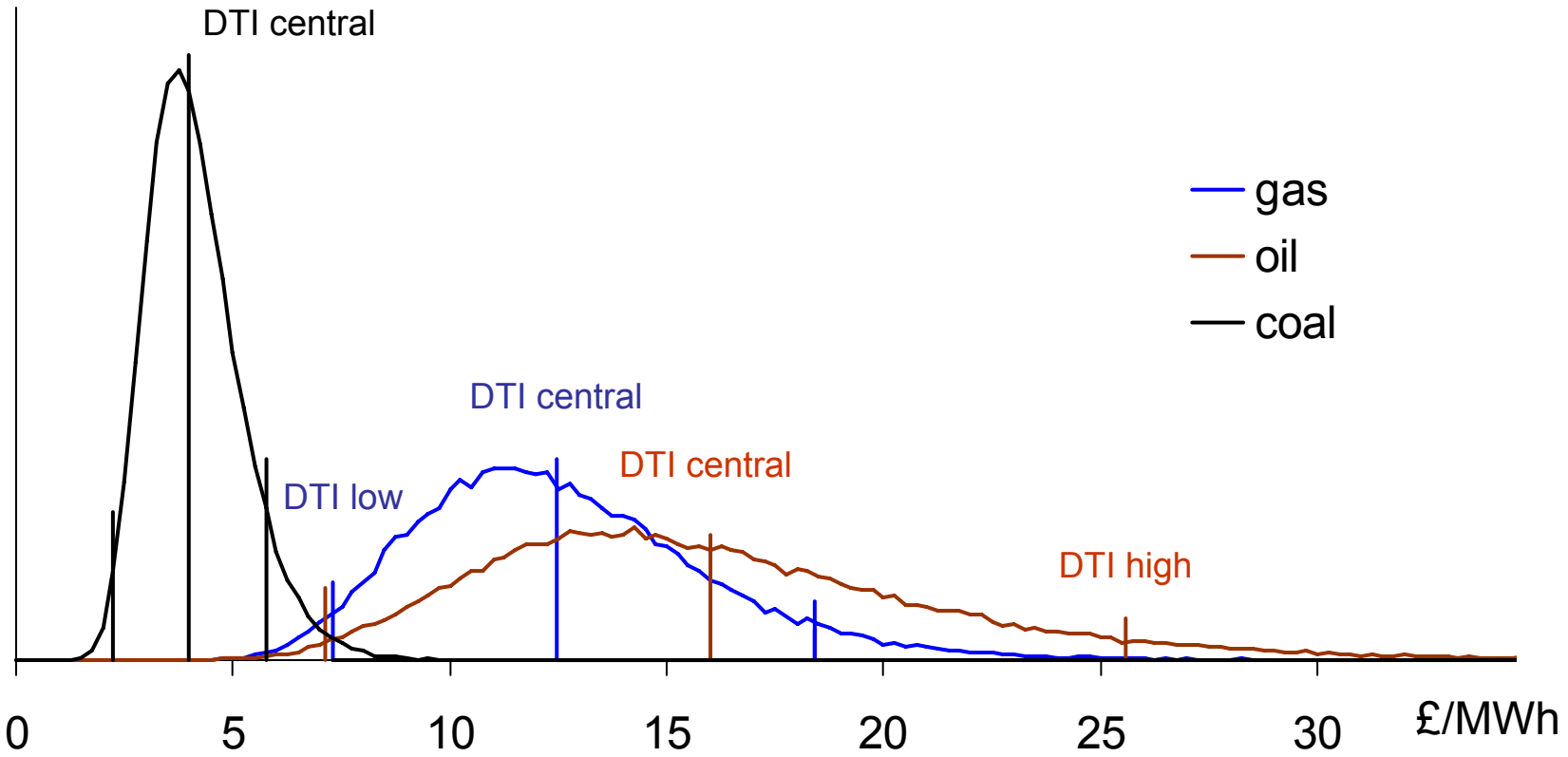
Fuel price distributions



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The Policies

- Carbon permits with a price that equalises MC of coal and gas generation + N(0,2)
  - Permits are auctioned

$$\frac{P_G + 0.19C}{0.53} = \frac{P_C + 0.34C}{0.35}$$

$$C = 3.15P_G - 4.77P_C$$

- Carbon tax = the expected permit price

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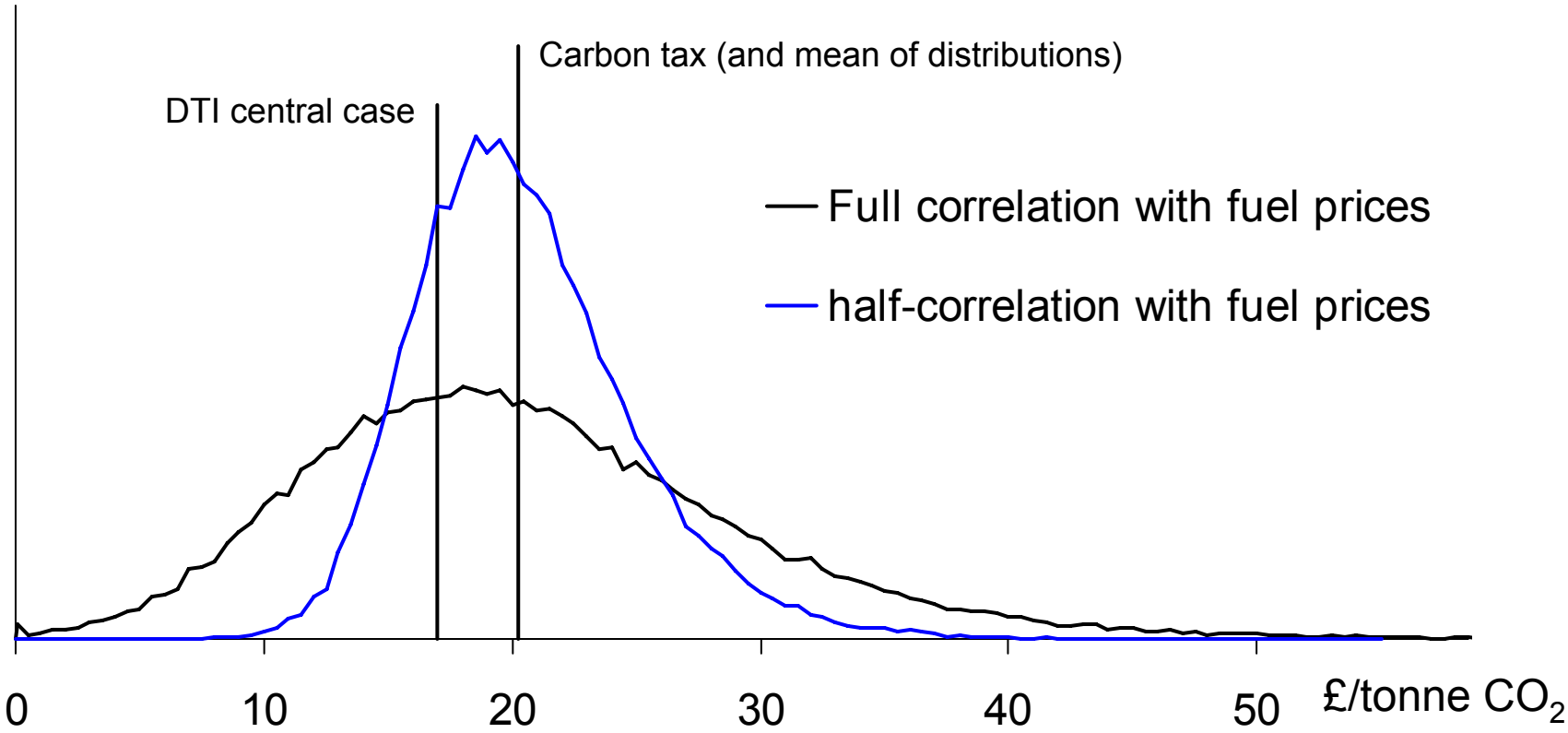
Carbon price distributions



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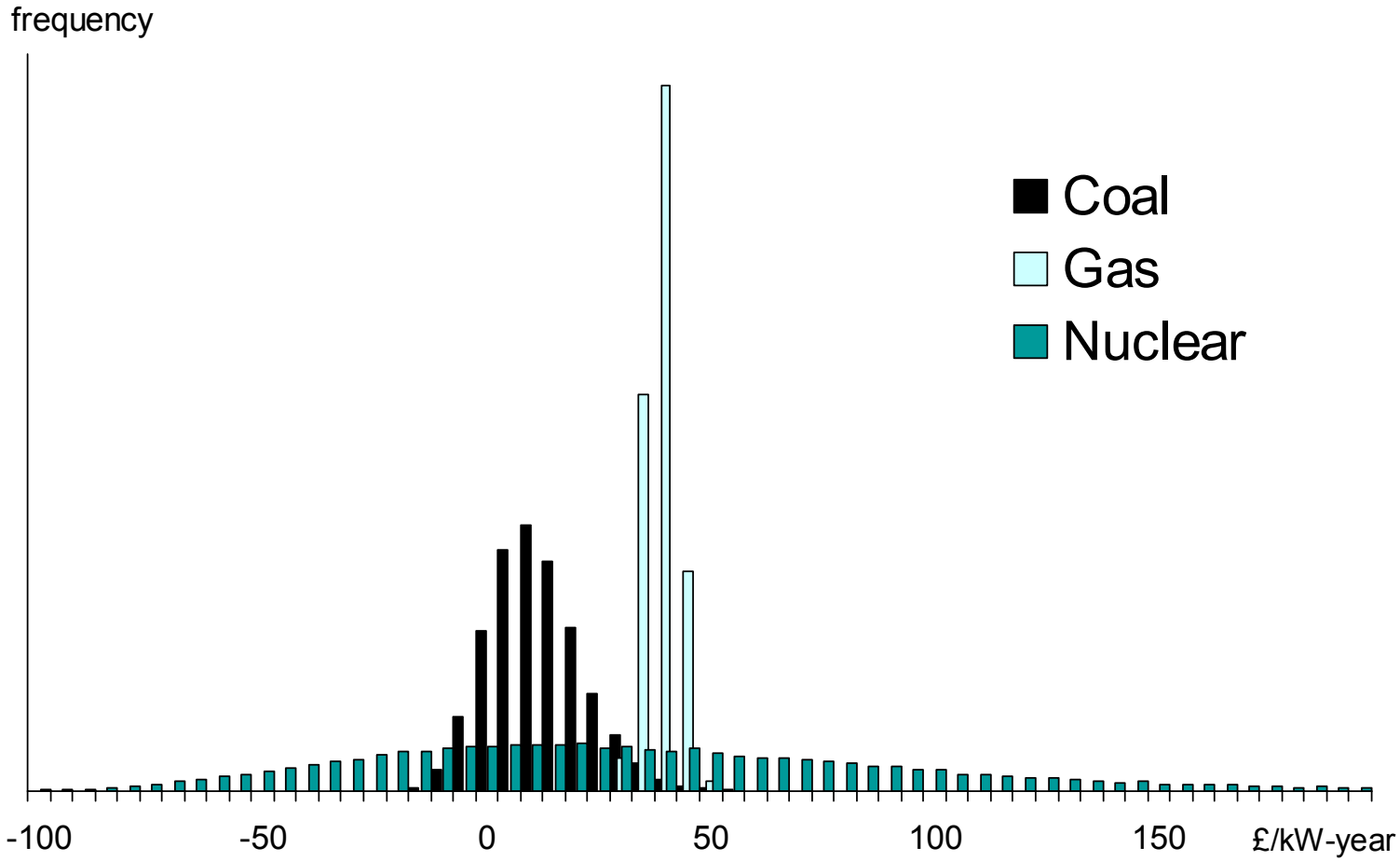
Profits with carbon emissions permits



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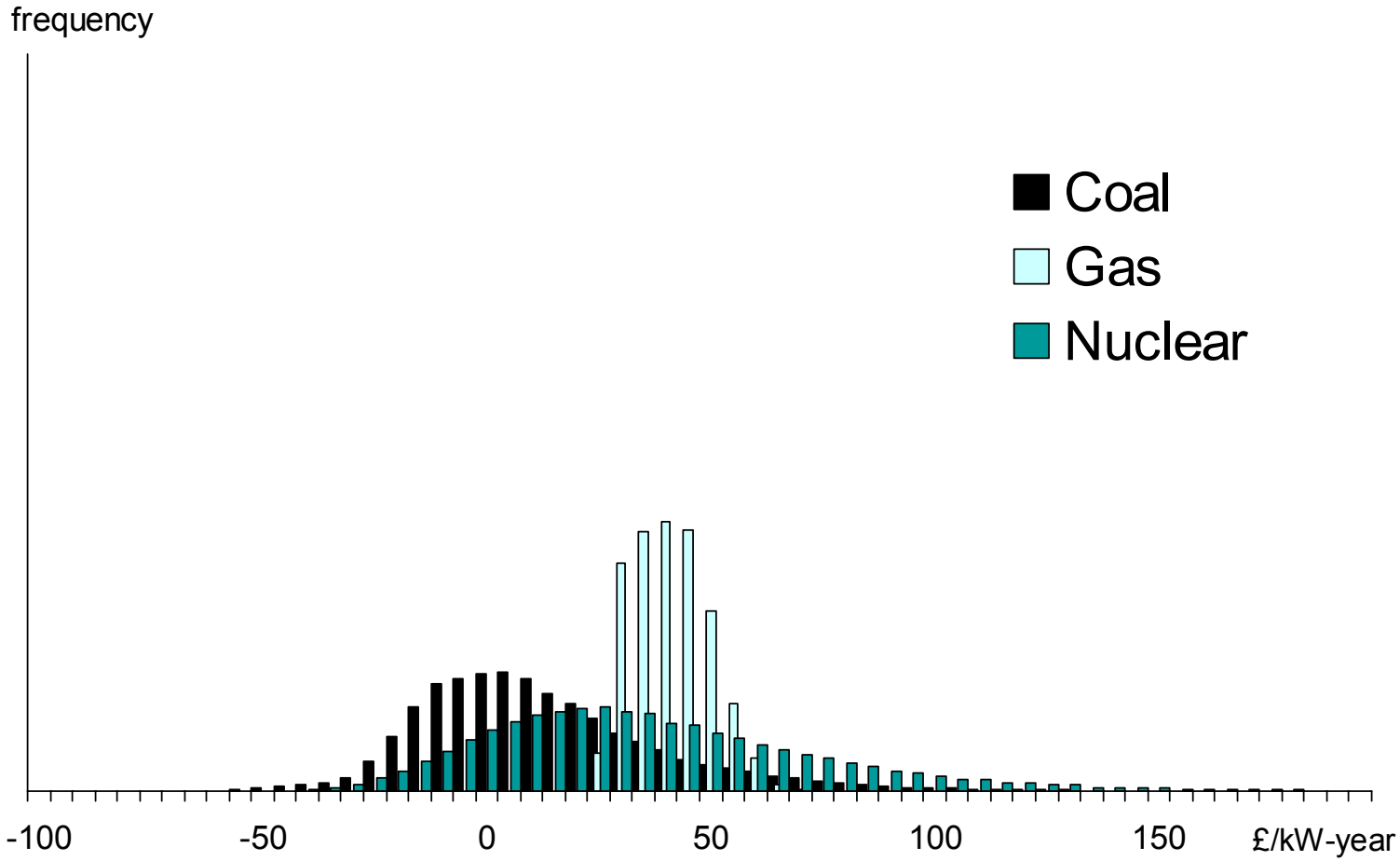
Profits with a carbon tax



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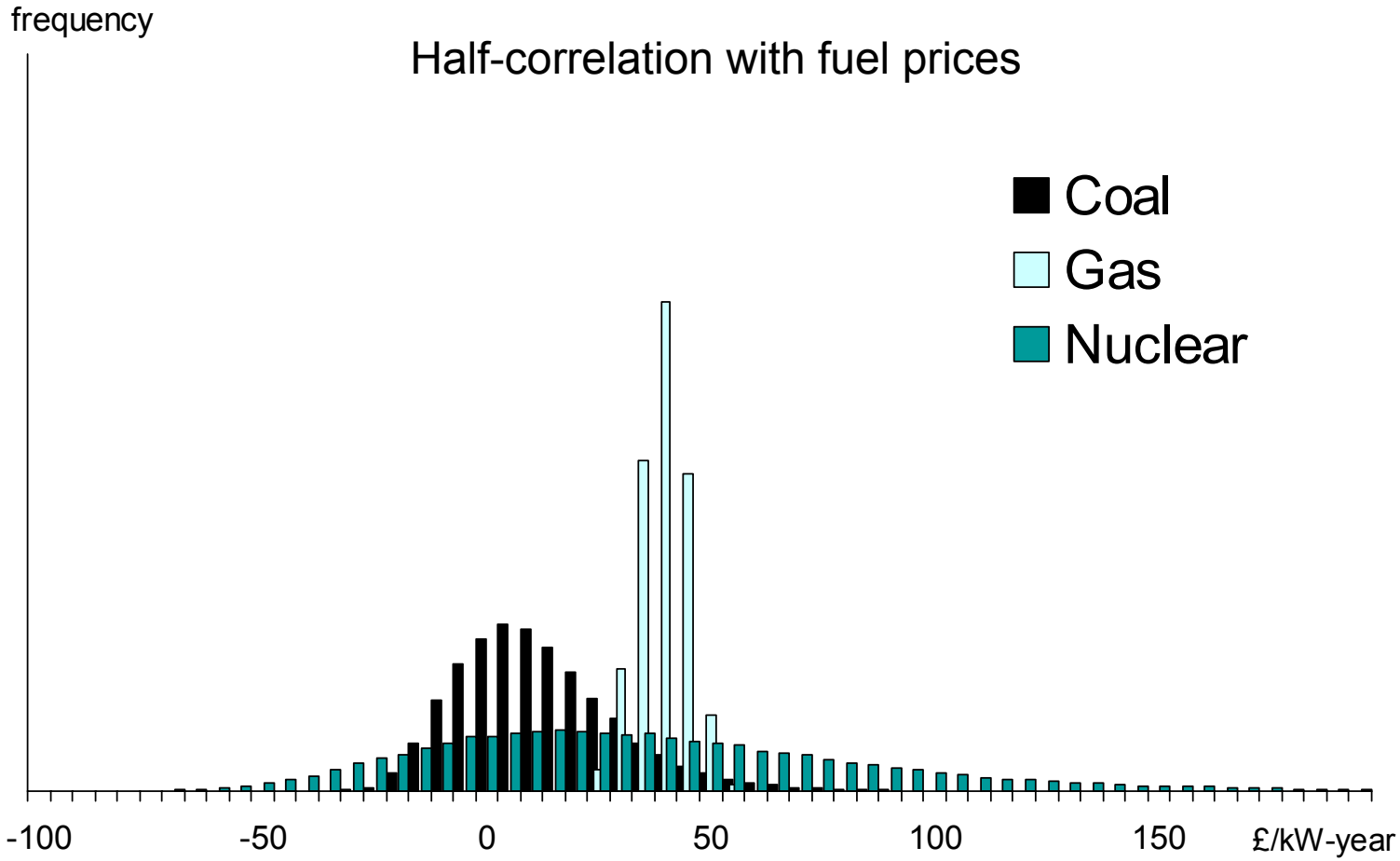

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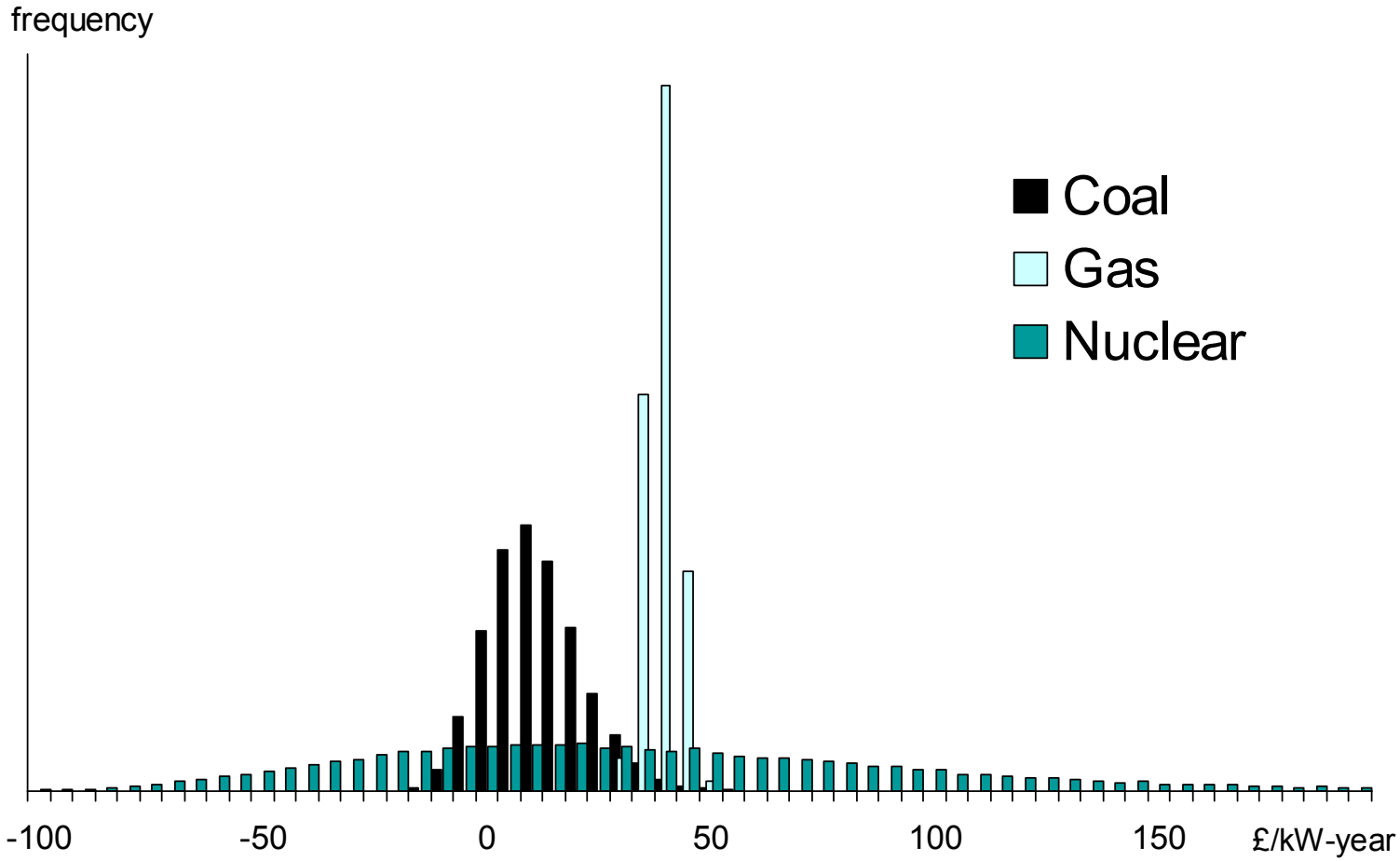

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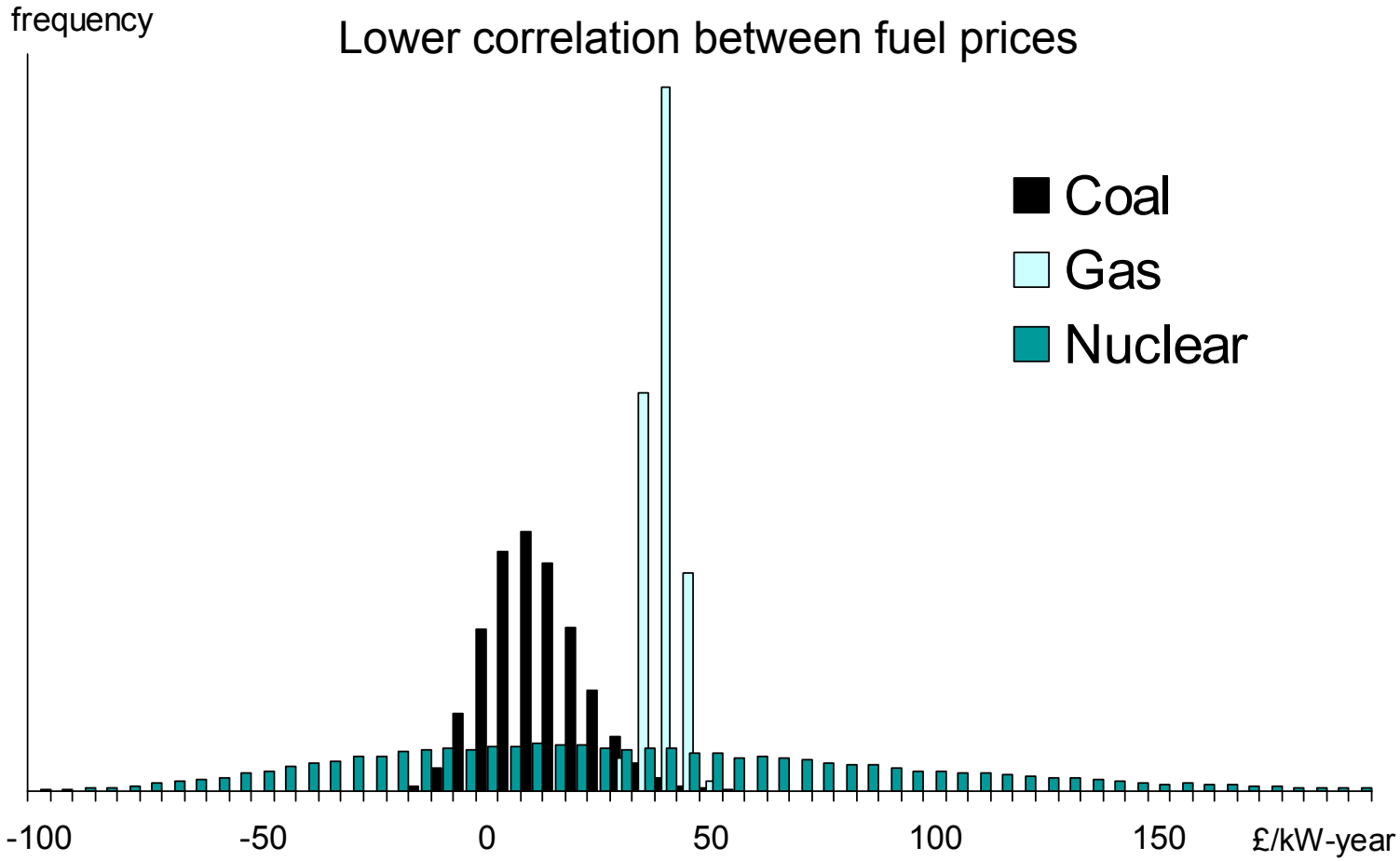

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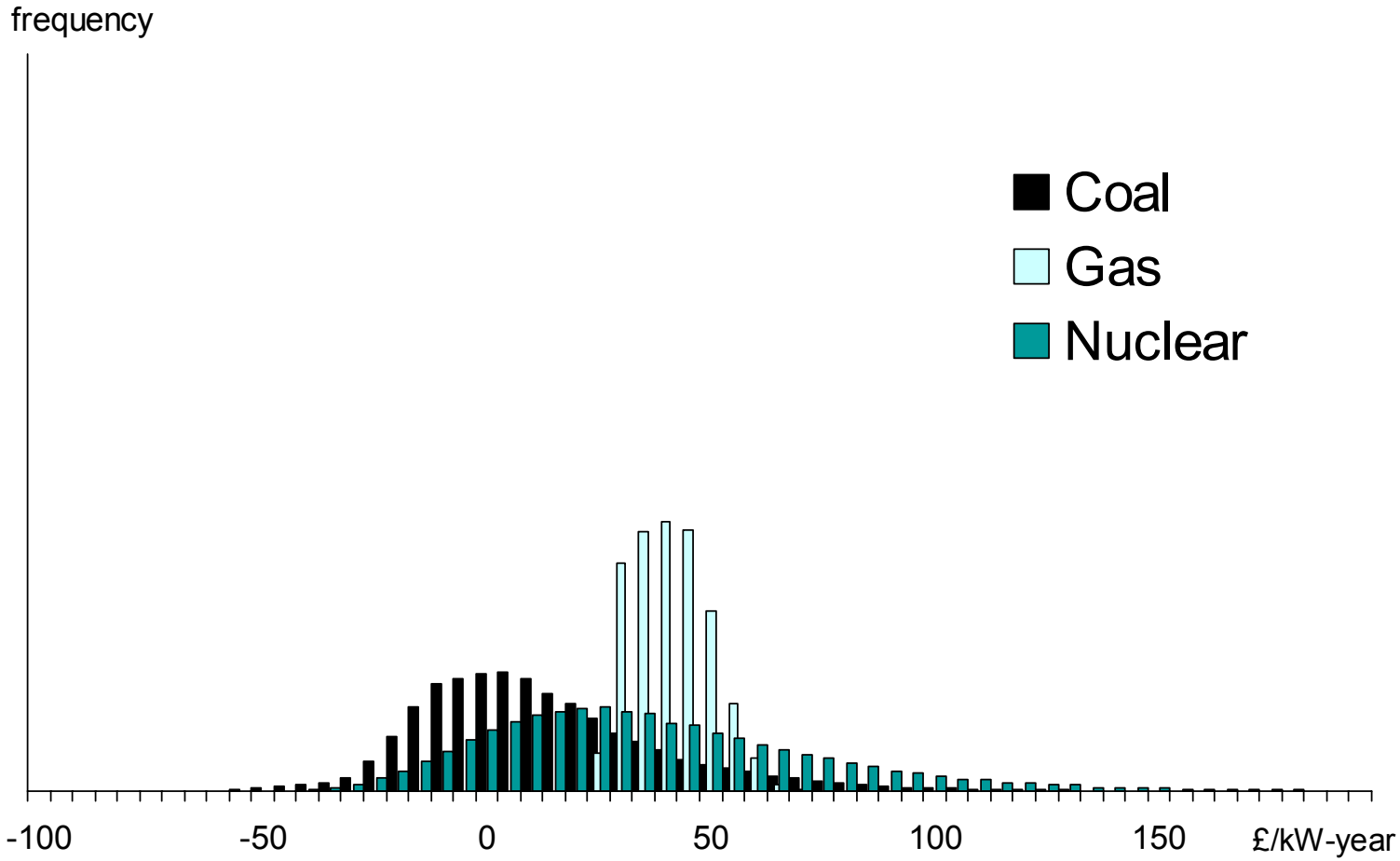

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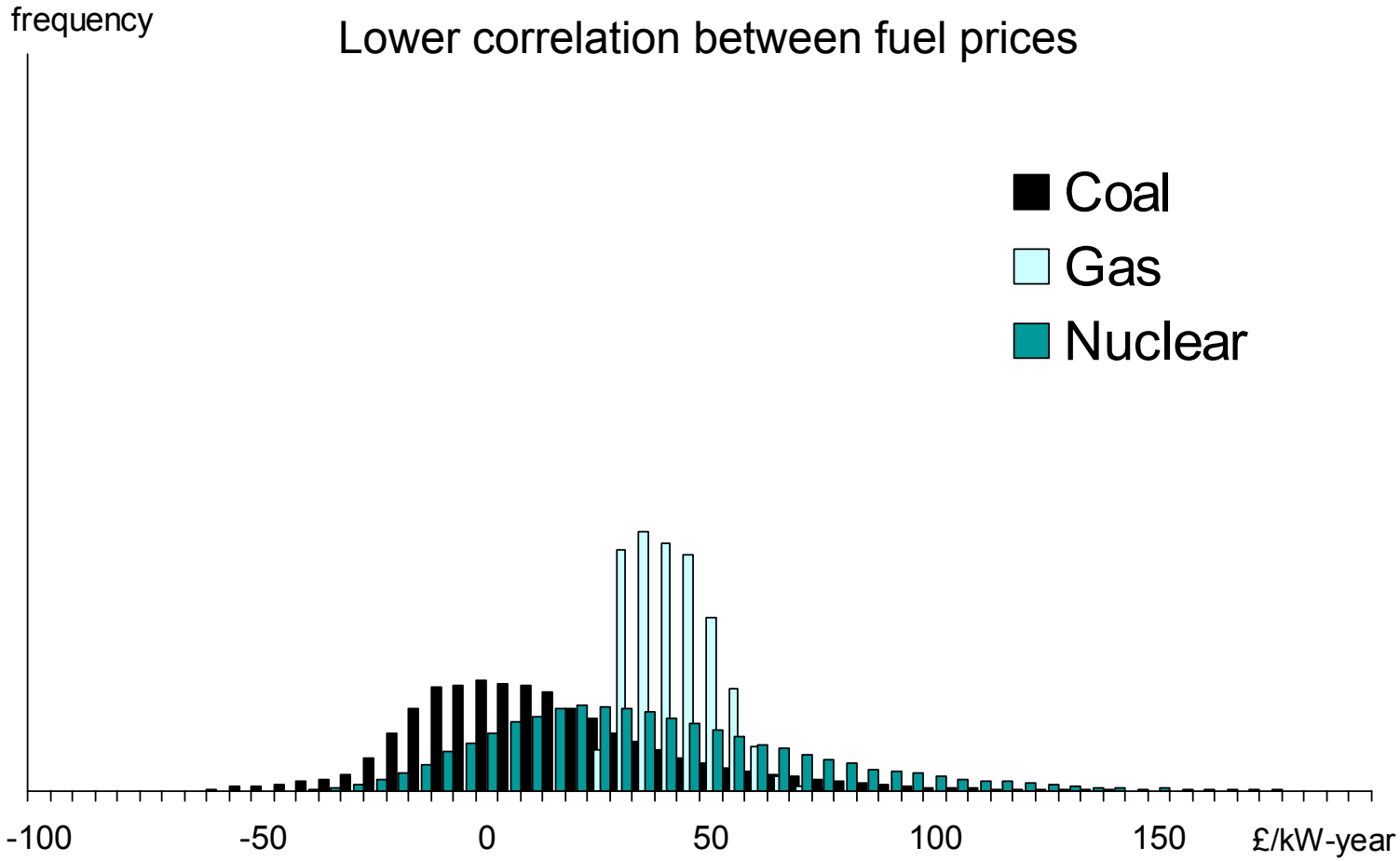
Profits with a carbon tax

Lower correlation between fuel prices



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Contracts

- Sell some output at a fixed price
  - Equal to mean of out-turn price
  - Will affect variance of profits

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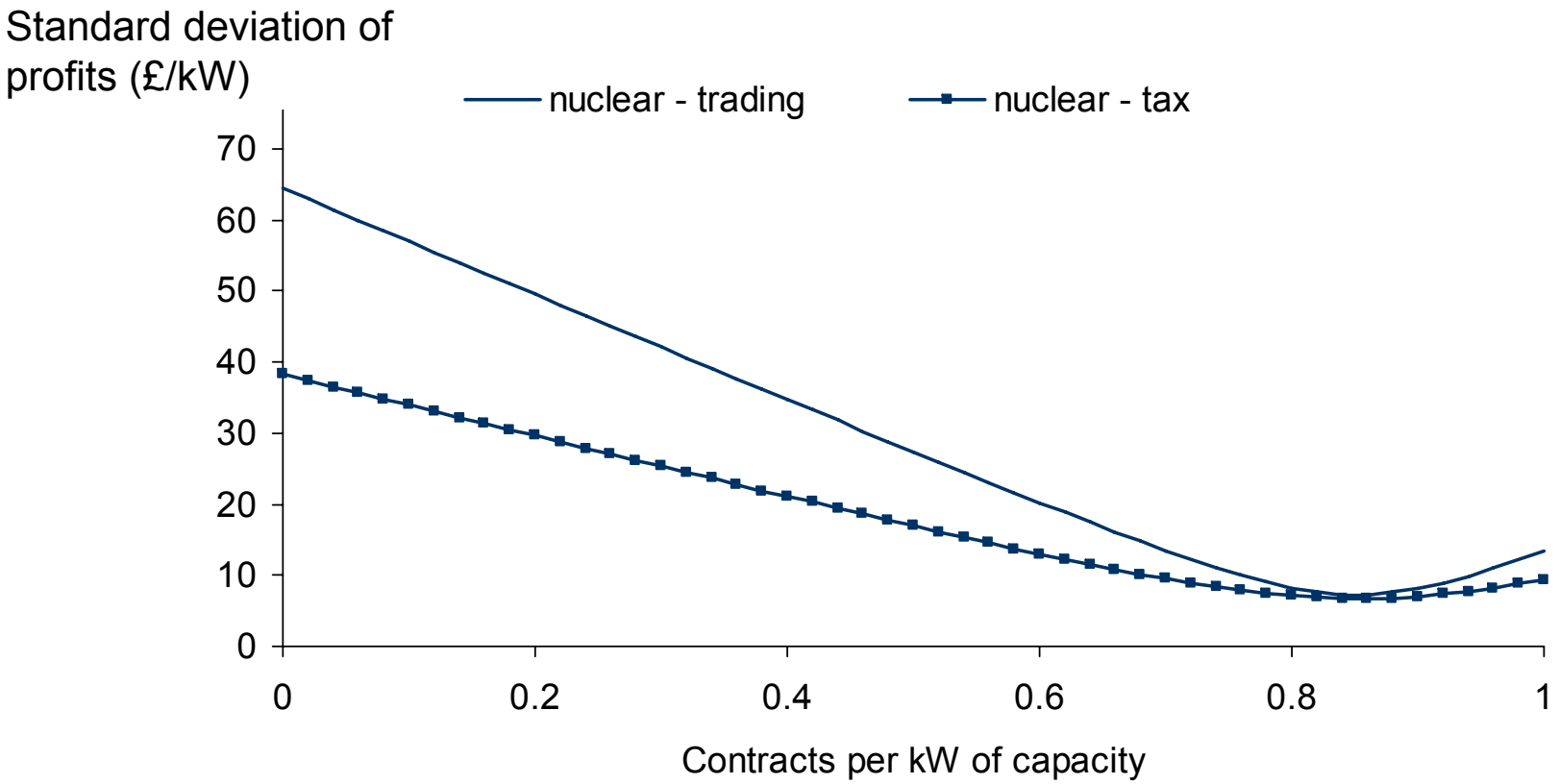
The impact of contracts



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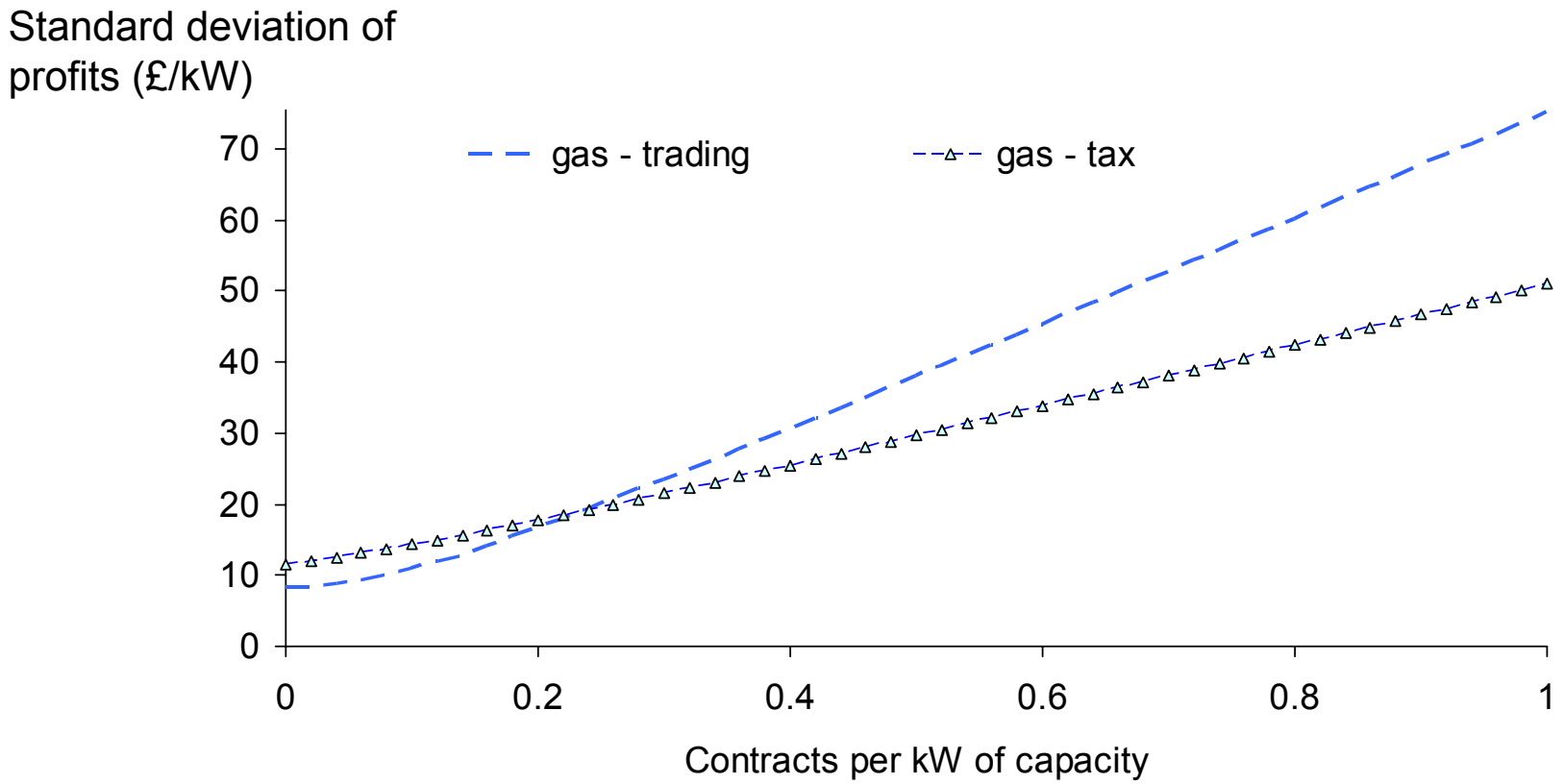

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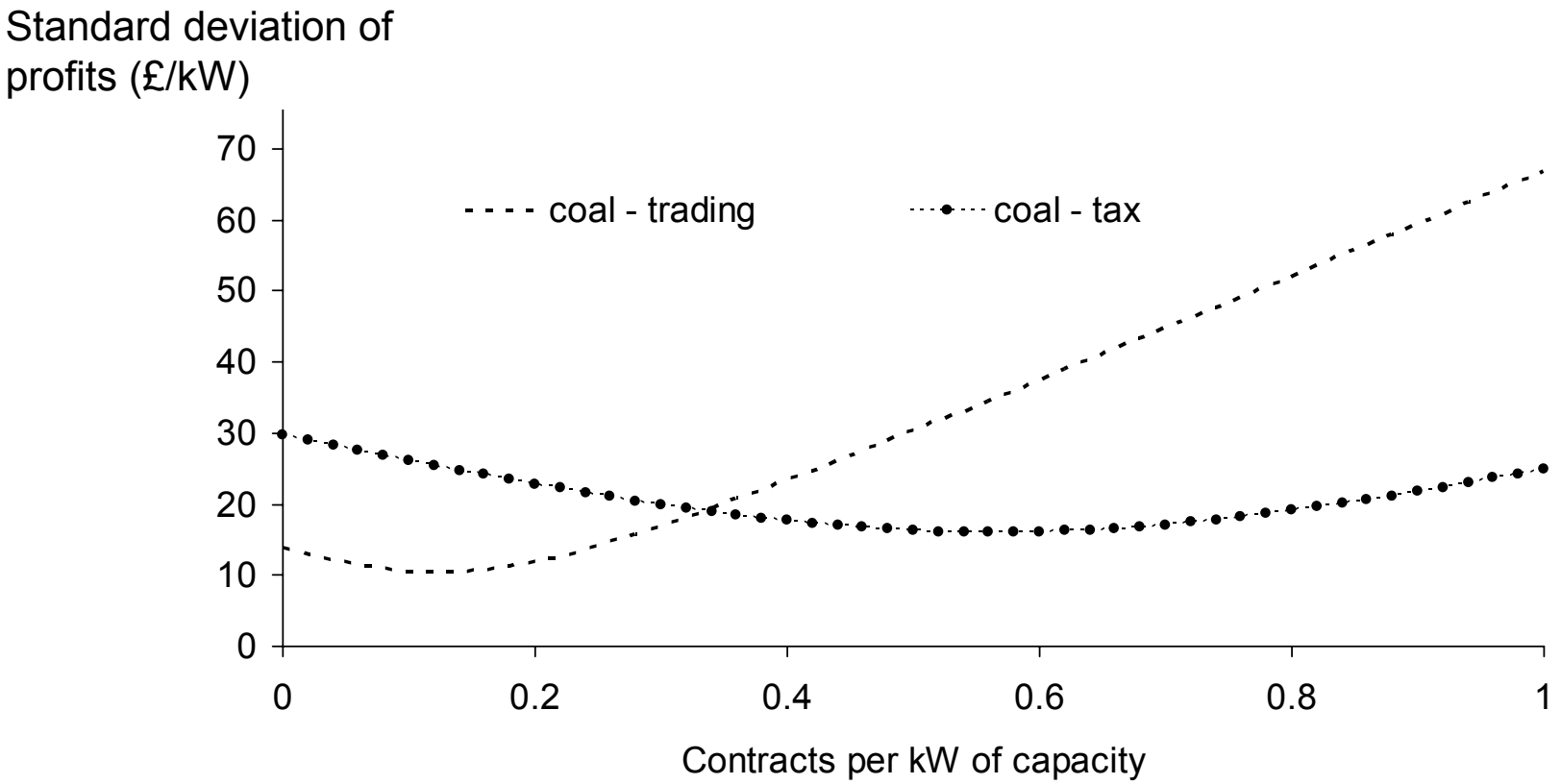

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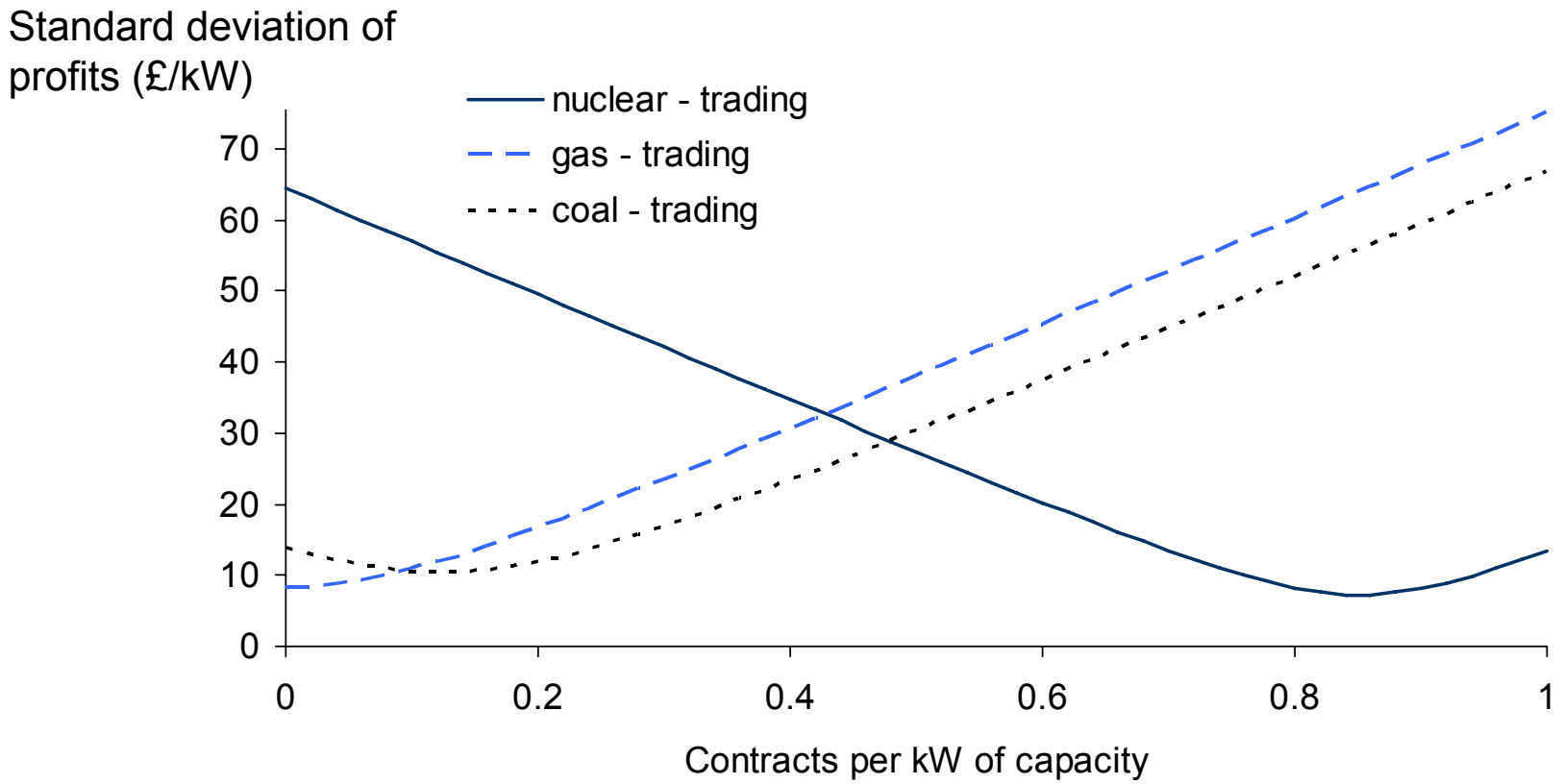

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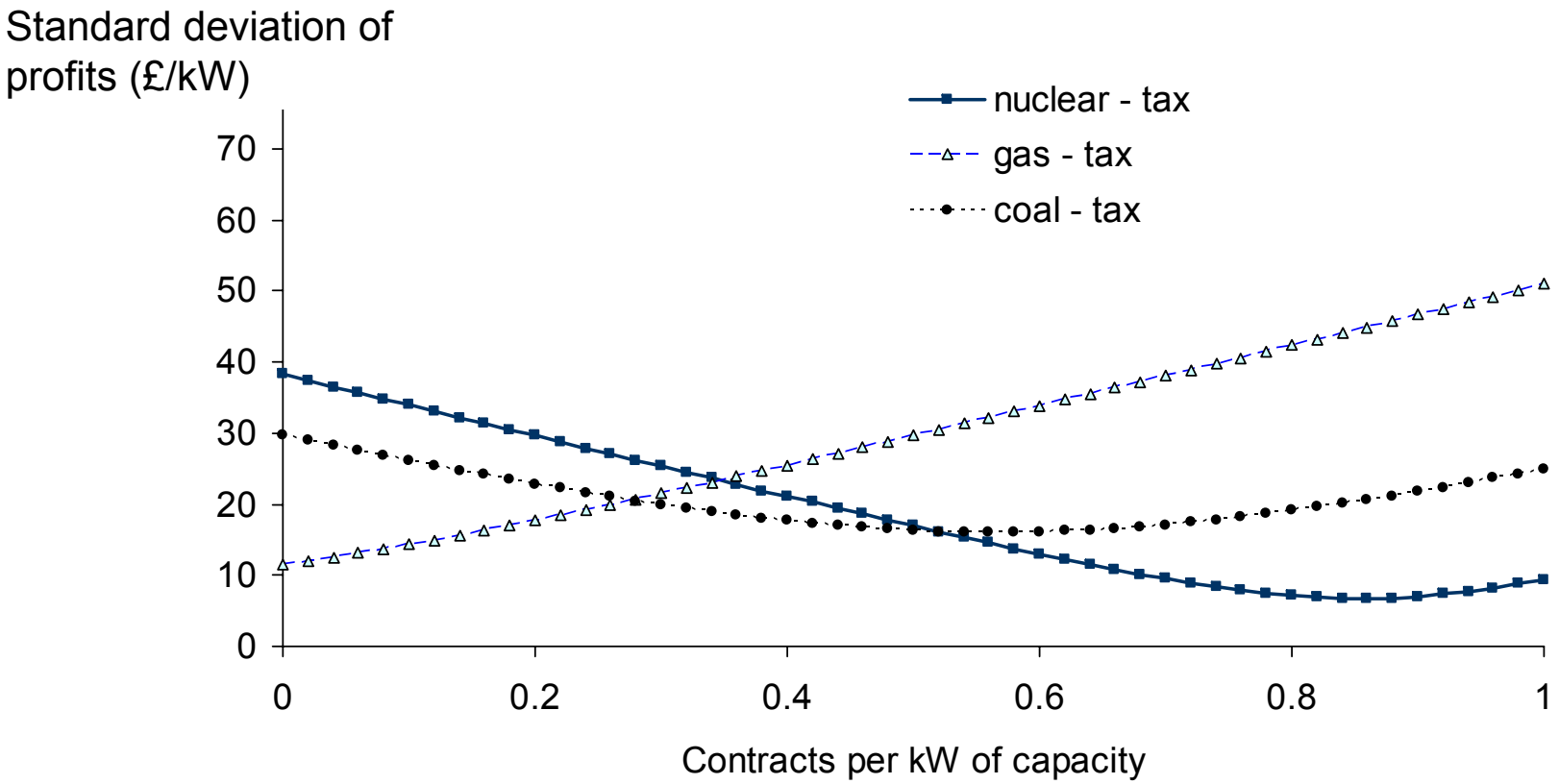

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Portfolio Effects

- Nuclear and coal have more risk and lower expected profit than gas
- Gas profits negatively correlated with those of coal and nuclear
- Combining in a portfolio may reduce risk

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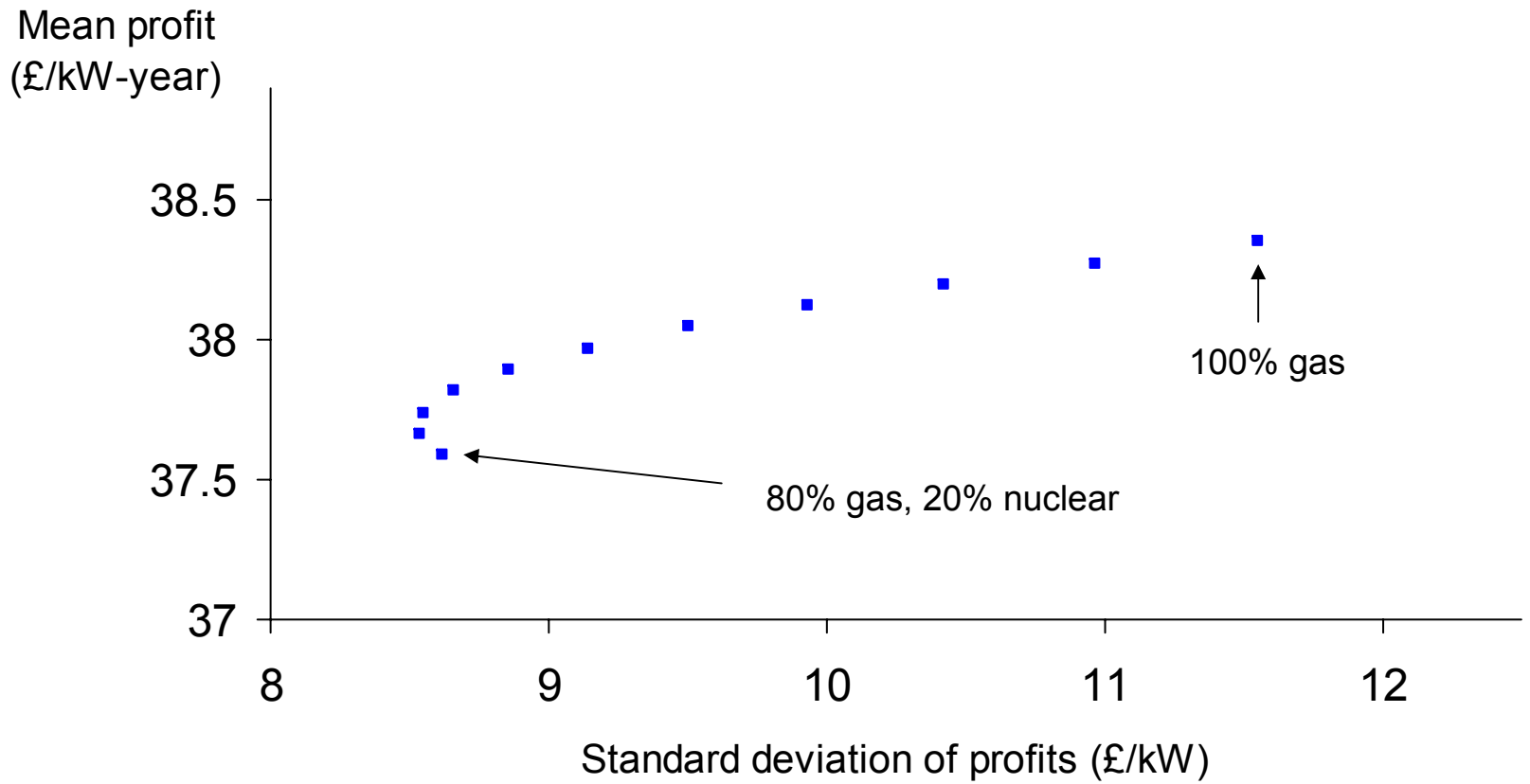
Risk and return with carbon tax



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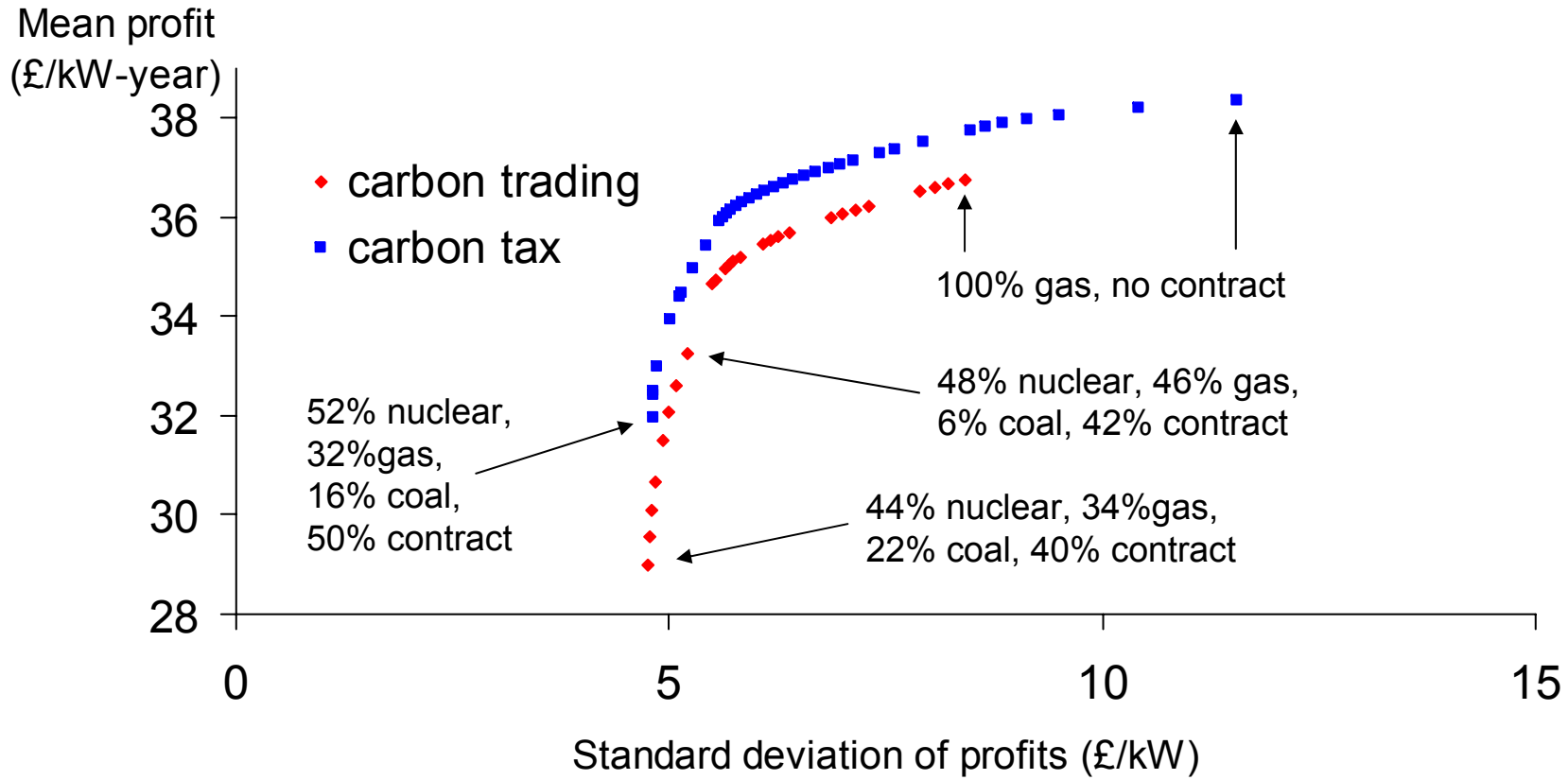
Risk and return



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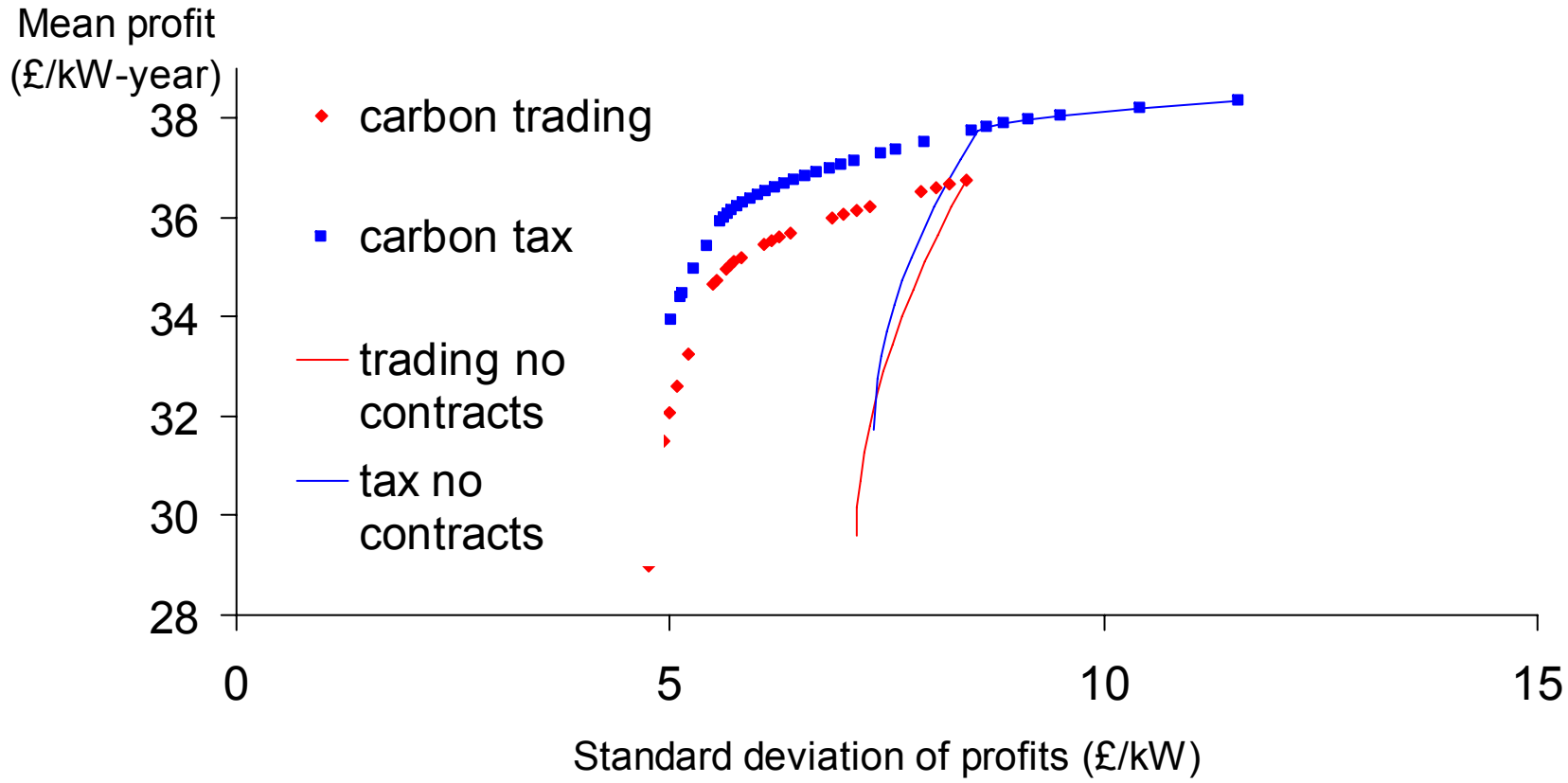

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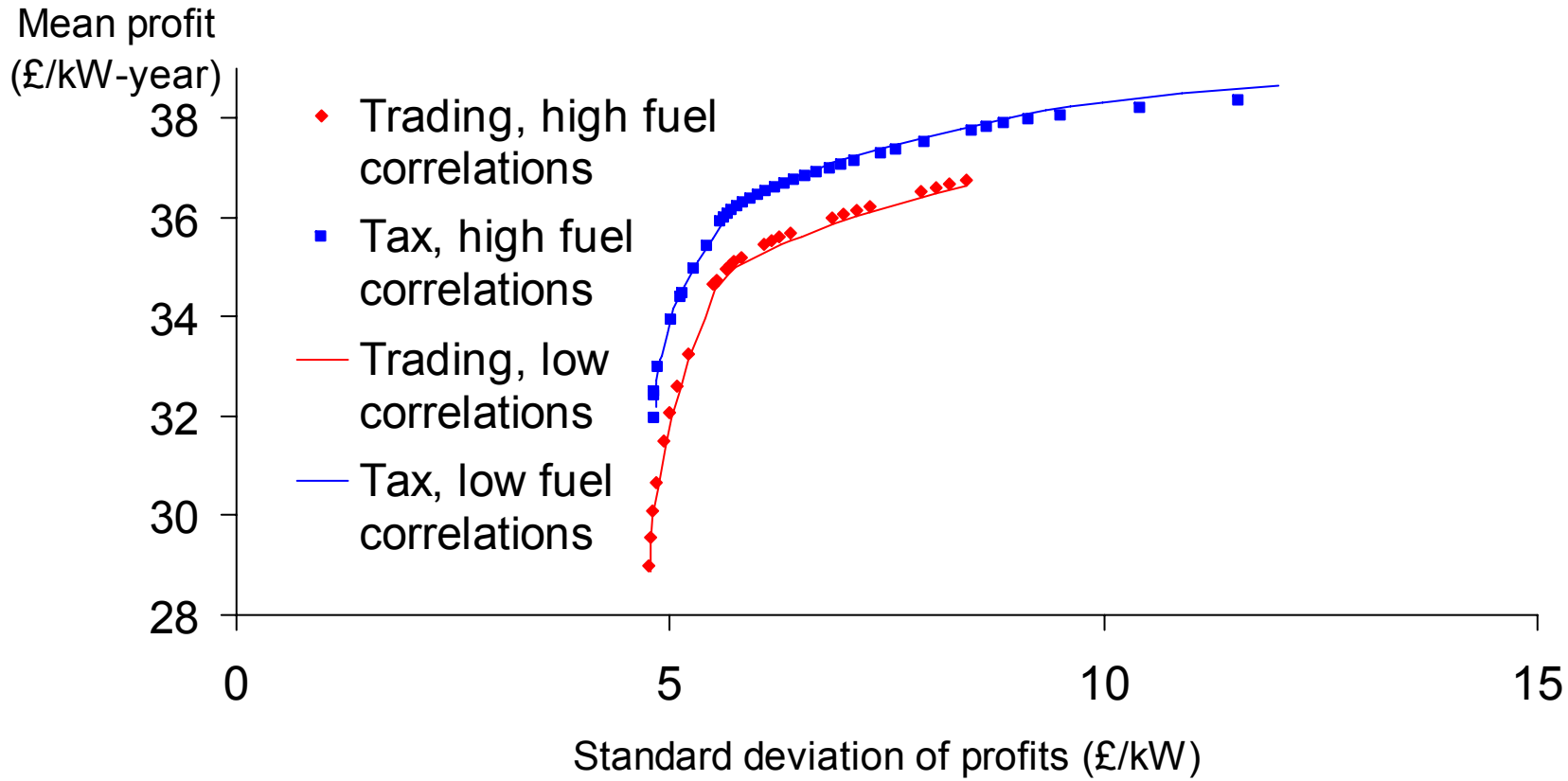

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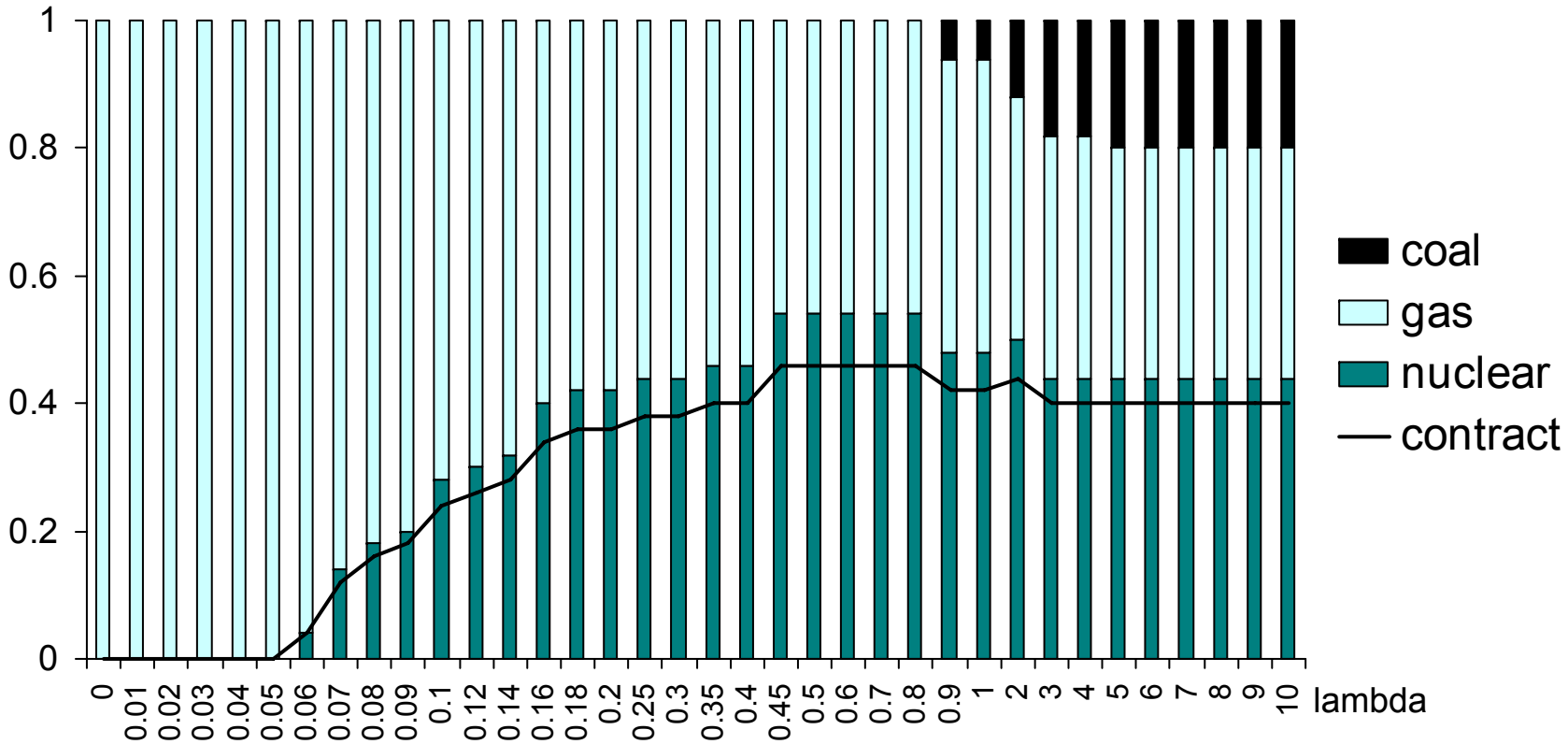
Optimal portfolios with carbon trading



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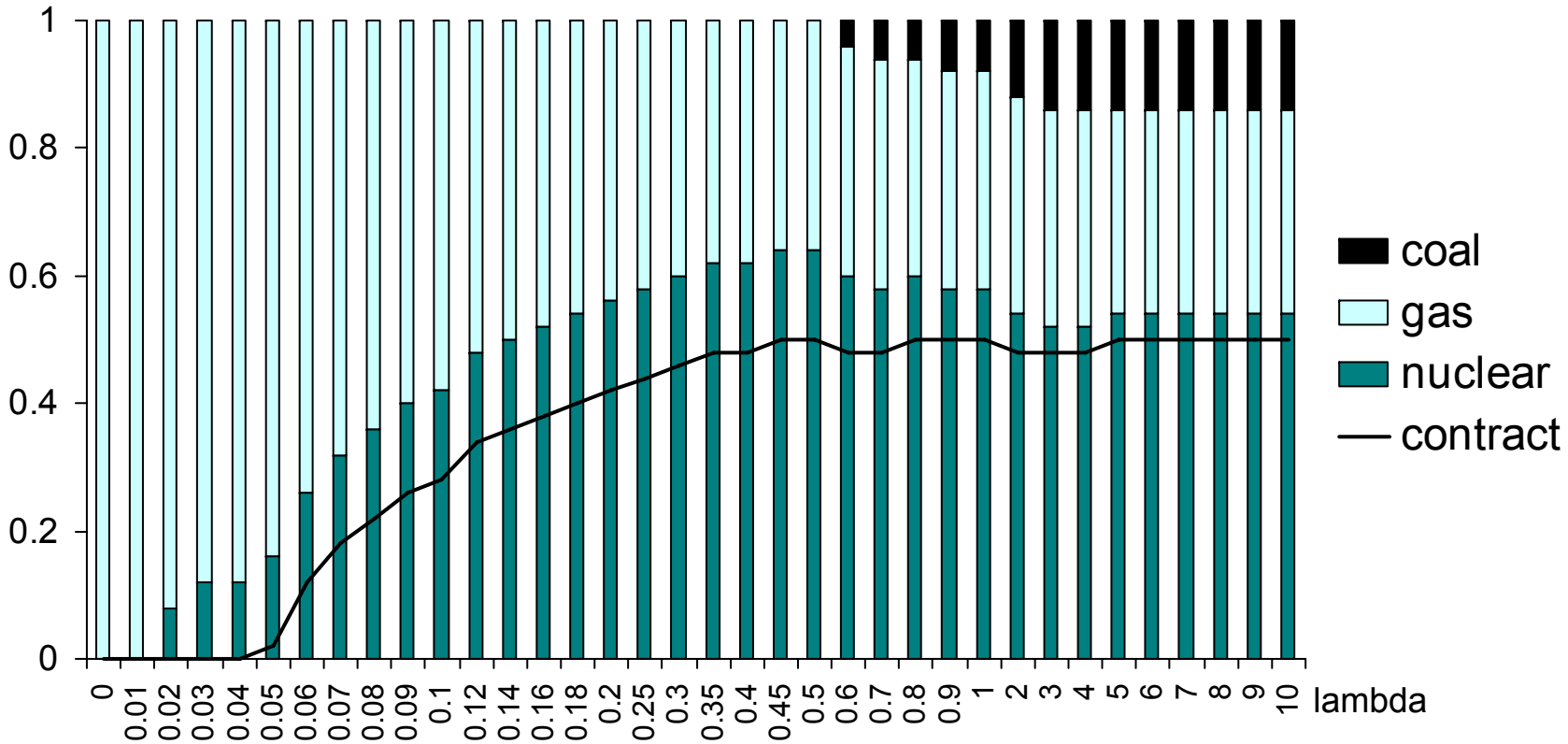
Optimal portfolios with a carbon tax



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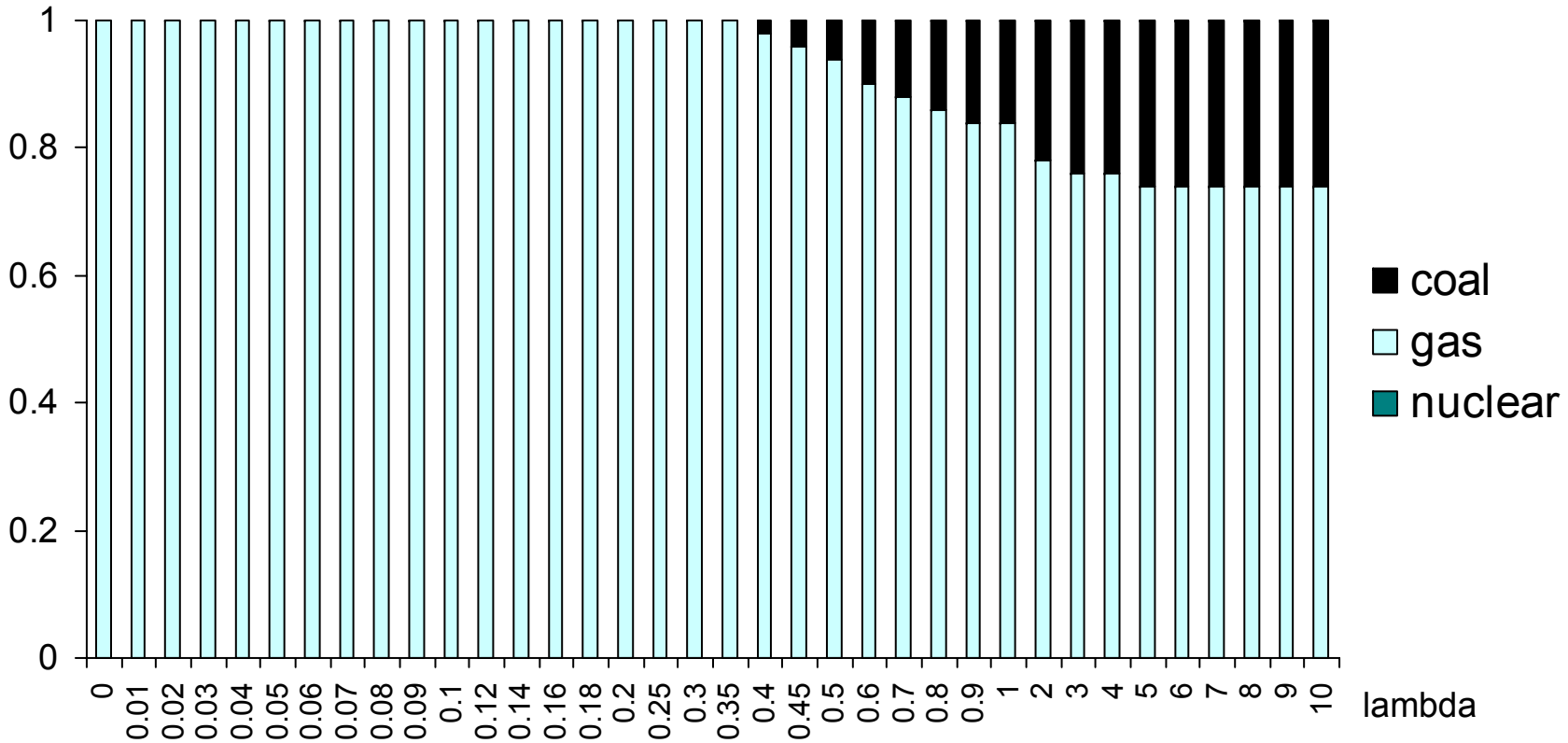
Optimal portfolios with carbon trading and no long-term contracts



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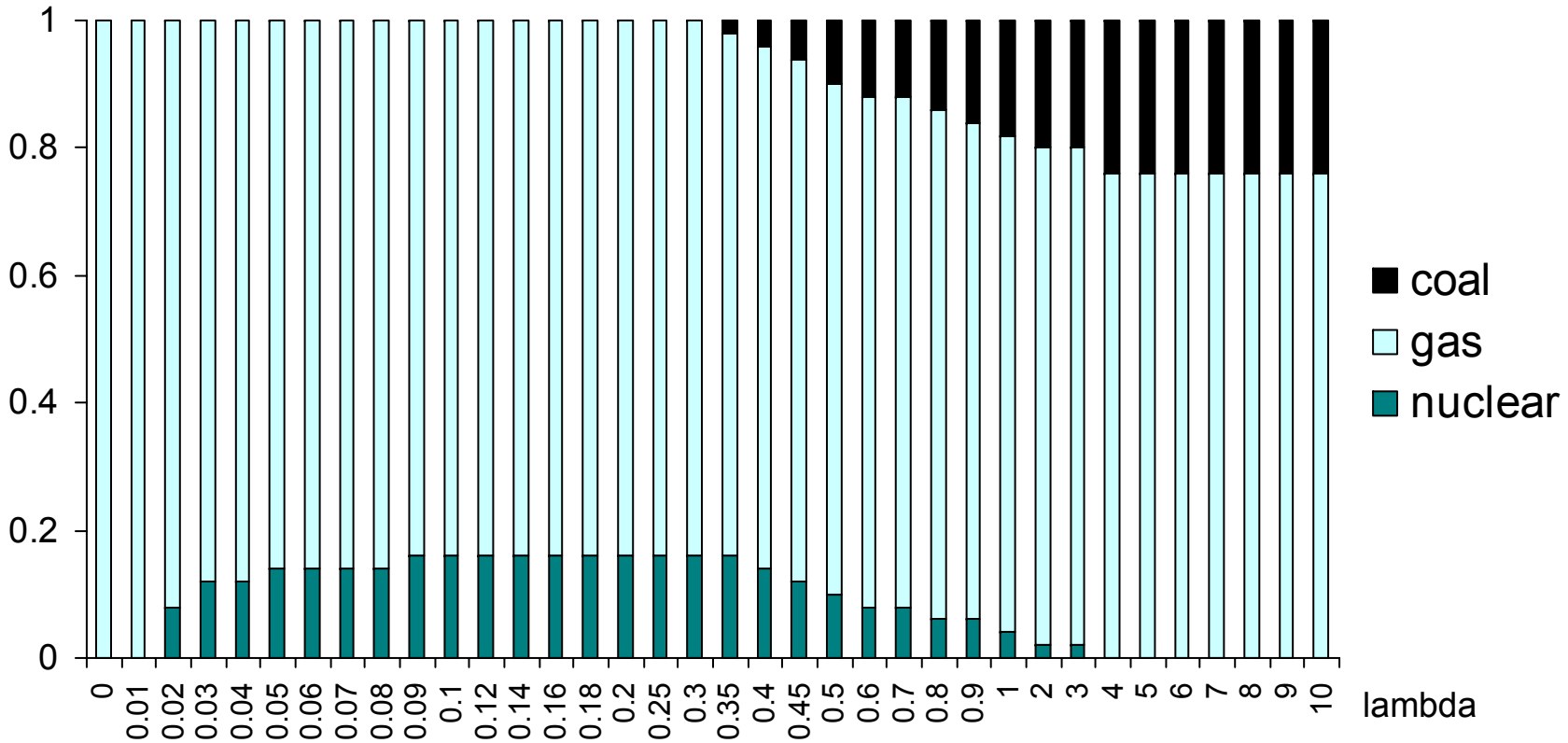

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Conclusion

- Nuclear stations have lower risks with carbon tax than emissions trading
  - Optimal share in portfolio may still be zero
- Mainly-gas portfolios have higher risk (and return) with carbon tax than with permits
- Nuclear is far more attractive to firms if combined with long-term contracts

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