

The supply function equilibrium and its policy implications for wholesale electricity markets

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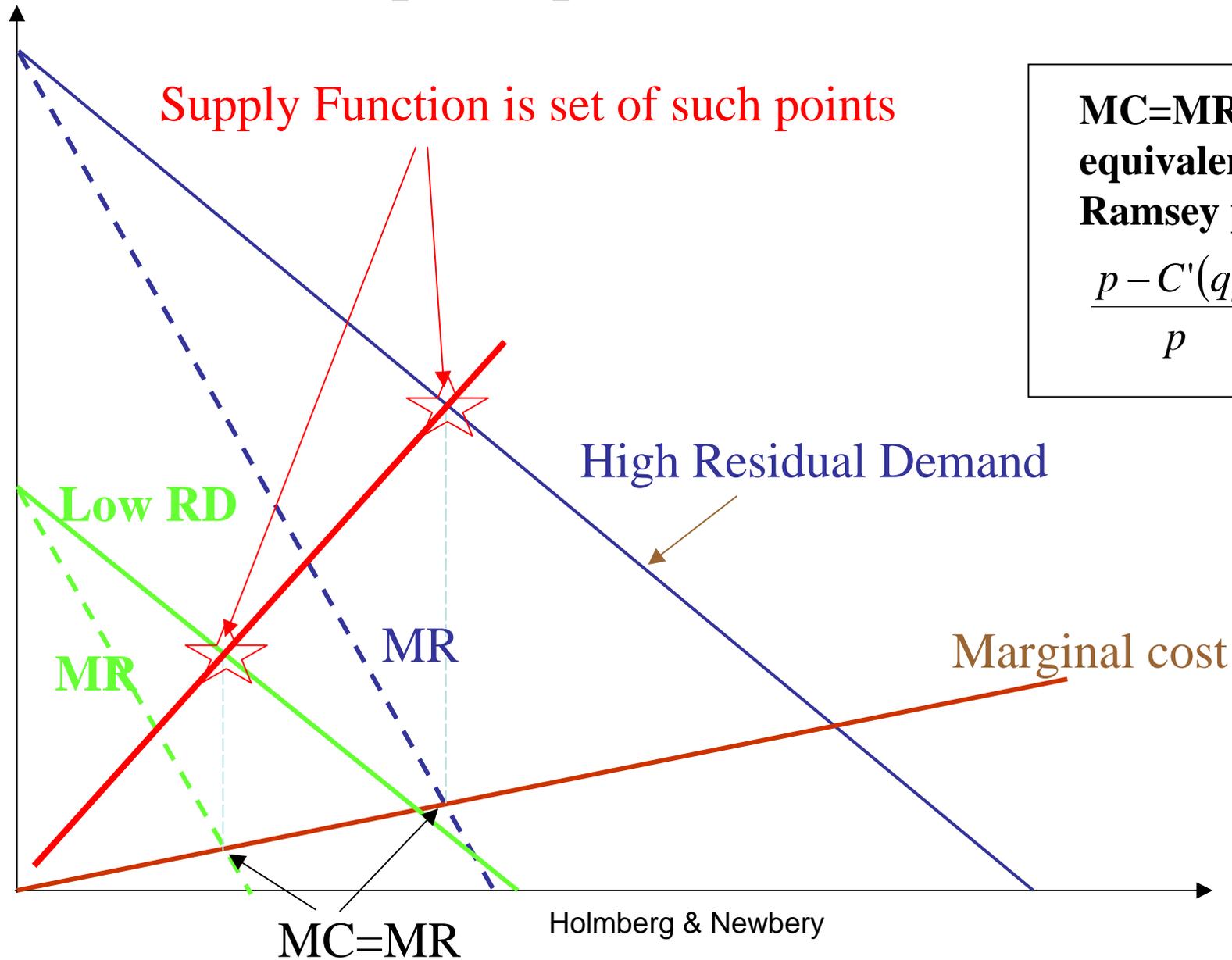
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Outline

- Supply function equilibrium (SFE)
- Short-run welfare losses in electricity auctions
- Policy implications

Ex-post optimal SFE



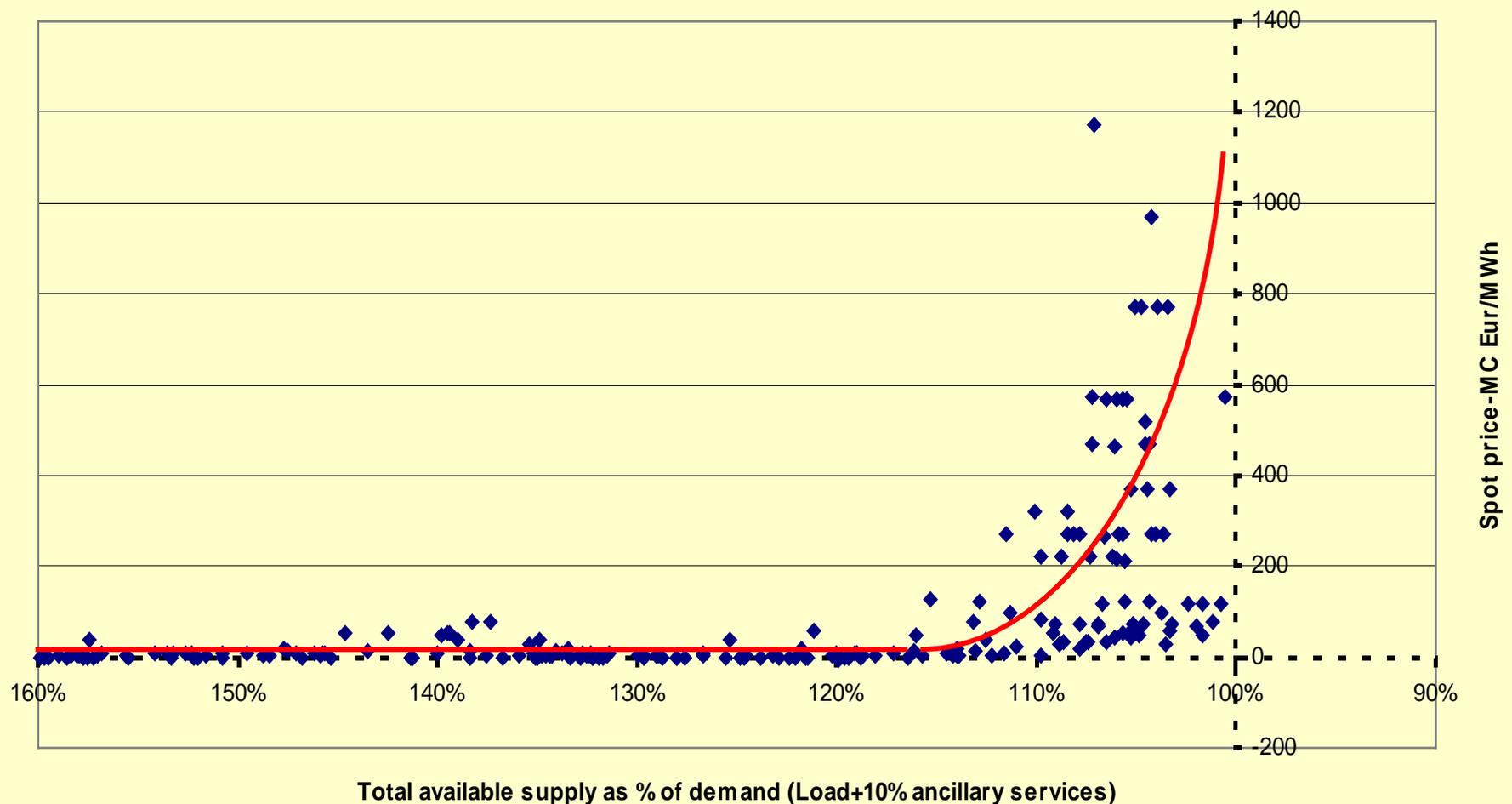
MC=MR is equivalent to Ramsey pricing:

$$\frac{p - C'(q_i)}{p} = \frac{-1}{\gamma_i^{res}}$$

Hockey-stick bidding

According to SFE theory mark-ups will increase sharply near market capacity (hockey-stick bidding). Observed in Texas (Hurlbut et al., 2004).

Price mark-up vs availability (Europe)

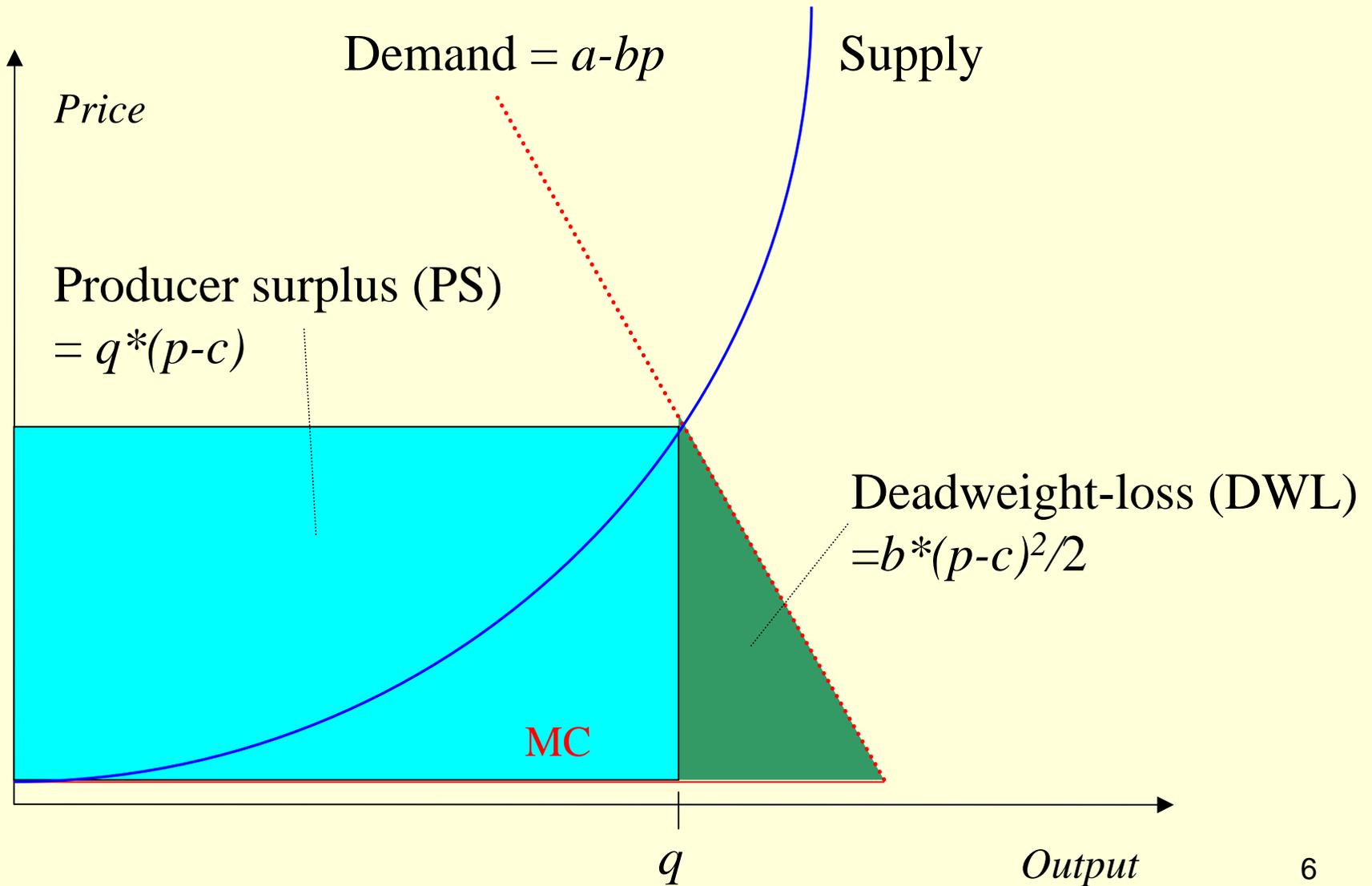


Quantitative tests of SFE

- Hortacsu & Puller, Sioshansi & Oren; **ERCOT**:
 - offers of largest producers match the SFE FOC
 - but not small firms
- Willems et al., **Germany**: replicate mark-ups
 - Cournot fits with choice of contracting levels
- Wolak, **Australia**: producers maximize profit given **smoothed** residual demand
- Sweeting **UK**: behaviour consistent with tacit collusion

Short-run welfare loss

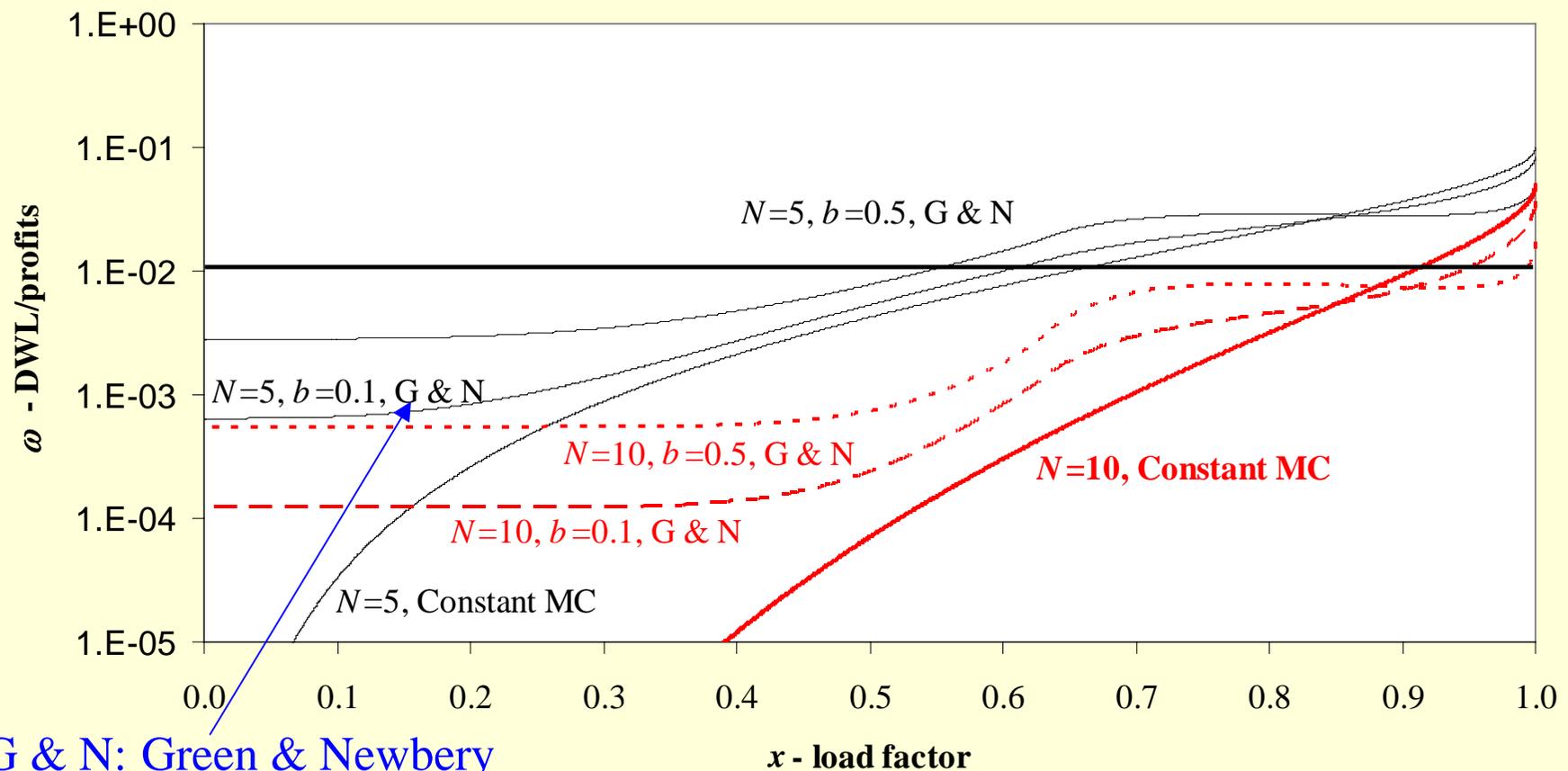
$$\omega = \text{DWL}/\text{PS} = b*(p-c)/(2*q)$$
$$(p-c) \sim 1/b$$



Short-run welfare loss: symmetric market

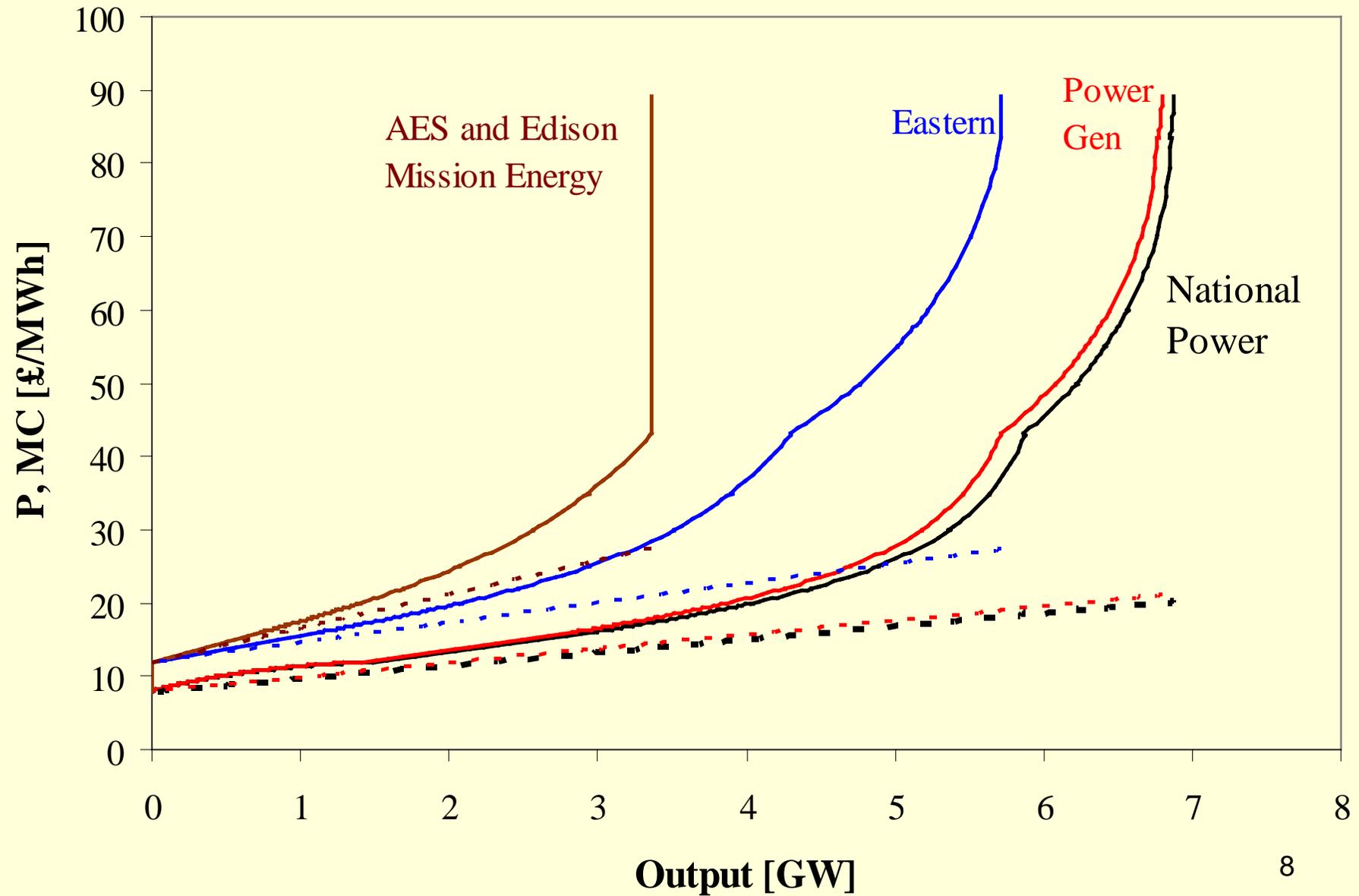
Compare constant MC with increasing MC for E&W '88/'89

- * Load factor $x < 0.5 \Rightarrow$ 5 firms keep $\omega < 1\%$.
- * $x < 0.9 \Rightarrow$ 10 firms keep $\omega < 1\%$.
- * Load duration curve for E&W \Rightarrow 5 firms keep $\omega < 1\%$ on average (Green & Newbery, 1992).

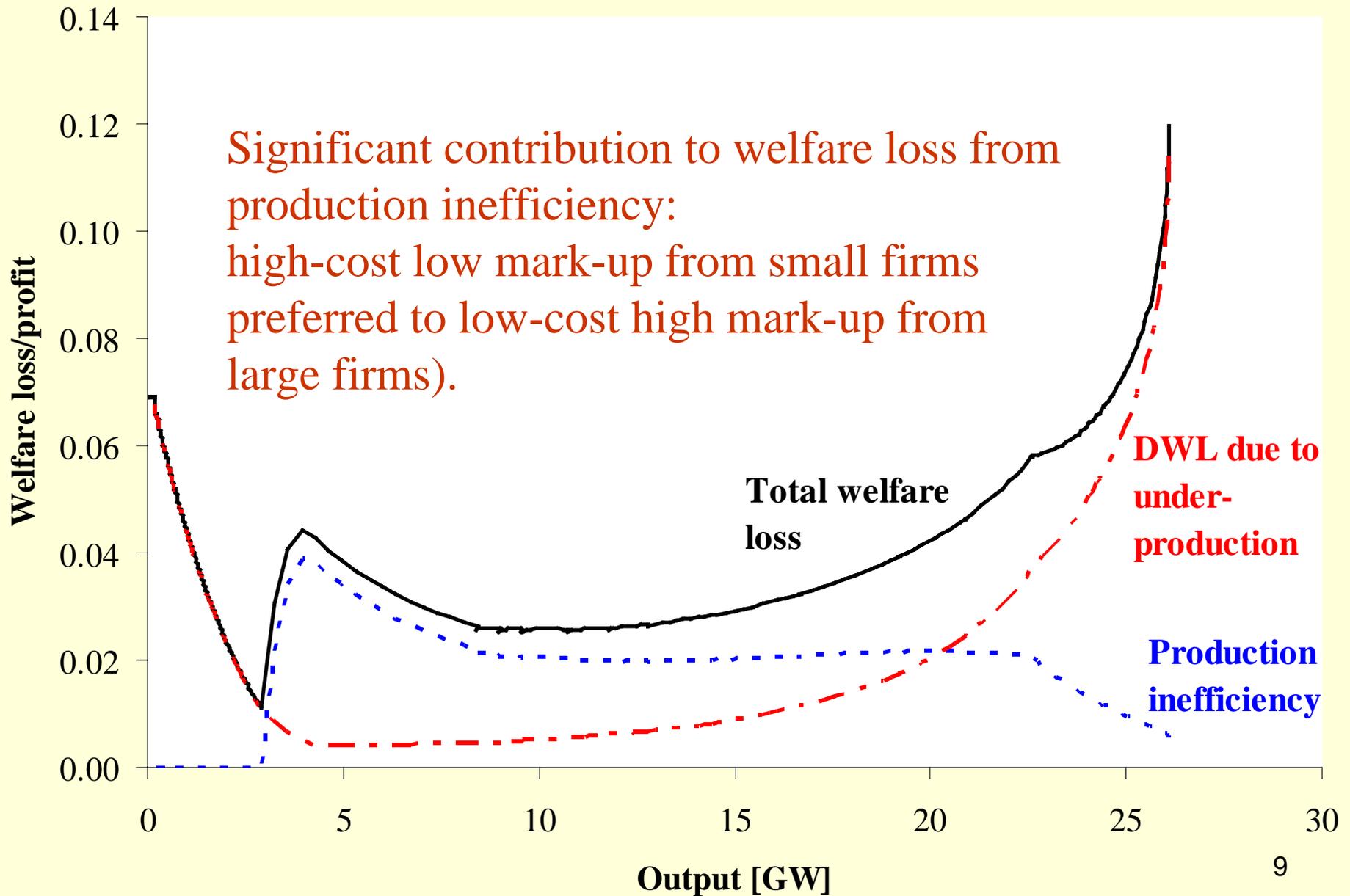


Asymmetric SFE model of England & Wales in 1999

(Anderson & Hu; Holmberg)



Short-run welfare loss: asymmetric market



Encouraging contracting

Why? ω reduced 4-10 times if half output sold forward

How? Require VPP auctions; Imbalance penalties; real-time bidding only from flexible units

- Risk-aversion
- Strategic retailers buy in the forward market (Anderson & Hu).
- Pro-competitive contracting of strategic producers:
 - Keep output high and mark-ups low to deter entry (Newbery)
 - Competitors are marginal forward buyers (Green, Holmberg).
 - Weak and non-robust when consumers are marginal forward buyers as in Allaz and Vila (Green, Holmberg).

Imbalance penalties

- Excessive penalty charges \Rightarrow self-balancing
 \Rightarrow reduces liquidity in real-time market
 \Rightarrow results in production inefficiencies

\Rightarrow **Cap penalty charges**

- penalty $<$ extra cost of self balancing \Rightarrow use real-time market.

Price caps and investment

- Most electricity not metered in real-time
=> welfare improving to ration demand at the VOLL
- Risk-averse producers sell capacity with call options
= implicit capacity payment (Oren, 2005)
- But investors may fear regulators will lower any cap
c.f. US “just and reasonable” pricing requirement

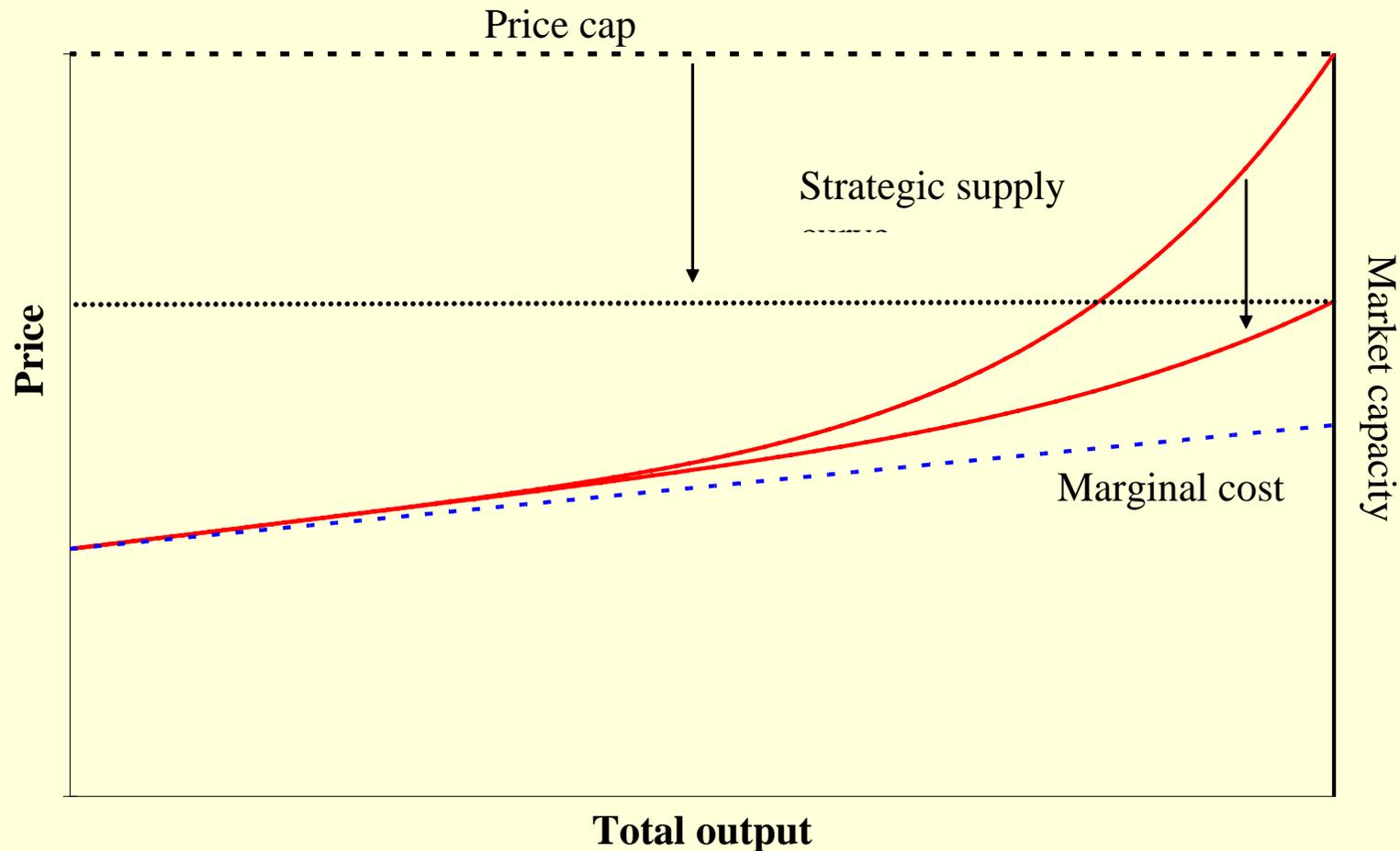
Market regulators need credible independence

Capacity payments: $LOLP \times (VOLL - p_{cap})$

- optimal investments can be maintained with a lower price cap.
- Producers not compensated for lower mark-ups

=> less over-investment and lower prices.

But risk of withholding and LOLP is difficult to estimate



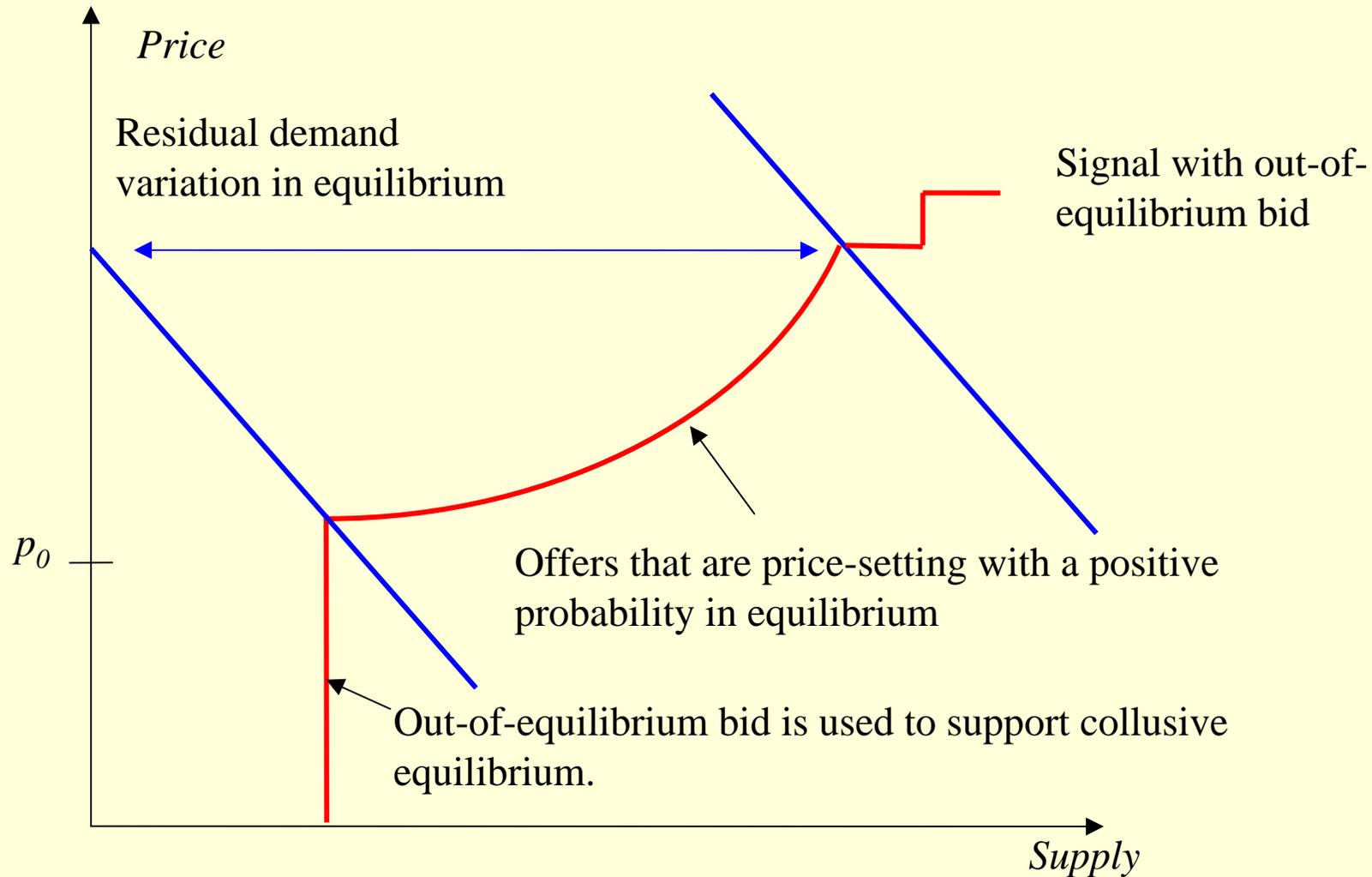
Disclose offer curves?

- Can then estimate residual demand elasticities and potential mark-ups (Wolak).
 - useful for market monitors if costs opaque (hydro)
- But facilitates collusion
 - => delay disclosure
 - => only disclose parts near the clearing price

Restrictions on offer curves

Long-lived bids increases range of prices for which offer curve is marginal

Reduces signalling and implicitly colluding with out of equilibrium bids.



Restrictions on offer curves

- Long-lived bids or clearing successive markets at same moment

=> reduces collusion in repeated games as the punishment for deviation reduced

- Small price tick sizes + fewer steps

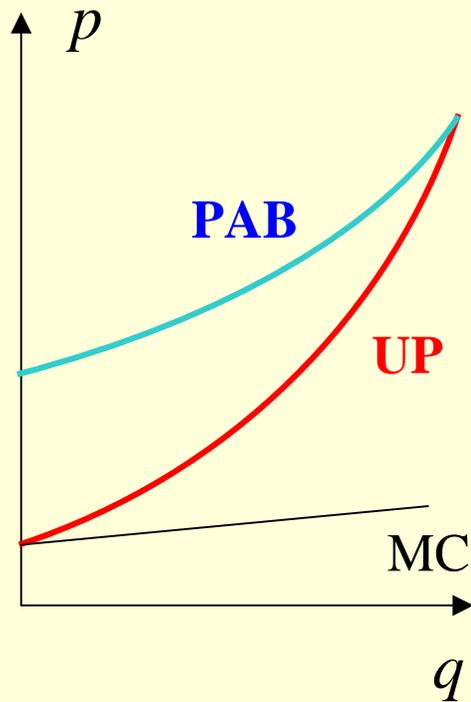
=> mixed-strategy NE (v. d. Fehr and Harbord) with larger variation in residual demand

=> Lowers risk of collusion

Increases uncertainty, creates production inefficiency

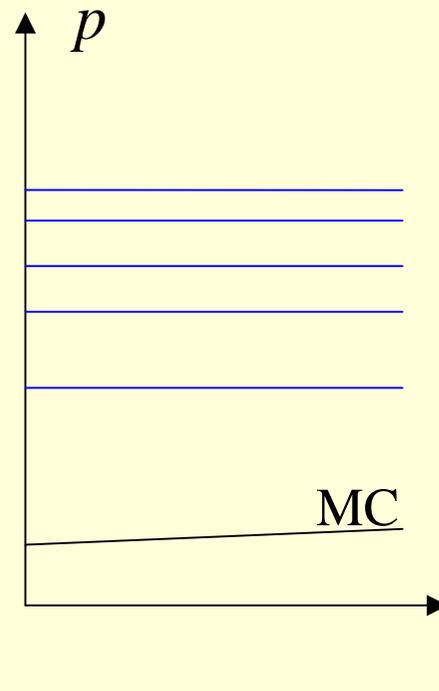
Pay-as-bid equilibria are not ex-post optimal

$(p - C'_i(q_i)) * H(q)$ is decreasing
 \Rightarrow pure-strategy NE



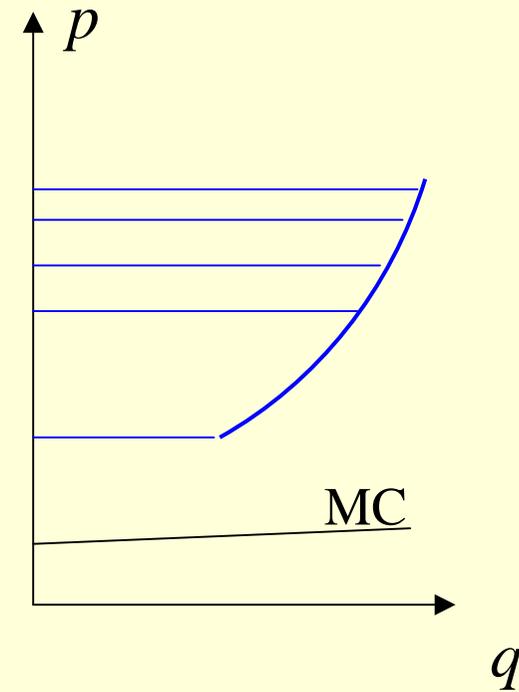
Holmberg

$(p - C'_i(q_i)) * H(q)$ is increasing \Rightarrow flat mixture



Bertrand-Edgeworth with demand uncertainty
 Fabra et al; Genc; Anderson et al.

$((p - C'_i(q_i)) * H(q))$ is first increasing and then decreasing \Rightarrow hockey-stick mixture



Anderson et al

Pay-as-bid vs uniform auctions

- Ranking uncertain if costs are uncertain (Ausubel & Cramton)
- If costs are common knowledge, PAB preferable for auctioneer/consumers (Son et al; Fabra et al; Holmberg)
- Experiments contradict (Rassenti et al.)
- Lower British prices after NETA: more capacity and divestitures, not market design (Evans and Green)

Pay-as-bid vs uniform auctions

- Advantage: all accepted bids price-setting and mixed strategies increase variation in residual demand
 - => reduces scope for costless signalling and threats
 - => Lowers risk of collusion (Fabra ; Klemperer)

But: increases uncertainty, production inefficiency and bidding is more complicated

Conclusions - 1

- 5-10 firms keep short-run relative welfare losses below 1% on average.
 - Lower HHI needed to reduce inefficiency with asymmetric firms
- higher HHI acceptable under contracting, encouraged by VPP auctions, imbalance penalties, real-time bids only from flexible agents
- Strategic contracting pro-competitive under threat of entry or when competitors are marginal forward buyers
 - Effect less robust if consumers are marginal forward buyers

Conclusions - 2

- Capacity payments, lower price cap reduce mark-ups and DW losses, but may result in withholding
- Independent regulators can increase trust that price caps and capacity payments will not be lowered
- Disclose offer curves near MCP: improves market monitoring, especially in hydro dominated markets
 - delay to deter collusion
- Long-lived bids deter collusion
- Small price ticks and few steps => mixed strategies
 - discourages collusion at cost of inefficiency and uncertainty

Conclusions - 3

- Character of NE in pay-as-bid sensitive to cost and demand uncertainty
- should lower prices and reduce collusion

But:

- *empirical evidence are mixed*
- *increases uncertainty and inefficiency*
- *deters entry*