Prices vs Quantities Strategic and Intertemporal Considerations

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Workshop **„Aktuelle Fragen zur Regulierung von Energie- und Telekommunikationsmärkten**
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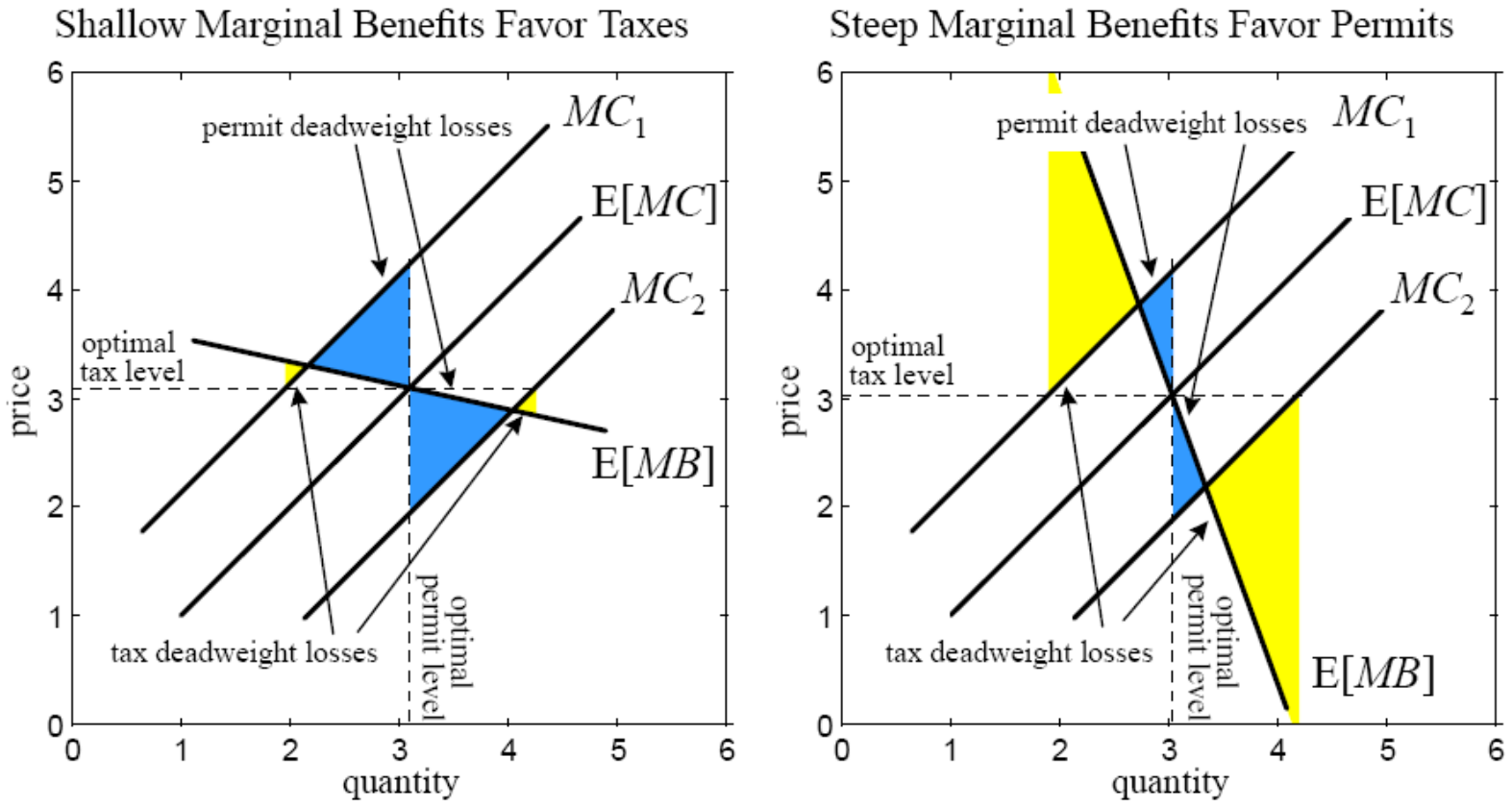
Advertisement for energy related issues

- **Big** & international & interesting ***IO* issues**
- ***Resources***
- ***Externalities***
  air, global warming, security of supply, networks (Kirchhof)
- Politics,
  Games & ***Public Choice***
- Recent **JEL**: 5 Climate
  1 Oil
  3 others

	Company	Revenues ($ millions)	Profits ($ millions)
1	Wal-Mart Stores	408,214	14,335
2	**Royal Dutch Shell**	285,129	12,518
3	**Exxon Mobil**	284,650	19,280
4	**BP**	246,138	16,578
5	Toyota Motor	204,106	2,256
6	Japan Post Holdings	202,196	4,849
7	**Sinopec**	187,518	5,756
8	**State Grid**	184,496	-343
9	AXA	175,257	5,012
10	**China National Petroleum**	165,496	10,272
11	**Chevron**	163,527	10,483

M. Weitzman (1974)

Review of Economic Studies 41: 477-491

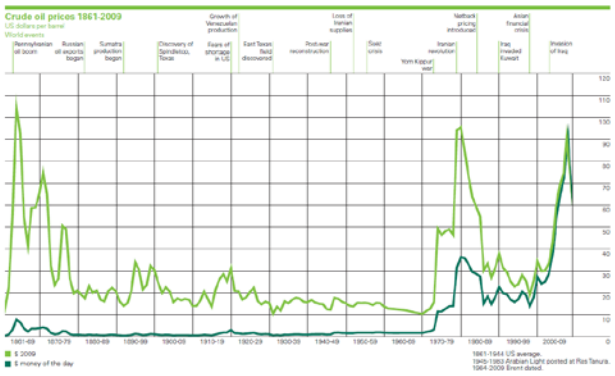


[a] E[MB] indicates expected marginal benefits, E[MC] indicates expected marginal costs, and MC_1 and MC_2 indicate alternative cost outcomes.

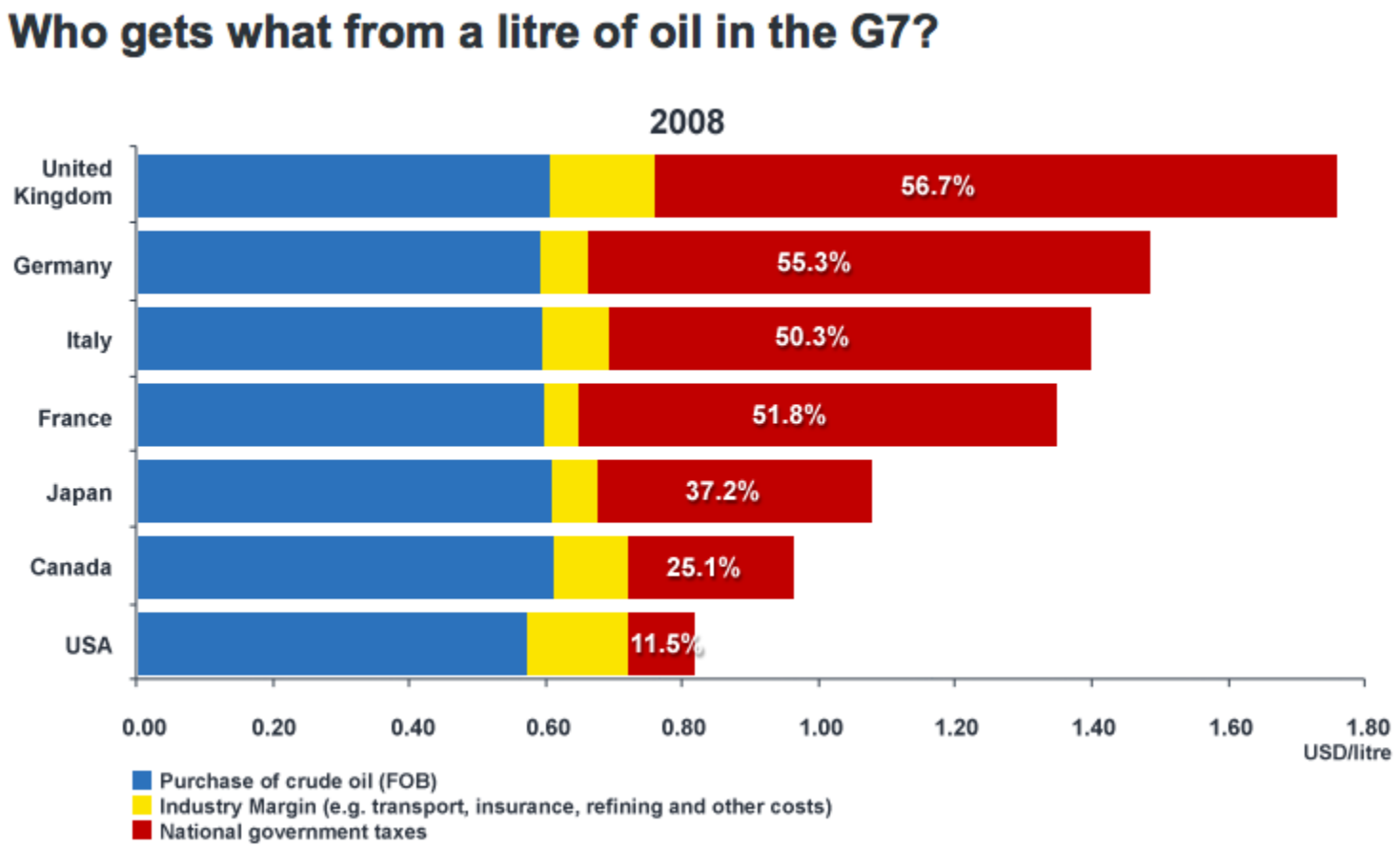
Figure taken from Pizer

This presentation

- Prices vs quantities in a **carbon rent contest**
- **Motivation**:
  Past – prices and taxes but recently:
  dominance of quantity strategies:
  demand - permits instead of taxes
  ETS, *Waxman-Markey* bill
  supply – OPEC quotas
- Topical (oil price volatility, permit price evolution)

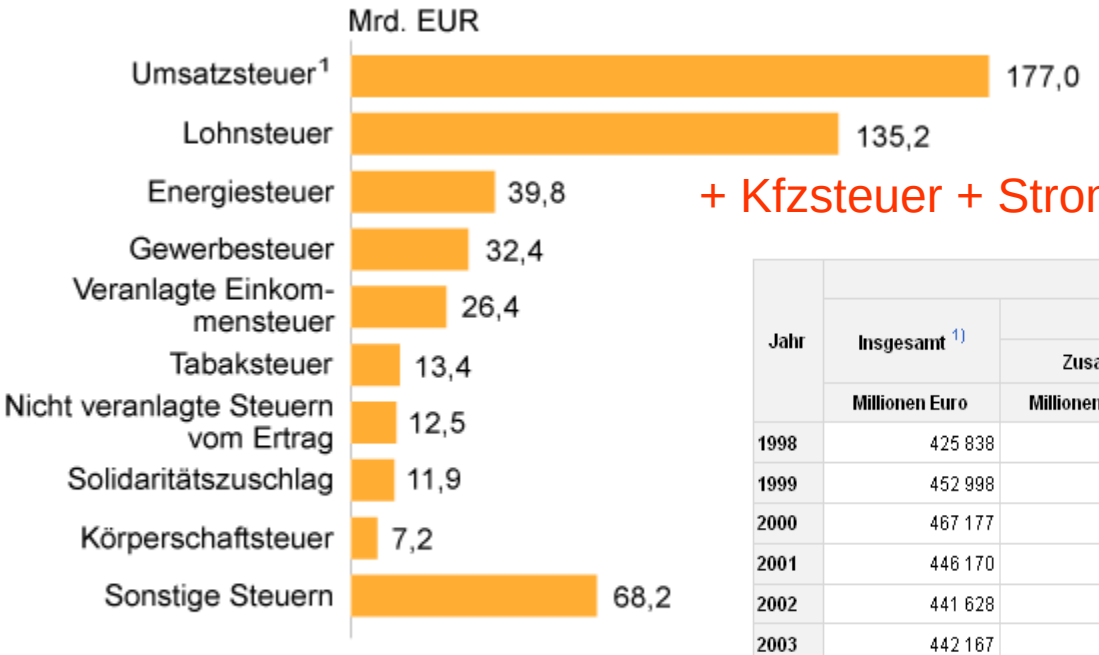


Demand side
Taxes vs *cap and trade*



Environmental Taxes are substantial

Steueraufkommen 2009 nach Steuerarten



Kassenmäßige Steuereinnahmen des Bundes, der Länder Gemeinden/Gv. nach Steuerarten vor der Verteilung.

[1] Einschließlich Einfuhrumsatzsteuer.

+ Kfzsteuer + Stromsteuer + Kfzsteuer = 10%

Jahr	Kassenmäßige Steuereinnahmen öffentlicher Haushalte					
	Insgesamt [1]	darunter: umweltbezogene Steuern				
		Zusammen [2]		Energiesteuer [3]	Kraftfahrzeugsteuer	Stromsteuer
	Millionen Euro	Millionen Euro	%	Millionen Euro	Millionen Euro	Millionen Euro
1998	425 838	41 848	9,8	34 091	7 757	–
1999	452 998	45 298	10,0	36 444	7 039	1 816
2000	467 177	48 197	10,3	37 826	7 015	3 356
2001	446 170	53 389	12,0	40 690	8 376	4 322
2002	441 628	54 882	12,4	42 193	7 592	5 097
2003	442 167	57 055	12,9	43 188	7 336	6 531
2004	442 761	56 118	12,7	41 782	7 739	6 597
2005	452 079	55 236	12,2	40 101	8 673	6 462
2006	488 444	55 126	11,3	39 916	8 937	6 273
2007	538 243	54 207	10,1	38 955	8 898	6 355
2008	561 182	54 350	9,7	39 248	8 842	6 261

[1] Ohne steuerähnliche Einnahmen und nach Abzug verteilungsrelevanter Positionen (Kindergeld, Erstattungen, Altersvorsorge).

[2] Abweichungen in den Summen durch Runden der Zahlen.

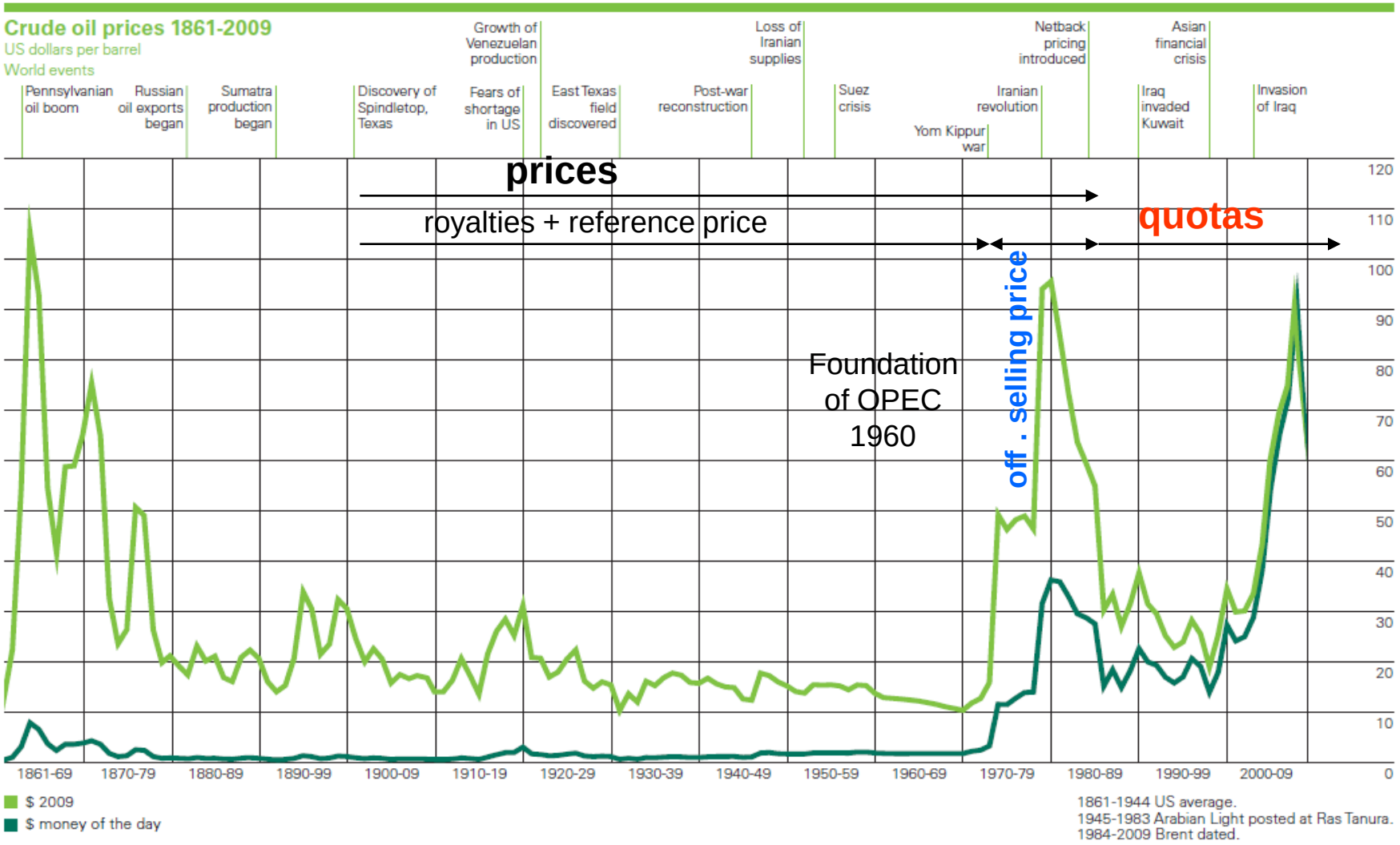
[3] Bis 2006 Mineralölsteuer.

Demand
Cap and trade vs taxes

EU: ETS

Obama: "My presidency will mark a new chapter in America's leadership on climate change that will strengthen our security and create millions of new jobs in the process"
"Our generation's response to this challenge will be judged by history, for if we fail to meet it - boldly, swiftly, and together - we risk consigning future generations to an irreversible catastrophe."
Yet **Waxman-Markey cap-and-trade bill is now dead.**

Supply:
OPEC: **Prices** and *quotas*



Rent Contests around Carbon Mitigation Policies

Consumers
q = quantity

$$U(q) = \left(q - \frac{q^2}{2}\right) - Pq, \qquad U' = 1 - q = P$$

Tax or permit price

$$P - p = \tau,$$

consumer price — producer price

Global Warming $\dot{X} = q, \; X(0) = 0.$

Supply Cartel $\max \int_0^\infty e^{-rt} p(t)\, q(t)\, dt.$

Consumer Governm.
IEA
'revenue neutral'

$$\max \int_0^\infty e^{-rt} \left[q(t) - \frac{q^2(t)}{2} - p(t)\, q(t) - C(X(t)) \right] dt$$

Equilibria

Asymmetric dynamic game, fortunately solveable via a meta-value function for:

- **Markov perfect Nash equilibria**
- and for allowing for short run commitments (on both sides)
- Nonlinear equilibria, if existing are Pareto-dominated by the linear ones.

	Monopoly (**M**) - price			Monopoly - quota		
Govnmt(**G**)	sim.	M - 1st	G – 1st	sim.	M - 1st	G – 1st
Tax						
Permits						

Price vs Tax
Sketch of solution

HJB-equations for the value functions V of monopoly and W of government

$$rV = \max_p \{(1-p-\tau)(p+V')\},$$
$$rW = \max_\tau \left\{ \frac{(1-p)^2}{2} - \frac{\tau^2}{2} - \frac{c}{2}X^2 + W'(1-q-\tau) \right\}$$

$$\Longrightarrow \quad p = \tfrac{1-V'+W'}{2}, \qquad \tau = -W'$$

$$\Longrightarrow P = p + \tau = \frac{1-(V'+W')}{2},$$

Preemption weak & strong

Pigouvian tax

$$rV = \frac{(1+(V'+W'))^2}{4},$$
$$rW = \frac{(1+(V'+W'))^2}{8} - \frac{c}{2}X^2.$$

$$rZ = \frac{3(1+Z')^2}{8} - \frac{c}{2}X^2, \quad Z := V + W,$$

Price vs Tax

Proposition 1: *The explicit solution of the strategies*

$$P = \frac{1-(z_1+z_2X)}{2} = 1+\frac{\left(r-\sqrt{r^2+3c}\right)}{3}\left(X-\frac{r}{c}\right), \quad (14)$$

$$p = \frac{r\left(r-\sqrt{r^2+3c}\right)-6c}{9r}\left(X-\frac{r}{c}\right) \quad (15)$$

$$\tau = 1+\frac{6c+2r\left(\sqrt{r^2+3c}-r\right)}{9r}\left(X-\frac{r}{c}\right) \quad (16)$$

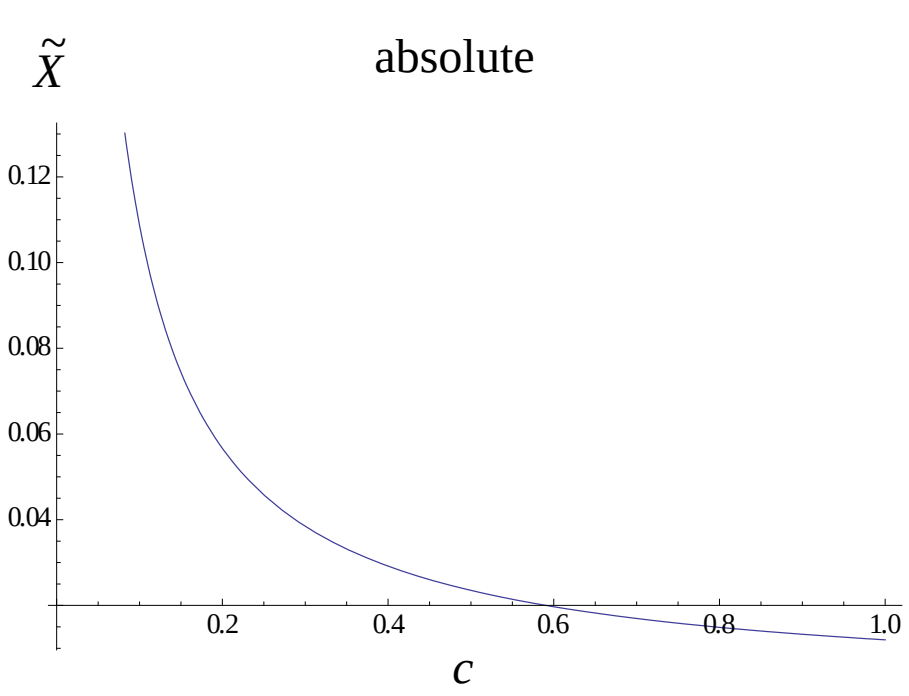
implies that consumer price and tax increase up to the choke price, P and $\tau \to 1$, *which is asymptotically reached at the steady state*[3],

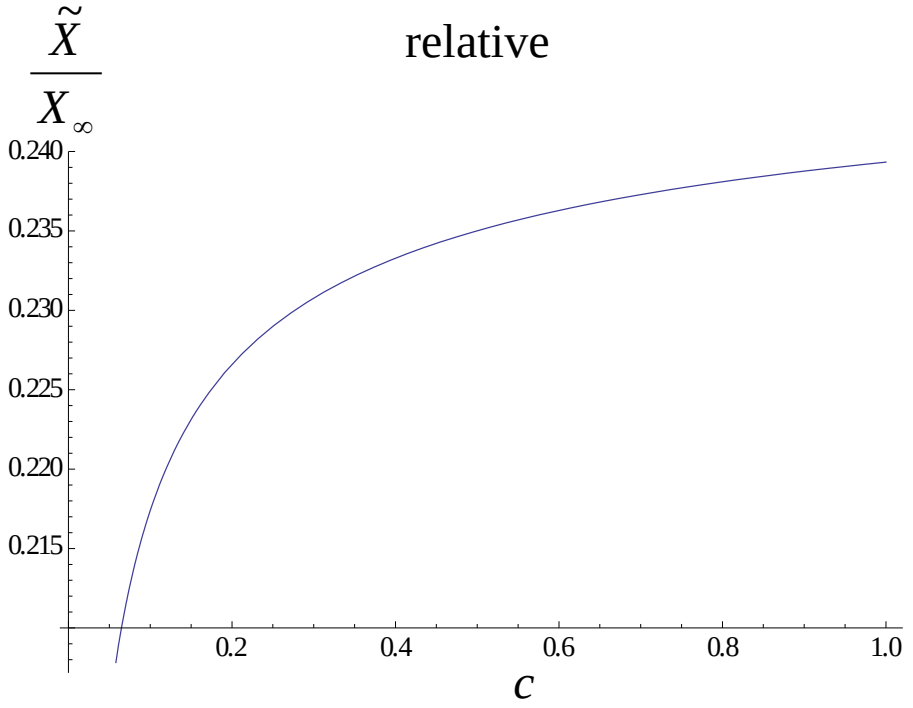
$$X_\infty = \frac{r}{c}. \quad (17)$$

Remarks:

1. Efficient stationary pollution level.
2. As in many DG there exist multiple equilibria in non-linear = non-singular strategies. In this case, they are Pareto dominated by the linear strategy.

(Strong) Preemption



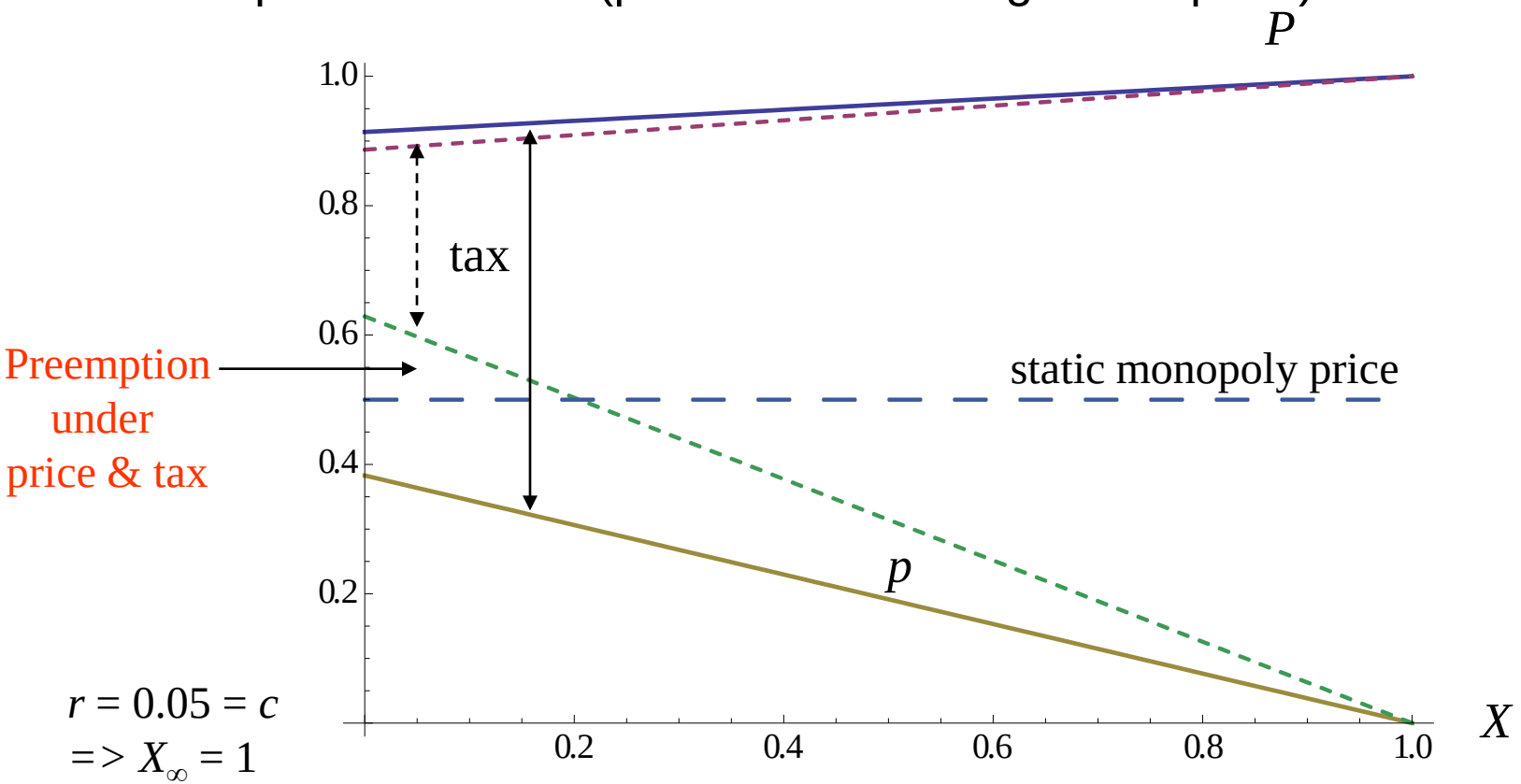


Preemption domain, absolute and relative (r = 0.05)

$$\tilde{X} = \frac{r^2 + \frac{3}{2}c - \sqrt{r^4 + 3r^2 c}}{r^2 + 6c - \sqrt{r^4 + 3r^2 c}} X_\infty$$

Tax versus Supply Quotas

- Same stationary pollution (17) and similar qualitative picture
- Identical to Price-Tax game & government commits (shortrun)
- No preemption
- Comparison of both (price/tax = dashing & tax/quota) outcomes

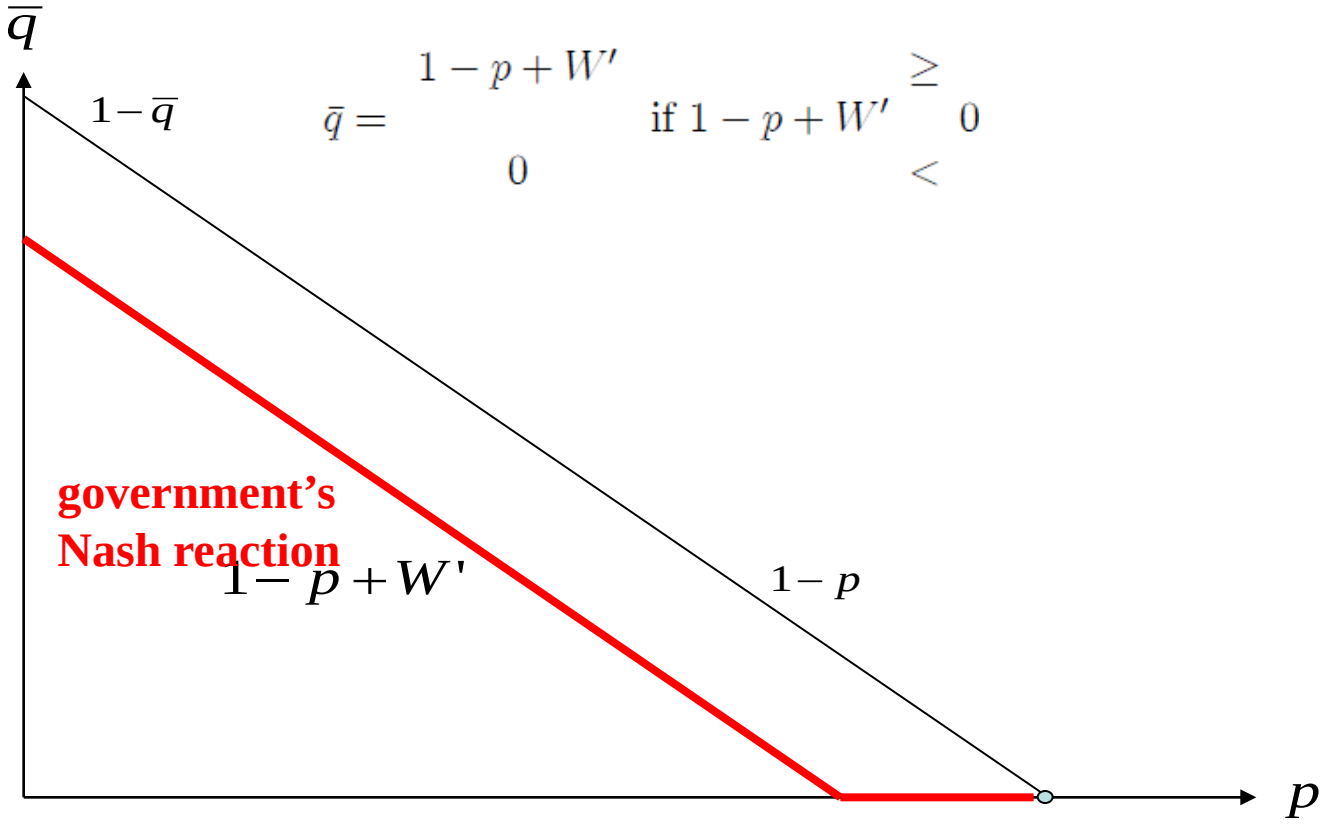


Permits vs Prices - Government

$$q = \min\{\bar{q}, 1-p\}$$

$$rW = \max_{0 \le \bar{q} \le 1-p} \left\{ q - \frac{q^2}{2} - pq - C(X) + W'q \right\}$$

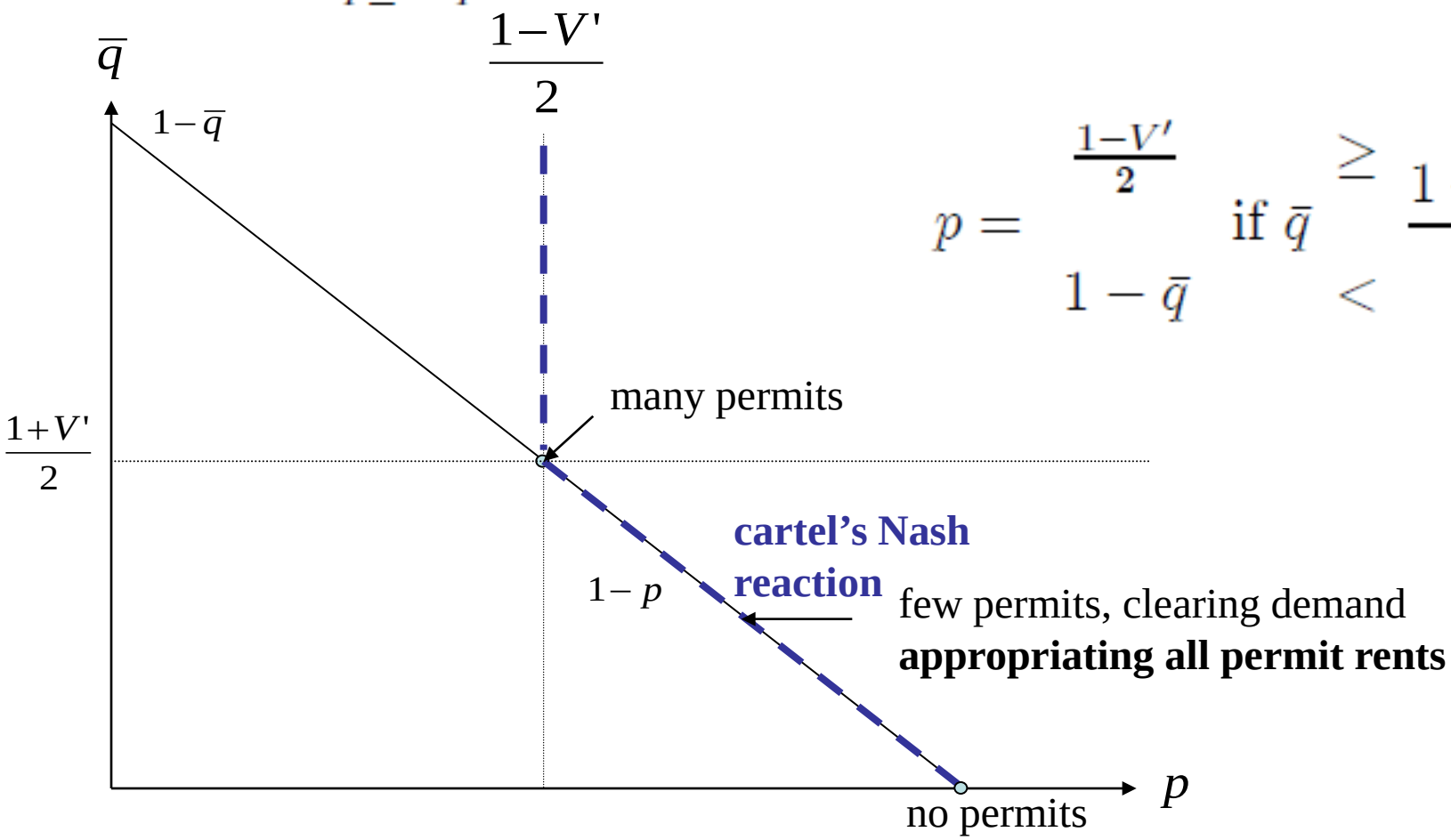
$$\bar{q} = \begin{cases} 1-p+W' & \text{if } 1-p+W' \geq 0 \\ 0 & \text{if } 1-p+W' < 0 \end{cases}$$



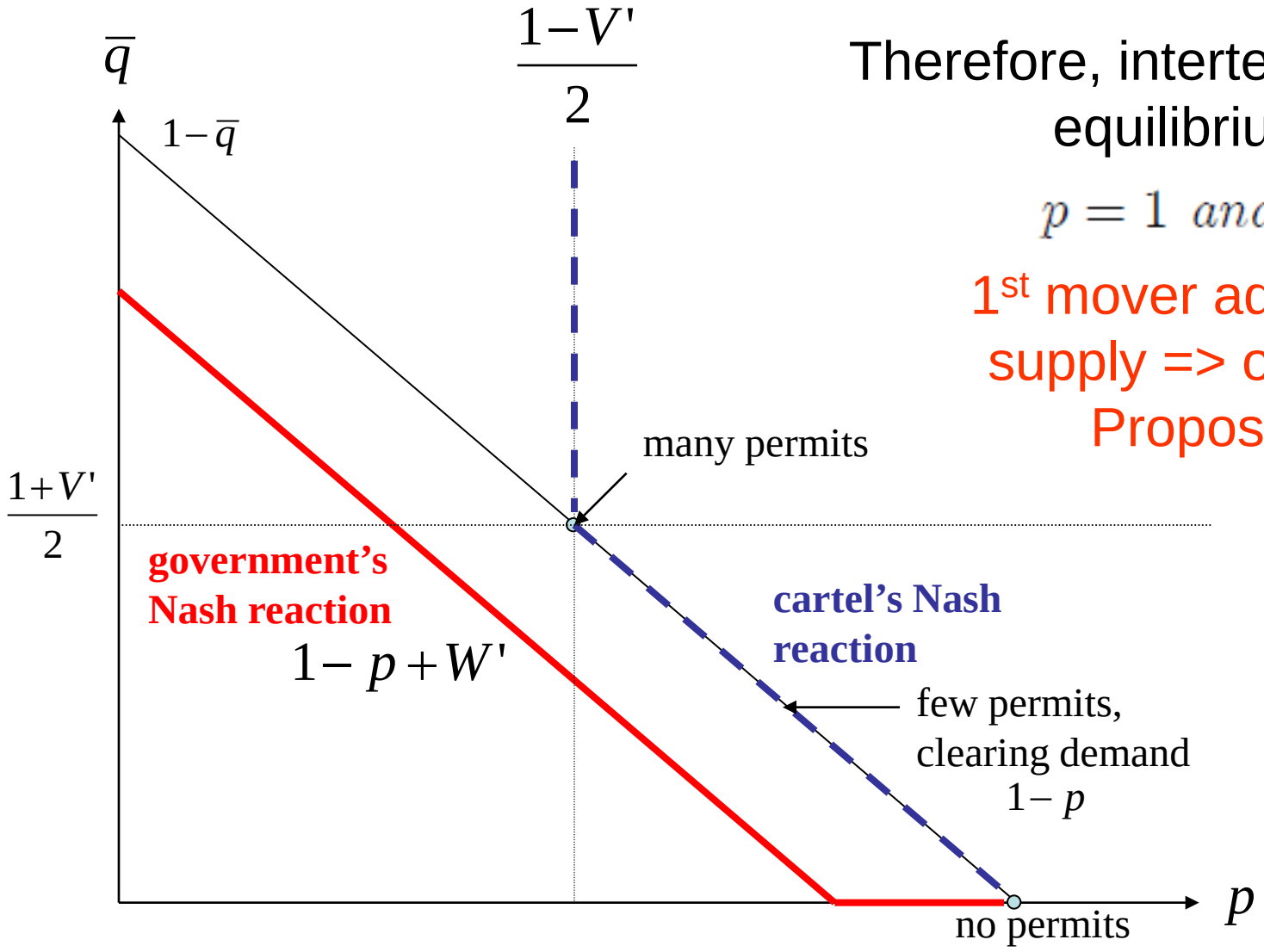
Permits vs Prices - Monopoly

$$
\begin{aligned}
rV &= \max_{p} \left\{ p \min\left\{\bar{q}, 1-p\right\} + V' \min\left\{\bar{q}, 1-p\right\} \right\} \\
&= \max_{p \geq 1-\bar{q}} \left\{ p\left(1-p\right) + V\left(1-p\right) \right\}.
\end{aligned}
$$

$$
p = \begin{cases} \frac{1-V'}{2} & \text{if } \bar{q} \geq \frac{1+V'}{2} \\ 1-\bar{q} & \text{if } \bar{q} < \frac{1+V'}{2} \end{cases}
$$



Permits vs Prices



Therefore, intertemporal **Nash** equilibrium is:

$$p = 1 \ and \ \bar{q} = 0,$$

1st mover advantage of supply => outcome of Proposition 1

Permits vs Prices
Government moves first

$$rW = \max_{0 \leq \bar{q} \leq \frac{1+V'}{2}} \left\{ \bar{q} - \frac{\bar{q}^2}{2} - p(\bar{q})\,\bar{q} - C + W'\bar{q} \right\}$$

$$rW = \max_{0 \leq \bar{q} \leq \frac{1+V'}{2}} \left\{ \frac{\bar{q}^2}{2} - C + W'\bar{q} \right\}$$

Convex objective!

⇓

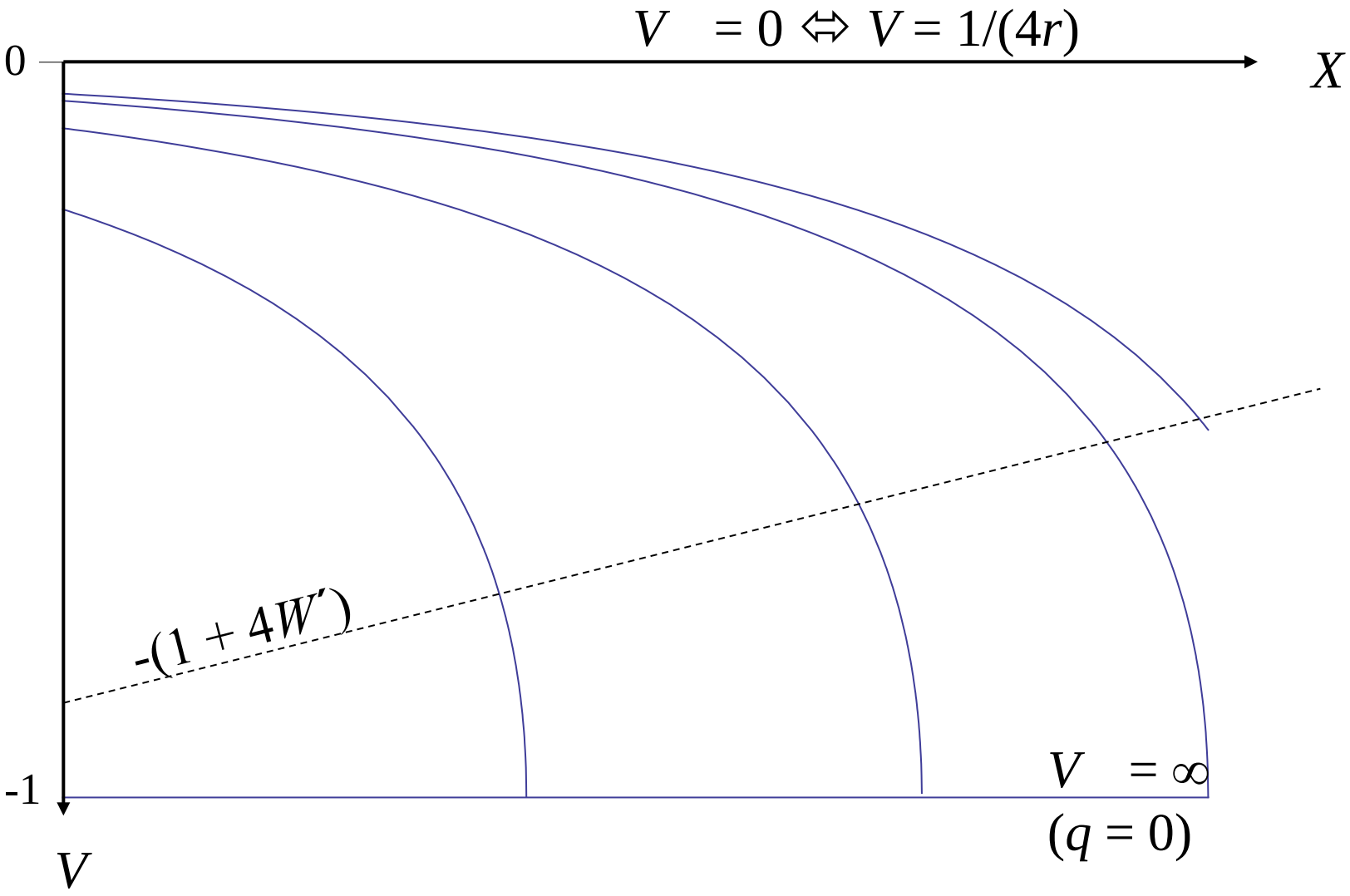
$$\bar{q} = \begin{cases} \frac{1+V'}{2} & \text{if } \frac{1+V'}{2} > -2W' \\ 0 & \text{if } \frac{1+V'}{2} \leq -2W' \end{cases}$$

Boundary solutions

Therefore, intertemporal equilibrium is again

$$p = 1 \text{ and } \bar{q} = 0,$$

because substituting upper bound does not satisfy all optimality conditions (in particular SP).



Phase digram for price setting cartel facing a permit issuing government, which can commit in the short run.

Permits vs Quotas

- Seems impossible because both parties cannot fix the quantity at the same time.
- However, each party may overwrite the other's choice in particular if one party moves first.

$$q = \min\{\bar{q}, Q\}$$

- Moreover, this is the game in town.

Permits vs Quotas
HJB equations

$$rW = \max_{\bar{q}} \left\{ q - \frac{q^2}{2} - (1-q)\, q - C + W' q \right\}$$

$$rV = \max_{Q} \left\{ (1-q)\, q + V' q \right\}$$

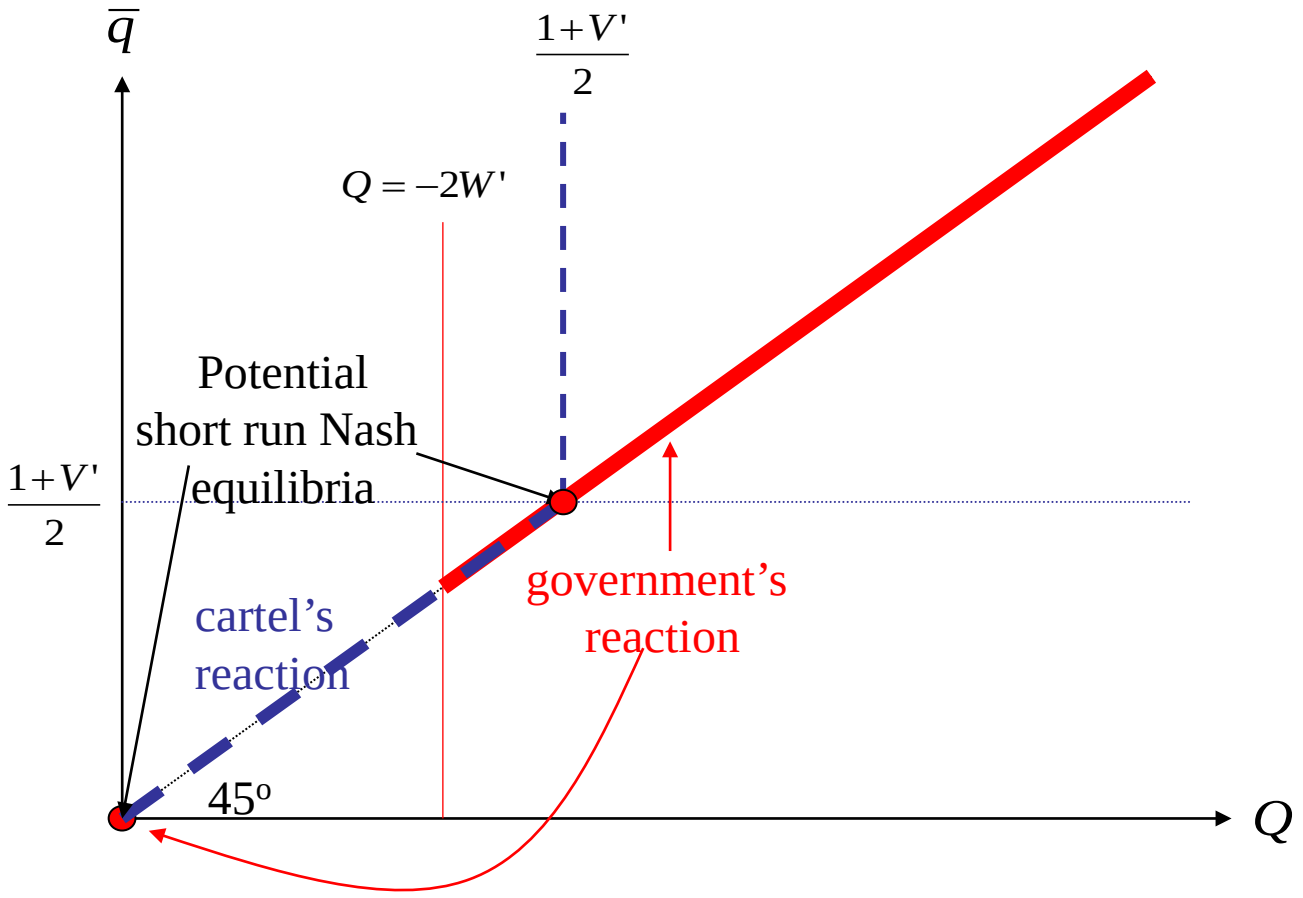
$$\begin{aligned} rW &= \max_{\bar{q} \leq Q} \left\{ \bar{q} - \frac{\bar{q}^2}{2} - (1-\bar{q})\, \bar{q} - C + W' \bar{q} \right\} \\ &= \max_{\bar{q} \leq Q} \left\{ \frac{\bar{q}^2}{2} - C(X) + W' \bar{q} \right\}. \end{aligned} \quad \Longrightarrow \quad \bar{q} = \begin{cases} Q & \geq \\ & \text{if } Q \\ 0 & < \end{cases} \quad -2W'$$

$$rV = \max_{Q \leq \bar{q}} \left\{ (1-Q)\, Q + V' Q \right\} \quad \Longrightarrow \quad Q = \begin{cases} \frac{1+V'}{2} & \geq \\ & \text{if } \bar{q} \\ \bar{q} & < \end{cases} \quad \frac{1+V'}{2}$$

Hence, $0 \leq \bar{q} \leq \frac{1+V'}{2}$

Thus for positive emissions: $Q = \frac{1+V'}{2} = \bar{q} > -2W'$.

Permits vs Quotas intraperiod reaction functions



Nash reactions of a permit issuing government and a quantity setting cartel depending on the shadow prices (*V*' and *W*').

Permits vs Quotas
Results

- There exists no Nash equilibrium in Markov strategies with positive emissions.

- This holds as well after allowing for first mover advantages (on either side).

Summary of Outcomes

	M - price			M - quota		
	sim	M 1^{st}	G 1^{st}	sim.	M 1^{st}	G 1^{st}
G - tax	$X \uparrow X^*$	$X \uparrow X^*$	$X \nearrow X^*$	$X = 0$	$X = 0$	$X \nearrow X^*$
G - quota	$X \uparrow X^*$	$X \uparrow X^*$	$X \nearrow X^*$	$X = 0$	$X = 0$	$X = 0$

M = monopoly, G = consumer government, sim = simultaneous moves
$\uparrow$ convergence, $\nearrow$ slower convergence due to higher consumer price P,
$X^* = 1^{st}$ best.

Summary

- Objective: investigate strategic implications of price and quantity instruments in a strategic game about carbon emissions and fossil fuel supply with both sides being monopolized
- Quantities are bad choices for both parties (albeit for different reasons). Hence **prices and taxes are the natural choices** in this strategic setup.
- Surprisingly, today's players seem to prefer quantity strategies with consumer governments eschewing carbon taxes and issuing permits and with OPEC announcing quantities.
- Explanations – future research
  politics,
  oligo… rather than mono… ,
  restriction to Markov strategies.

Thank You for Your attention!