Time of Use Pricing and Electricity Demand Transfer: A Long Run Analysis of Capacity and Prices

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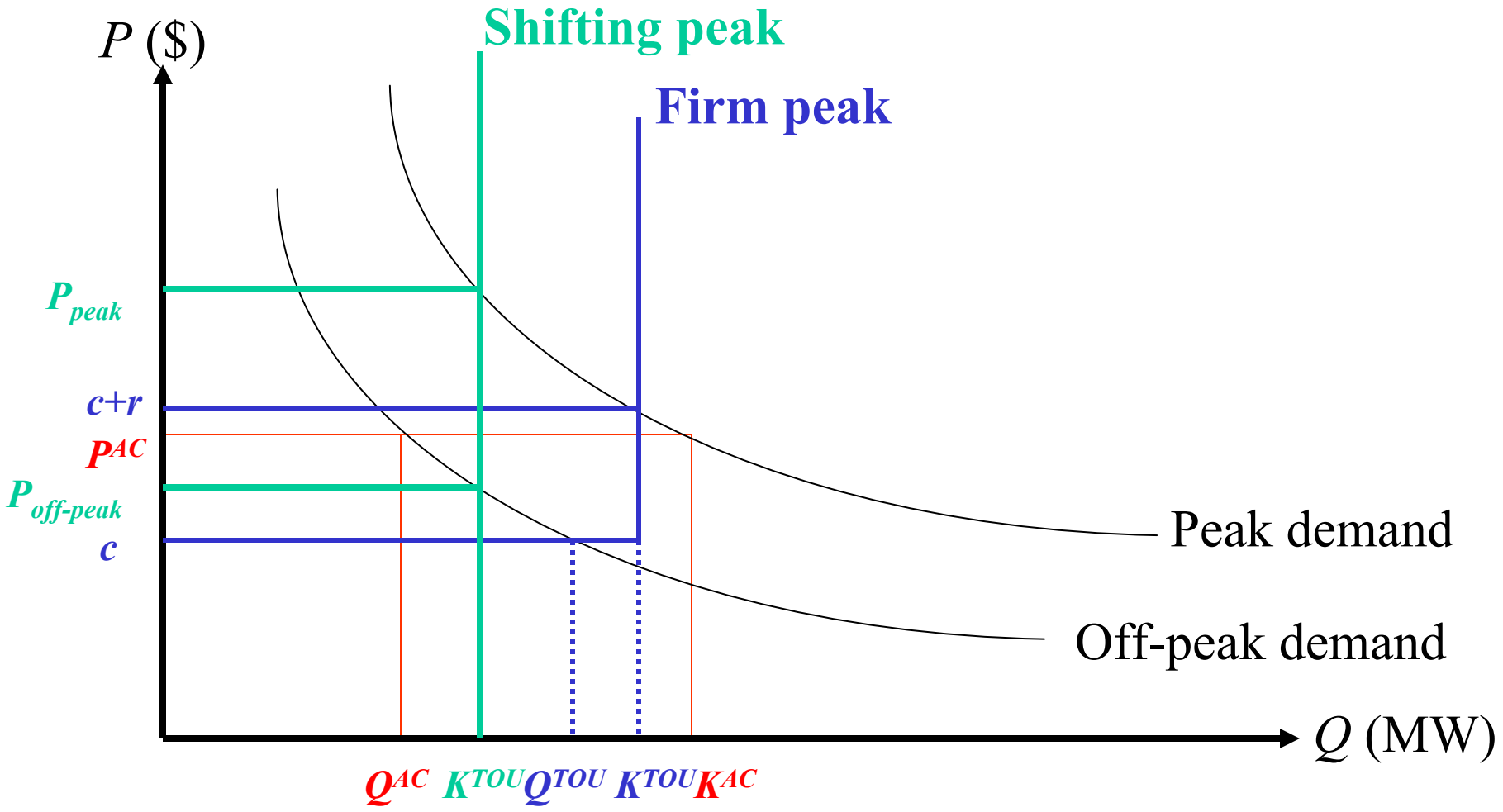
Plan

1. Introduction & Model
2. Analytical Results
3. Numerical Application: Ontario (Canada)
   - Capacity reduction
   - Prices
   - Energy consumption & Technologies

1. Introduction & Model



1. Introduction & Model

1. When do we get a firm or a shifting peak?
2. What are the **capacity**, **price** and **energy consumption** changes?
3. How do different price **elasticities** influence the results?
4. What about **cross-price** elasticities? (transfer of demand from peak to off-peak periods)

1. Introduction & Model

- 2 time periods: peak (ω) and off-peak
- 1 technology: c = variable cost
  r = fixed cost
- Demand functions:

Off-peak (Low) period $Q_L = aP_L^{\,b}$

Peak (High) period $Q_H = aZP_H^{\,\alpha b}$

a and Z : parameters scaling demand

b : price elasticity

$0 < \alpha < 1$: parameter adjusting elasticity (peak)

2. Analytical Results

- ACP conditions

Revenue constraint $(P\text{-}c)[(1\text{-}\omega)Q_L+\omega Q_H]=rQ_H$

$Q_H=K$

- TOU conditions: Firm peak

$P_L=c;\ P_H=c+r/\omega;\ Q_H=K$

Revenue constraint $(P_L\text{-}c)(1\text{-}\omega)Q_L+(P_H\text{-}c)\omega Q_H=rQ_H$

- TOU conditions: Shifting peak

$Q_L=Q_H=K$

Revenue constraint $(P_L\text{-}c)(1\text{-}\omega)+(P_H\text{-}c)\omega=r$

2. Analytical Results

- ACP solution

$$(P\text{-}c)[P^{b(1-\alpha)}(1-\omega)+\omega Z]=rZ$$

- TOU solution: Firm peak

$$P_L=c$$

$$P_H=c+r/\omega$$

- TOU conditions: Shifting peak

$$P_L=Z^{1/b}P_H^{\alpha}$$

$$(1-\omega)Z^{1/b}P_H^{\alpha}+\omega P_H=c+r$$

2. Analytical Results

Firm peak or Shifting peak?

Firm peak means $Q_H > Q_L$. This is true when

$$r < \omega\left[\left(\frac{c}{Z^{\frac{1}{b}}}\right)^{\frac{1}{\alpha}} - c\right]$$

Or alternatively

$$Z > \left(\frac{c}{\left(c + \frac{r}{\omega}\right)^{\alpha}}\right)^{b}$$

2. Analytical Results

Transfer of demand

- Demand functions:

Peak (High) period

$$Q'_H = aZP_H^{\alpha b} - \gamma aZP_H^{\alpha b}$$

$$= (1-\gamma)aZP_H^{\alpha b}$$

Off-peak (Low) period

$$Q'_L = aP_L^{b} + \gamma aZP_H^{\alpha b}$$

$0 < \gamma < 1$: exogenous parameter representing the percentage of demand transferred from the peak to the off-peak period

2. Analytical Results

Firm peak or Shifting peak?

Firm peak means $Q'_H > Q'_L$. This is true when

$$r < \omega\left[\left(\frac{c^b}{Z(1-2\gamma)}\right)^{\frac{1}{\alpha b}} - c\right]$$

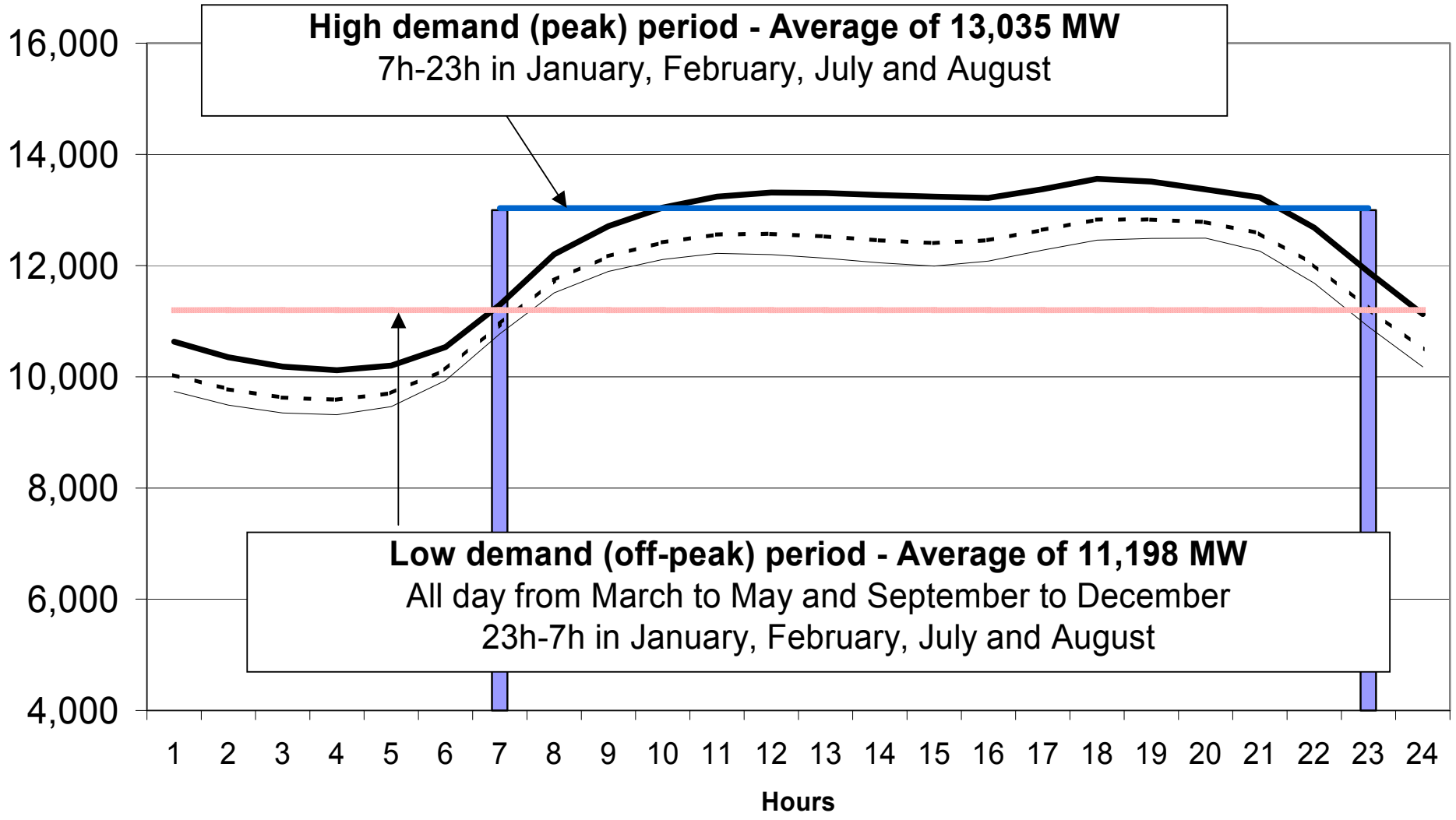
or $Z > \dfrac{c^b}{\left(c+\dfrac{r}{\omega}\right)^{\alpha b}(1-2\gamma)}$ or $\gamma < \dfrac{Z\left(c+\dfrac{r}{\omega}\right)^{\alpha b} - c^b}{2Z\left(c+\dfrac{r}{\omega}\right)^{\alpha b}}$

2. Analytical Results

- **Result 2.** It can be shown that a Firm peak is **less likely** when there is transfer of demand.
- **Result 3.** $P_H=P_L=c+r$ when

$$\gamma = \frac{Z-\left(c+r\right)^{b\left(1-\alpha\right)}}{2Z}$$

3. Numerical Results:Ontario



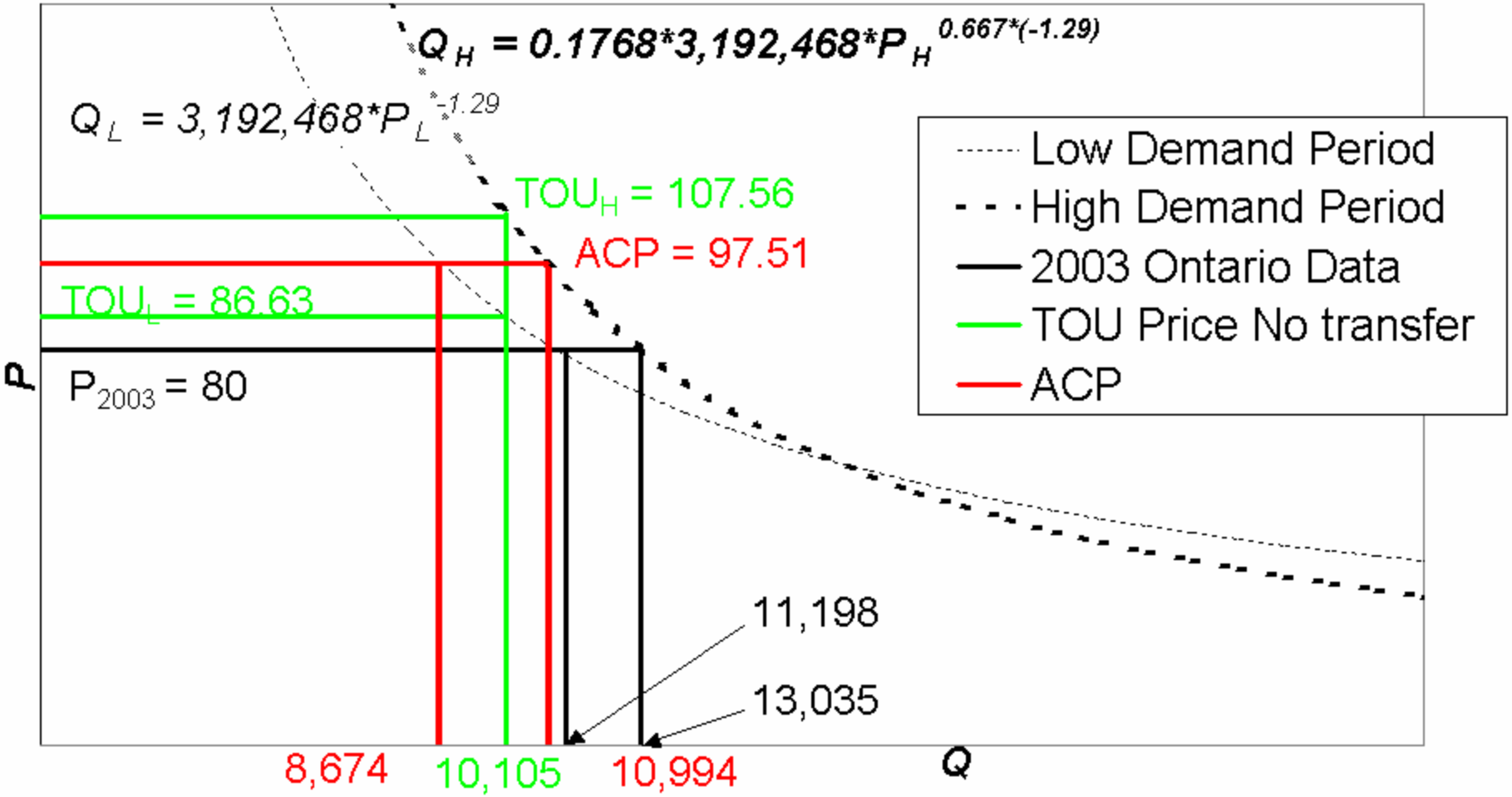
3. Numerical Results:Ontario

- Nuclear: c=22.80+37=59.80/MWh

  r=31.56/MW (per hour)
- Na.Gas: c=53.59+37=90.59/MWh

  r=9.15/MW (per hour)
- b=-1.29 α=0.667
- Z=0.17 a=3,192,468 ω=0.22
- γ=0.05 equal prices for γ=0.094 (nuclear) and γ=0.109 (natural gas)

3. Numerical Results:Ontario



3. Numerical Results:Ontario

	Average Cost Pricing		
	1 Nuc	2 Gas	3 =inelas
Capacity MW	10,994	10,607	11,945
P_L	97	101	95
P_H	97	101	95
Total Energy TWh	80	76	93

	TOU Pricing % of change		
	1 Nuc	2 Gas	3 =inelas
Capacity MW	-8.09	-13.79	-8.90
P_L	-11.16	-7.93	-11.06
P_H	10.30	18.84	20.51
Total Energy TWh	10.00	4.54	2.33

3. Numerical Results:Ontario

	Average Cost Pricing			**TOU Pricing** (% of change) **with transfer**		
	1 Nuc	2 Gas	3 =inelas	1 Nuc	2 Gas	3 =inelas
Capacity MW	10,994	10,607	11,945	-6.33	-12.23	-6.41
P_L	97	101	95	-8.71	-5.32	-6.11
P_H	97	101	95	1.66	9.64	3.06
Total Energy TWh	80	76	93	12.10	6.43	5.12

3. Numerical Results:Ontario

	TOU Pricing **% of change**			**TOU Pricing** (% of change) **with transfer**		
	1 Nuc	2 Gas	3 =inelas	1 Nuc	2 Gas	3 =inelas
Capacity MW	-8.09	-13.79	-8.90	-6.33	-12.23	-6.41
P_L	-11.16	-7.93	-11.06	-8.71	-5.32	-6.11
P_H	10.30	18.84	20.51	1.66	9.64	3.06
Total Energy TWh	10.00	4.54	2.33	12.10	6.43	5.12

Summary

Analytical results

- **Result 2**. With transfer of demand, full capacity is used in all periods under less stringent conditions.
- **Result 3**. There is a specific level of transfer for which prices will be equal with TOU pricing.

Numerical results

- With transfer of demand, the **reduction in capacity** is limited.
- With transfer of demand, the **increase in consumption** is even greater.
- **Technology** has a tremendous impact on capacity, prices and energy consumption.
- **Elasticity** and **transfer of demand** are very important factors.

Conclusion

TOU pricing (and real time pricing) have perverse effects, that create other problems:

higher prices in some periods & **overall increase in consumption**

The dilemmas that electricity policy creates are far from being easily solved.