Ramsey Pricing and Fixed Cost Recovery

Numerical Problem with Welfare Analysis

This problem walks you through a numerical example of alternative methods for recovering fixed costs when serving different types of consumers. Be sure that you've read Borenstein (2016) and the relevant section of Viscusi, Henderson and Vernon Chapter 12 for a theoretical treatment of this topic.

Problem Setup

A regulated electric utility serves two customer groups with the following demand curves:

- **Residential Customers:**
  - Demand: $Q_R = 6 - 10P$ (where Q is in MWh per month, P is in \$/kWh)
  - Inverse demand: $P = 0.6 - 0.1Q_R$
- **Industrial Customers:**
  - Demand: $Q_I = 8 - 20P$ (where Q is in MWh per month)
  - Inverse demand: $P = 0.4 - 0.05Q_I$

Cost Structure:

- Short-run marginal cost (SMC) = \$0.08 per kWh
- Total fixed costs = \$800,000 per month

1. **Price Elasticity of Demand**

   Calculate the price elasticity of demand for each customer group at the efficient price ($P = MC = \$0.08$/kWh). Use the formula:

$$\varepsilon = \frac{dQ}{dP} \times \frac{P}{Q}$$

   Evaluated at $P = \$0.08$/kWh and the corresponding quantities.

   Which group has more elastic demand?

   Solution: Residential Customers:

   From $Q_R = 6 - 10P$, we get $\frac{dQ_R}{dP} = -10$

   At $P = \$0.08$: $Q_R = 6 - 10(0.08) = 5.2$ MWh

$$\varepsilon_R = -10 \times \frac{0.08}{5.2} = -10 \times 0.0154 = -0.154$$

   Industrial Customers:

From $Q_I = 8 - 20P$, we get $\frac{dQ_I}{dP} = -20$

At $P = \$0.08$: $Q_I = 8 - 20(0.08) = 6.4$ MWh

$$\varepsilon_I = -20 \times \frac{0.08}{6.4} = -20 \times 0.0125 = -0.25$$

Answer:

- Residential elasticity: $\varepsilon_R = -0.154$
- Industrial elasticity: $\varepsilon_I = -0.25$
- **Industrial customers have more elastic demand** ($|\varepsilon_I| = 0.25 > |\varepsilon_R| = 0.154$)

Economic interpretation: Industrial customers are more price-sensitive. A 1% increase in price causes industrial quantity demanded to fall by 0.25%, but residential quantity to fall by only 0.154%. This likely reflects industrial customers' ability to relocate, substitute other energy sources, or adjust production processes more easily than residential customers can adjust household consumption.

2. **Baseline Efficient Pricing Analysis**

First, establish the baseline scenario where price equals marginal cost ($P = \$0.08$/kWh).

(a) Calculate the quantity consumed by each customer group.

(b) Calculate consumer surplus for each group using the formula: $CS = \frac{1}{2} \times (\text{Maximum WTP} - \text{Price}) \times \text{Quantity}$

(c) Calculate the utility's profit (or loss), accounting for both variable costs and fixed costs.

(d) Calculate total welfare (Consumer Surplus + Producer Surplus).

Solution: (a) Quantities at $P = \$0.08$:

Residential: $Q_R = 6 - 10(0.08) = 5.2$ MWh

Industrial: $Q_I = 8 - 20(0.08) = 6.4$ MWh

Total Quantity: $5.2 + 6.4 = 11.6$ MWh

(b) Consumer Surplus:

Residential Customers:

- Maximum willingness to pay (price intercept): \$0.60/kWh
- $CS_R = \frac{1}{2} \times (0.60 - 0.08) \times 5.2 = \frac{1}{2} \times 0.52 \times 5.2 = \$1.352$ million

Industrial Customers:

- Maximum willingness to pay: \$0.40/kWh
- $CS_I = \frac{1}{2} \times (0.40 - 0.08) \times 6.4 = \frac{1}{2} \times 0.32 \times 6.4 = \$1.024$ million

Total Consumer Surplus = \$1.352M + \$1.024M = **\$2.376 million**

(c) Utility Profit:

- Revenue = $\$0.08 \times 11.6$ MWh = \$0.928 million
- Variable Cost = $\$0.08 \times 11.6$ MWh = \$0.928 million
- Fixed Cost = \$0.800 million
- **Producer Surplus (Profit)** = \$0.928M −\$0.928M −\$0.800M = −\$0.800 **million**

The utility faces a **revenue shortfall of \$800,000** when pricing at marginal cost.

(d) Total Welfare:

Total Welfare = Consumer Surplus + Producer Surplus

Total Welfare = \$2.376M + (−\$0.800M) = **\$1.576 million**

This represents the maximum possible welfare achievable. Any pricing above marginal cost will reduce total welfare by creating deadweight loss.

(12) 3. **Uniform Pricing Analysis**

To recover the \$800,000 fixed cost shortfall, the regulator considers charging both customer groups the same price above marginal cost. Suppose the regulator sets a uniform price of $P = \$0.23$**/kWh** for both customer groups.

(a) Calculate the quantities consumed by each group at this price.

(b) Calculate the new consumer surplus for each group.

(c) Calculate the utility's profit under this pricing scheme.

(d) Calculate total welfare and deadweight loss compared to efficient pricing.

Solution:

(a) Quantities under Uniform Pricing ($P = \$0.23$):

Residential: $Q_R = 6 - 10(0.23) =$ **3.7** MWh

- Change: $\Delta Q_R = 3.7 - 5.2 = -1.5$ MWh

Industrial: $Q_I = 8 - 20(0.23) =$ **3.4** MWh

- Change: $\Delta Q_I = 3.4 - 6.4 = -3.0$ MWh

Total Quantity: $3.7 + 3.4 = 7.1$ MWh

(b) Consumer Surplus under Uniform Pricing:

Residential:

$CS_R = \frac{1}{2} \times (0.60 - 0.23) \times 3.7 = \frac{1}{2} \times 0.37 \times 3.7 = \$0.685$ million

- Loss in CS = \$1.352M −\$0.685M = **\$0.667 million**

Industrial:

$CS_I = \frac{1}{2} \times (0.40 - 0.23) \times 3.4 = \frac{1}{2} \times 0.17 \times 3.4 = \$0.289$ million

- Loss in CS = \$1.024M −\$0.289M = **\$0.735 million**

Total Consumer Surplus = \$0.685M + \$0.289M = **\$0.974 million**

(c) Utility Profit:

- Revenue = $\$0.23 \times 7.1 = \$1.633$ million
- Variable Cost = $\$0.08 \times 7.1 = \$0.568$ million
- Fixed Cost = \$0.800 million
- **Producer Surplus** = \$1.633M −\$0.568M −\$0.800M = **\$0.265 million**

(d) Total Welfare and Deadweight Loss:

Total Welfare (uniform) = \$0.974M + \$0.265M = **\$1.239 million**

Deadweight Loss = Efficient Welfare − Uniform Pricing Welfare

DWL = \$1.576M −\$1.239M = **\$0.337 million**

This deadweight loss represents the value destroyed by pricing above marginal cost—transactions that would have created value but don't occur because of the higher price.

(15) 4. **Ramsey Pricing Analysis**

Now consider **Ramsey pricing**, which sets different prices for each group to minimize deadweight loss while still recovering fixed costs. The Ramsey pricing rule states that markups over marginal cost should be inversely proportional to demand elasticities:

$$\frac{P_i - MC}{P_i} = \frac{k}{|\varepsilon_i|}$$

This means groups with less elastic (more inelastic) demand should face higher markups.

Suppose the regulator implements the following Ramsey pricing scheme:

- Residential price: $P_R = \$0.20$/kWh (markup of \$0.12 over MC)

- Industrial price: $P_I = \$0.14$/kWh (markup of \$0.06 over MC)

(a) Calculate the quantities demanded by each group under Ramsey pricing.

(b) Verify that this pricing scheme generates approximately \$800,000 in additional revenue above variable costs.

(c) Calculate consumer surplus for each group under Ramsey pricing.

(d) Calculate the utility's profit.

(e) Calculate total welfare and deadweight loss.

(f) Compare the deadweight loss under Ramsey pricing to uniform pricing. Explain intuitively why Ramsey pricing is more efficient.

Solution: (a) Quantities under Ramsey Pricing:

Residential ($P_R = \$0.20$):

$Q_R = 6 - 10(0.20) = \mathbf{4.0}$ MWh

Industrial ($P_I = \$0.14$):

$Q_I = 8 - 20(0.14) = \mathbf{5.2}$ MWh

Total Quantity $= 4.0 + 5.2 = 9.2$ MWh

(b) Revenue Verification:

Residential contribution:

- Additional revenue above variable cost $= (P_R - MC) \times Q_R = (0.20 - 0.08) \times 4.0 =$ \$0.480 million

Industrial contribution:

- Additional revenue above variable cost $= (P_I - MC) \times Q_I = (0.14 - 0.08) \times 5.2 =$ \$0.312 million

Total additional revenue = \$0.480M + \$0.312M = \$0.792 million ≈ \$0.800M ✓

(The small shortfall of \$8,000 is close enough for our analysis—this could be made up with tiny price adjustments.)

(c) Consumer Surplus under Ramsey Pricing:

Residential:

$CS_R = \frac{1}{2} \times (0.60 - 0.20) \times 4.0 = \frac{1}{2} \times 0.40 \times 4.0 = \$0.800$ million

- Loss in CS from efficient pricing = \$1.352M −\$0.800M = **\$0.552 million**

Industrial:

$CS_I = \frac{1}{2} \times (0.40 - 0.14) \times 5.2 = \frac{1}{2} \times 0.26 \times 5.2 = \$0.676$ million

- Loss in CS from efficient pricing = \$1.024M −\$0.676M = **\$0.348 million**

Total Consumer Surplus = \$0.800M + \$0.676M = **\$1.476 million**

(d) Utility Profit:

- Total Revenue = $(0.20 \times 4.0) + (0.14 \times 5.2)$ = \$0.800M + \$0.728M = \$1.528 million
- Variable Cost = 0.08×9.2 = \$0.736 million
- Fixed Cost = \$0.800 million
- **Producer Surplus** = \$1.528M −\$0.736M −\$0.800M = −\$0.008 million ≈ \$0

(Essentially breaks even, as intended.)

(e) Total Welfare and Deadweight Loss:

Total Welfare (Ramsey) = \$1.476M + \$0 = **\$1.476 million**

Deadweight Loss = \$1.576M −\$1.476M = **\$0.100 million**

(f) Comparison and Economic Intuition:

Metric	**Efficient**	**Uniform**	**Ramsey**
Residential Price	\$0.08	\$0.23	\$0.20
Industrial Price	\$0.08	\$0.23	\$0.14
Residential Q (MWh)	5.2	3.7	4.0
Industrial Q (MWh)	6.4	3.4	5.2
Total CS	\$2.376M	\$0.974M	\$1.476M
Producer Surplus	−\$0.800M	\$0.265M	∼ \$0
Total Welfare	\$1.576M	\$1.239M	\$1.476M
Deadweight Loss	\$0	**\$0.337M**	**\$0.100M**

Key Findings:

1. **Ramsey pricing generates 70% less deadweight loss than uniform pricing** (\$0.100M vs \$0.337M)
2. **Ramsey pricing preserves \$237,000 more in total welfare** compared to uniform pricing (\$1.476M vs \$1.239M)
3. **The less elastic group (Residential, $\varepsilon = -0.154$) faces a higher markup** (\$0.12) than the more elastic group (Industrial, $\varepsilon = -0.25$, with markup \$0.06)

Economic Intuition:

DWL from taxation is the social value of net beneficial consumption that was not realized due to the tax. So it is proportional to the decline in quantity consumed.

In this example, industrial consumers are more elastic than residential consumers. Thus, a given price increase causes a larger quantity reduction for industrial customers than for residential customers, and therefore a larger deadweight loss.

Ramsey pricing minimizes deadweight loss by charging more elastic consumers lower prices.

This is mathematically optimal but raises significant **equity concerns**: Why should residential customers (who may have lower incomes and fewer alternatives) subsidize industrial customers through higher prices?