Econ 366 – Energy Economics

Fall 2012

Industrial Energy Demand

Microeconomic Analysis of Industrial Energy Demand

- As with households, industrial energy demand is a "derived demand"
- Firms purchase energy as one of many inputs into the production process:
  - K (capital)
  - L (labour)
  - E (energy)
  - M (materials)
    - KLEM
    - Which inputs can be changed in the short run? In the long run?

Possible Firm Goals

- Profit Maximization: Find the profit-maximizing level of output and the optimal amounts of the various inputs needed to produce this output level given prices (of output and inputs)
- Cost Minimization: Given a selected output level, find the least cost way of producing this amount
  - "dual" to the profit maximization problem
  - Easier to solve than the profit maximization problem

Production Functions and Isoquants

- Production Function: Summarizes the available technologies of the firm by showing the level of output that can be produced from a given set of inputs.
  - $Q = f(K, L, E, M)$
  - Simple textbook example with 2 inputs:
    - $Q = 10\, K^{0.5}\, E^{0.5}$

- Isoquant: provides the combinations of inputs that produce a given level of output
  - i.e., we set Q equal to a selected value and find the various combinations of K and E that yield this value

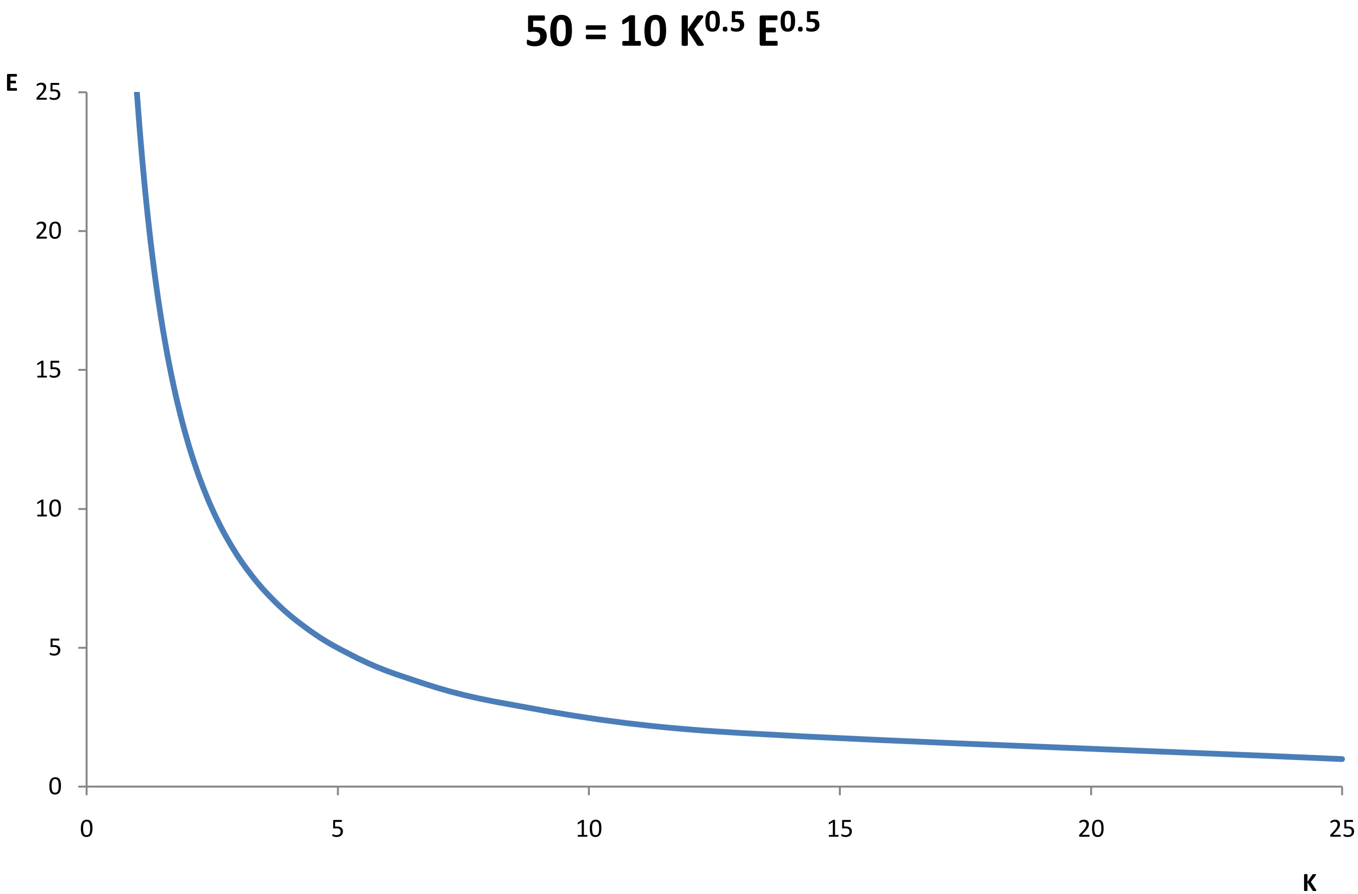
Isoquant Input Combinations for Q = 50

$$50 = 10\ K^{0.5}\ E^{0.5}$$

Energy (E)	Capital (K)	Output (Q)
1	25	50
4	6.25	50
5	5	50
8	3.125	50
10	2.5	50
16	1.5625	50
20	1.25	50
25	1	50

Isoquant for Q = 50

(Slope = Marginal Rate of Technical Substitution)



Marginal Rate of Technical Substitution

- Along an isoquant, Q remains constant ($\Delta Q = 0$).
- As we move along the isoquant, E falls and K increases.
- The fall in E leads to a drop in output. The size of this drop depends on the marginal product of energy ($\Delta E \times MP_E$)
- The increase in K leads to an increase in output. This increase depends on the marginal product of capital ($\Delta K \times MP_K$)
- The slope of the isoquant ,$\Delta E / \Delta K$, will be equal to $-(MP_K / MP_E)$

Production Costs

- $TC = P_K*K + P_E*E + [w*L + P_M*M]$
- Total costs consist of the amount paid for capital plus the amount paid for energy [plus the amounts paid for labour and materials]
- Isocost line: provides the combinations of inputs that can be purchased for a given level of expenditure
  - For example, if $P_K = P_E = \$1$, the combinations of K and E that can be purchased for $40 are given by:

    $$40 = 1 \times K + 1 \times E$$

    (What is the slope of this isocost line?)

Cost Minimizing Behaviour

- We want to find the combination of capital and energy inputs that minimize the costs of producing 50 units of output, for example.
- This will occur when the isoquant is tangent to an isocost line. (Why?)

Solution to this problem (assuming entire budget is spent):

Mathematical Result

$$\frac{MP_E}{P_E} = \frac{MP_K}{P_K}$$

Interpretation

- marginal productivities per dollar spent on each input must be equal
- otherwise, the firm can decrease costs (and thereby increase profits) by re-allocating their expenditures on capital and energy

Suppose Equality does not hold:

Costs NOT maximized

$$\frac{MP_E}{P_E} > \frac{MP_K}{P_K}$$

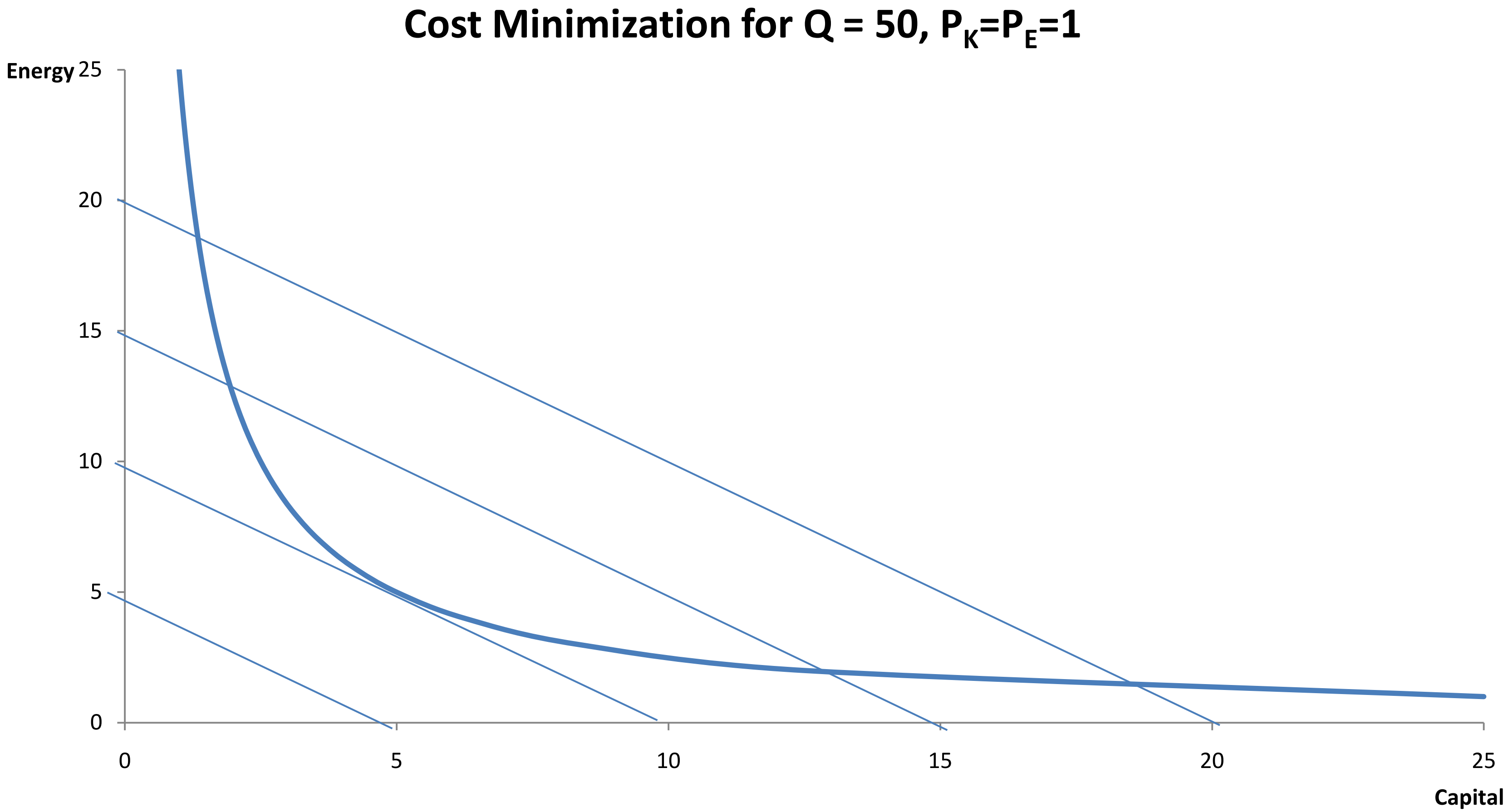
$$for\ example,$$

$$10 \quad > \quad 5$$

Interpretation

- additional output per dollar spent on energy exceeds the additional output per dollar spent on capital
- should use more energy and less capital
- leads to an decrease in costs (and therefore an increase in profits)

Cost Minimizing Input Combination



Cost Minimizing Production of 50 units of output at $P_K = P_E = 1$

Energy	Capital	Output	Cost
1	25	50	26
4	6.25	50	10.25
5	5	50	10
8	3.125	50	11.125
10	2.5	50	12.5
16	1.5625	50	17.5625

Tracing out a demand relationship:

Deriving a Demand Schedule

$$\frac{MP_E}{P_{E0}} = \frac{MP_K}{P_K}$$

decrease price of energy

from P_{E0} *to* $P_{E1} \rightarrow$

$$\frac{MP_{E1}}{P_{E1}} > \frac{MP_K}{P_K}$$

(*at original input quantities*)

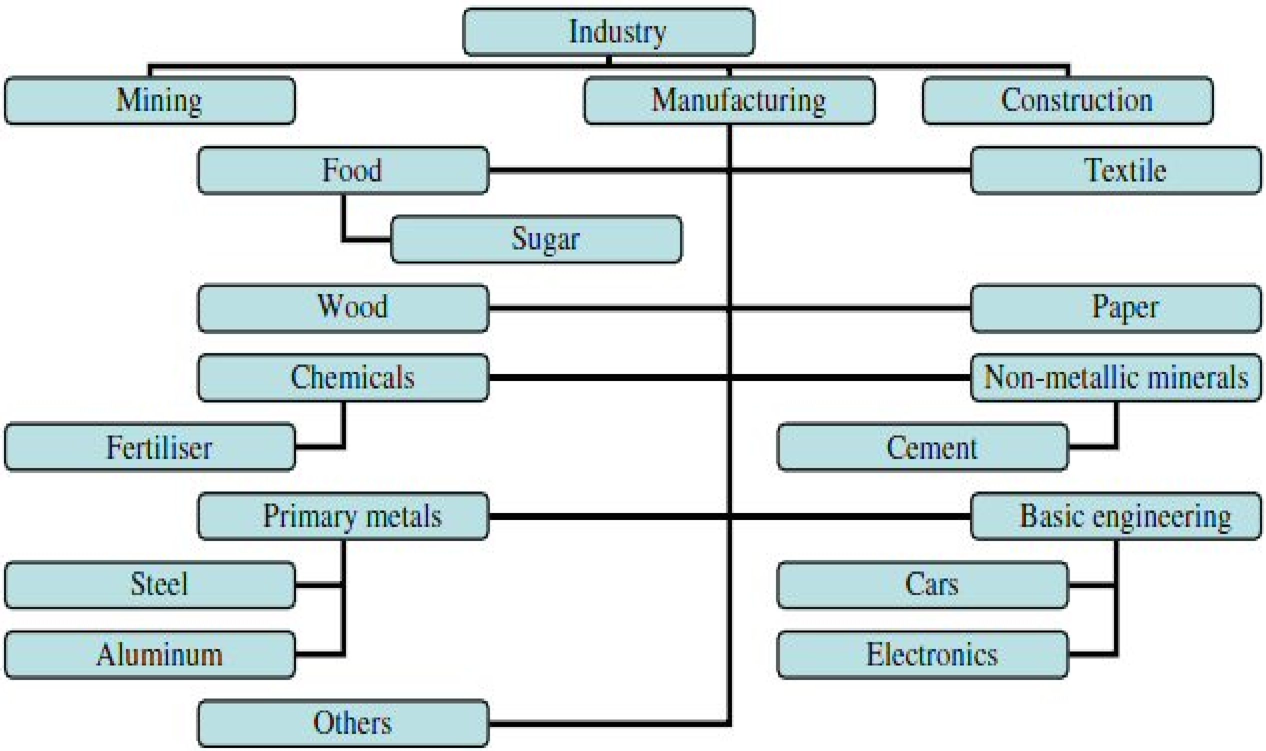
Method

- start in equilibrium and decrease (or increase) the price of energy (or output or the price of capital)
- results in a new situation where the firm is no longer minimizing costs
- figure out how input quantities should be re-adjusted
- (example on board in class)

Deriving the Demand Curve (continued)

- Once we have done this for several values of P_E , we can trace out the demand curve for one particular firm
- To 'aggregate' up to the demand curve for energy in the entire industrial sector, we need to add up over all firms.

Figure 4.1 : a possible breakdown of the industrial sector



General Breakdown Used in Canada

- Construction
- Pulp and Paper
- Smelting and Refining
- Petroleum Refining
- Cement
- Chemicals
- Iron and Steel
- Other Manufacturing
- Forestry
- Mining
- http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tablestrends2/agg_ca_3_e_4.cfm?attr=0

Diversity of Industrial Sector

- Technological options (including the ways in which capital and energy can be substituted) vary greatly across industries (steel making, pulp and paper, oil refining, chemicals, food, etc.)
- Some industries are more energy-intensive → energy costs a more significant portion of costs
- Some industries, such as oil sands mining, both use and sell energy → price changes affect both costs and revenues
- Policies may need to be industry-specific

Steel (see Box 4.3 in textbook)

- Many available technologies: blast furnaces (coal), direct reduction (natural gas), smelting reduction, electric arc furnaces (electricity)
- All are energy intensive processes, but older blast furnace technologies tend to use energy less efficiently

Other Energy-Intense Industries (Box 4.4)

- Cement – dry process requires less energy than wet process; economies of scale can be exploited: larger furnaces result in less energy used per tonne of cement produced.
- Aluminum – electricity intense production
- Chemicals – some activities are highly energy intensive. Chlorine and caustic soda production about 3x as energy intensive as ‘average’ in chemical industry; ammonia-based fertilizers 4x as intense as chemical industry average

Industrial Demand and Policy

- Usually aimed at encouraging the adoption of less energy-intensive processes. Scope of possibilities for lower energy intensity tends to be industry-specific.
- Carbon taxes used in some jurisdictions in order to elicit price-based responses
- Some Canadian policies:
  - Financial assistance available through ecoEnergy Retrofit program; R&D partnership programs through CanmetEnergy; investment tax credits for R&D through SR&ED (Scientific Research & Experimental Development) Program