Lecture #41

ERDM

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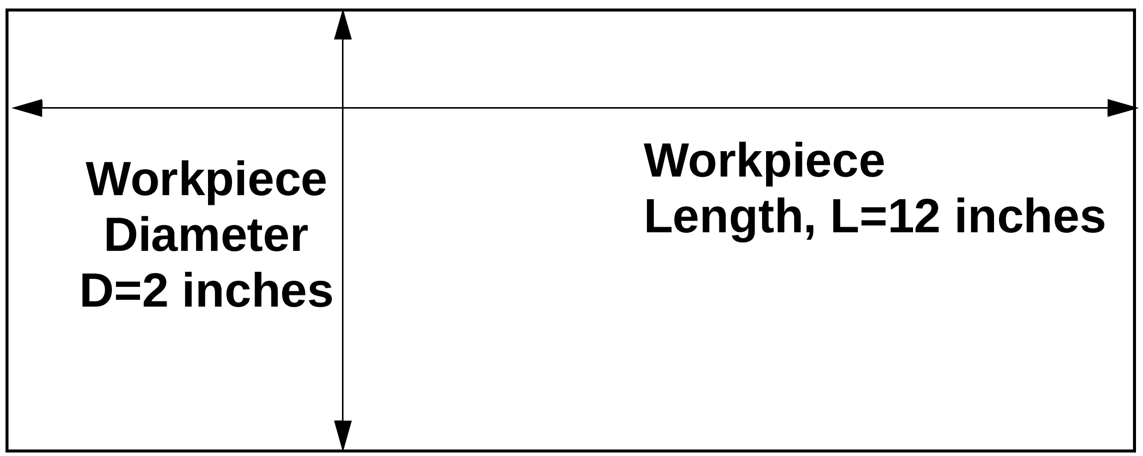
Simple Process Selection Example

Desire to reduce the diameter of a cylindrical aluminum workpiece from 2 to 1.9 inches.



Compare the energy consumed by two processes (turning and forming) to achieve this.

Turning

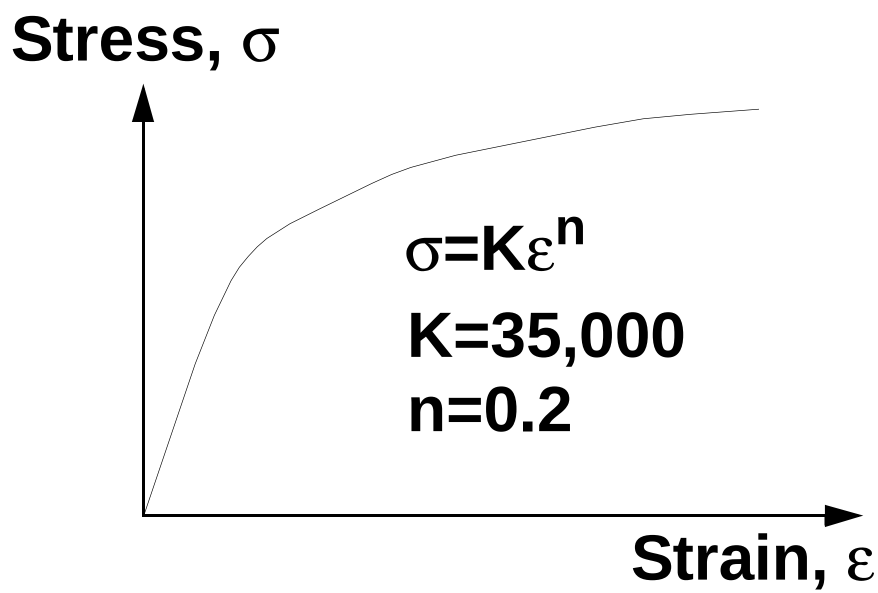
- **Specific cutting energy = 200,000 in lb/in^3**
- **Depth of cut = d = 0.050 inch**
- **Volume of material removed in the operation:**

$$Volume = \pi DdL$$

Volume removed = 3.77 in^3

- **Energy = 754,000 in lb**

Forming



$$\varepsilon_{rad} = \ln\left(\frac{1.9}{2}\right) = -0.0513$$

Longitudinal Strain = 0.1026

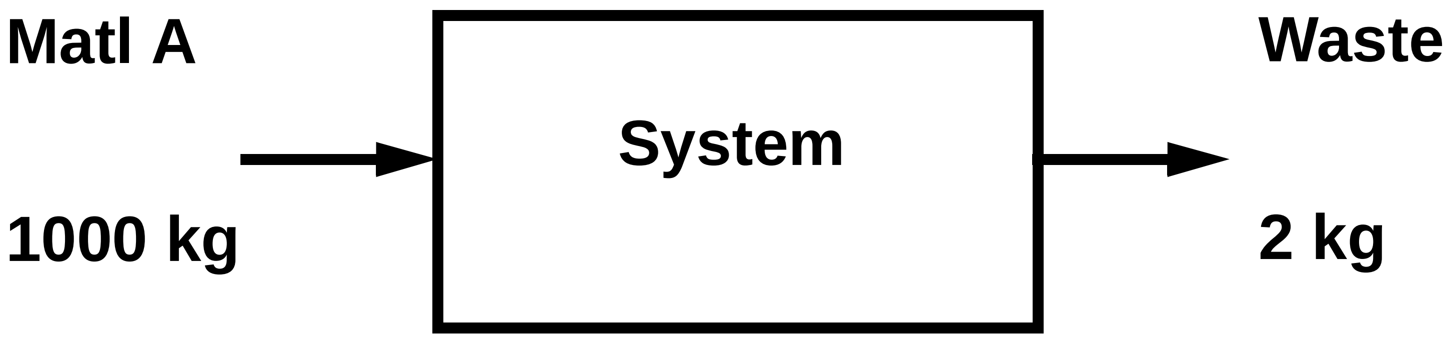
$$\frac{Deformation\ Energy}{Unit\ Volume} = \frac{K\varepsilon^{n+1}}{n+1}$$

- **Deformation energy/unit volume = 1,898 in lb/in^3**
- **Volume of workpiece = 37.699 in^3**
- **Energy = 71,547 in lb (about 10% of cutting energy)**

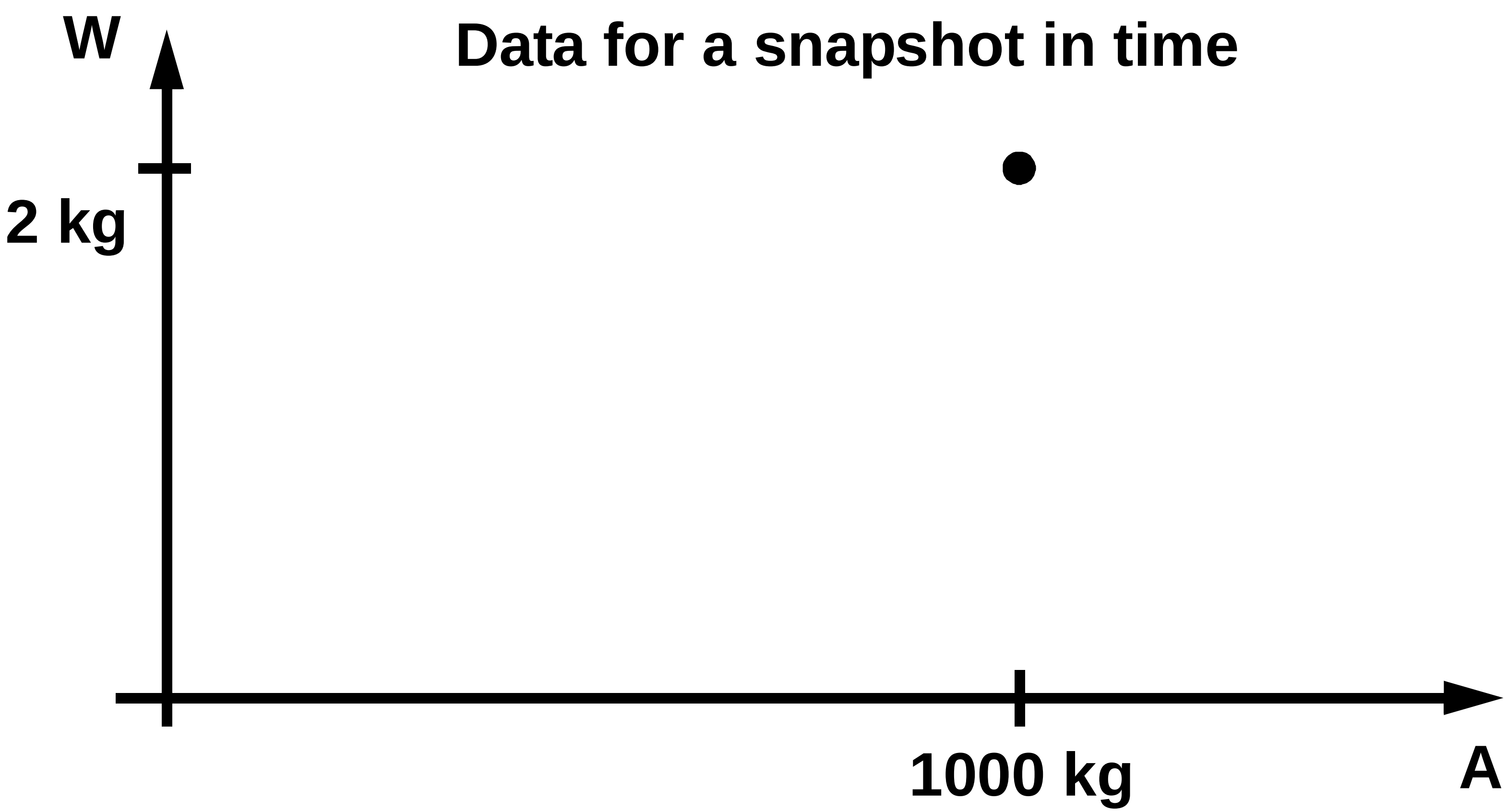
So, Forming is better than Turning from an Energy standpoint. Of course, energy is only one factor that must be considered.

EIO-LCA

- **EIO-LCA (Economic Input/Output - Life Cycle Assessment)**
- **Input / Output Analysis??**



Simple Input - Output Analysis



Input - Output Model

We have one data point. Let's assume that for no raw material input we have no waste. That will give us a second data point.

Create a line that relates the input and output

$$W = b_0 + b_1 * A$$

Slope = (2 - 0) / (1000 - 0) = 0.002
Intercept is zero -- since line passes through origin.

$$W = 0.002 * A$$

Using the Input - Output Model

- **What happens if input increases by 20% to 1200 kg?**
  W = 0.002 * 1200 = 2.4kg

- **To reduce waste to 1.0 kg??**
  W = 1.0 = 0.002 * A
  A = 500 kg

Economic Input-Output Models

- **Wassily Leontief received Nobel prize (1973) for work in this area**
- **An I/O table was used to study the effects of technological change on the American economy -- defense analyses during WW II**
- **Used an analytical tool by:**

  BEA - Bureau of Economic Analysis
  SNA - System of National Accounts- the international guidelines for economic accounts

What are I-O models?

- Used to capture inter-industry/system transactions.
- Industries use the products of other industries to produce their own products
  e.g. - Automobile manufacturers rely on products from chemical, metal, electronics, tire, etc. industries
- Outputs from one industry become inputs to another industry
- When you buy a car, the demand for steel, glass, plastic, etc. is affected.

Basic Idea

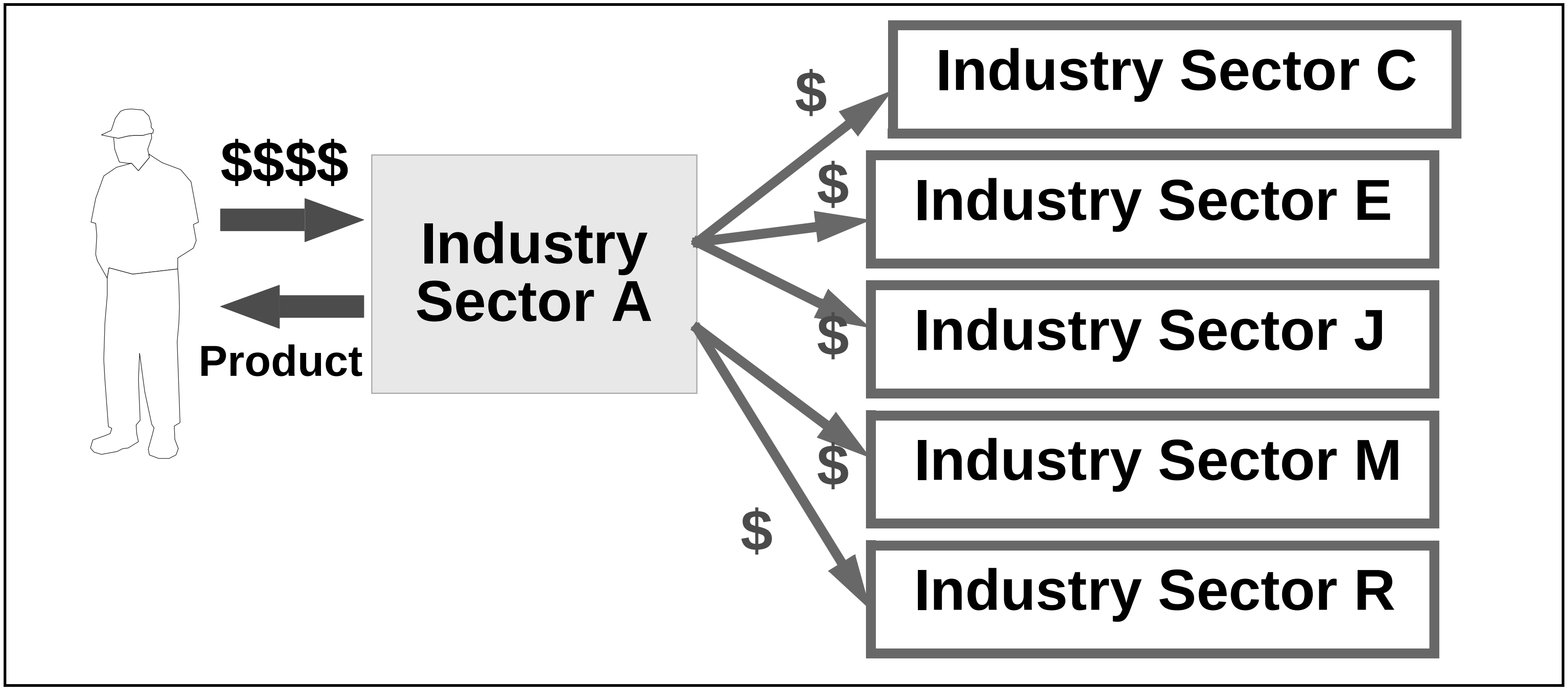
- When I buy a car for $20k, Ford doesn't get to keep all the money.

- Where does the money go??

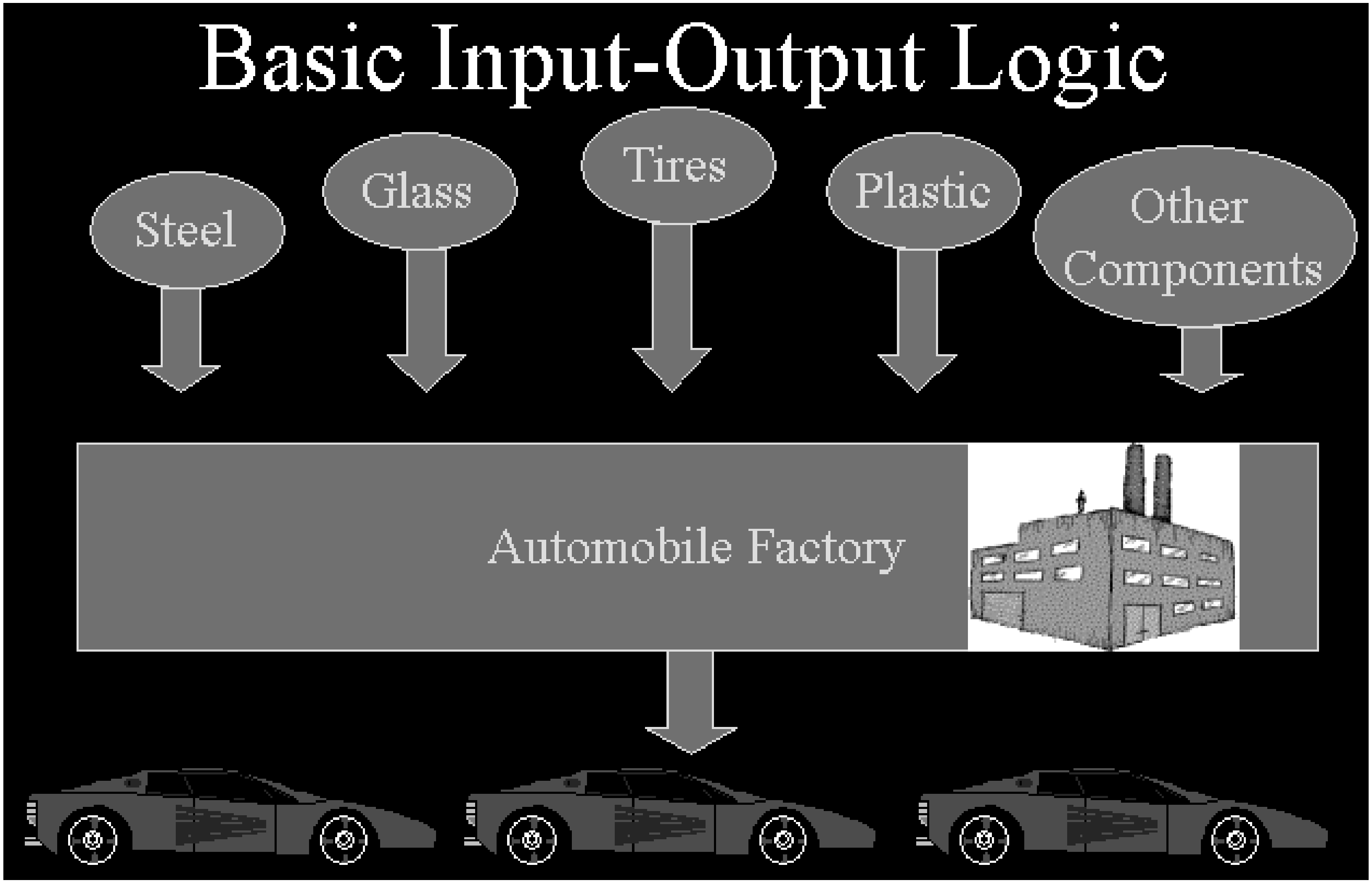
Visteon -- $4000
Lear -- $3000
Goodyear? -- $400
Quaker State -- $100
Detroit Edison -- $1000
and so forth

- Visteon doesn't get to keep all the $4000 either!

More on Basic Idea



A $1000 purchase results in way more than $1000 in total activity. Where to invest to get best total impact?


Basic Input-Output Logic
Steel
Glass
Tires
Plastic
Other Components
Automobile Factory

Assumptions

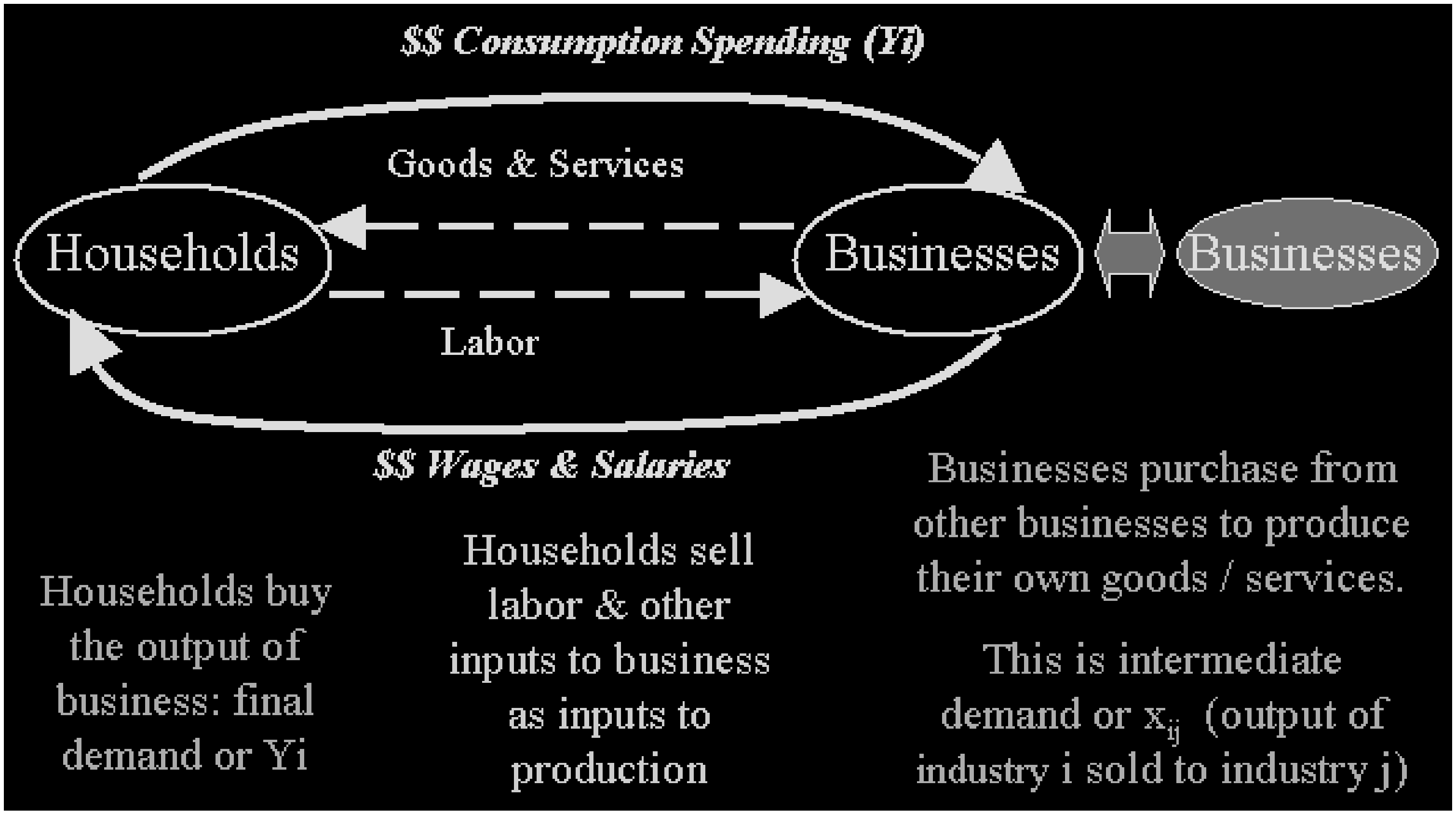
- **The economy/system is divided into *n* sectors [sectors - individuals, companies, nations,etc.]**
- **Each sector produces exactly one output**
- **One non-product - Labor**
- **Constant returns to scale [To increase output by ‘A’, scale input by ‘A’]**
- **No choice of production techniques [No substitution possible between inputs]**

Temporal Distinctions of I-O models

- **Static - Snap-shot of a system in motion. Represents phenomena at a single interval of time**
- **Comparative Static - Succession of snap-shots. Compares phenomena at several instances of time**
- **Dynamic - relation of a frame to the succeeding frame. Shows how phenomena within an interval are related to activities outside the interval**
- **Comparative Dynamic - comparison of two segments of motion picture**

Economic I-O Analysis

Method to systematically quantify the interrelationships among various sectors of an economic system.



Model Formulation

X_i : **Entire output of industry sector i -- in $$$$**

$$X_i = Z_{i1} + Z_{i2} + Z_{i3} + \ldots + Y_i$$

$$X_i = \Sigma Z_{ij} + Y_i$$

Z_{ij} : **Output of industry sector i sold to industry sector j**

Y_i : **Final demand for sector i's products (other than inter-industry exchanges) -- Govt., export, etc.**

Inter-industry Demand

$$Z_{ij} = a_{ij} \cdot X_j$$

Z_{ij} : **Output of sector i sold to sector j**

X_j : **Output of sector j**

a_{ij} : **Input-output coefficient ($0 < a_{ij} < 1$)**

$$X_i = a_{i1} \cdot X_1 + a_{i2} \cdot X_2 + a_{i3} \cdot X_3 + \ldots + Y_i$$

$$X_i = \Sigma a_{ij} \cdot X_j + Y_i \quad \textbf{or} \quad X_i - \Sigma a_{ij} \cdot X_j = Y_i$$

Matrix Form

In matrix form the complete n x n system is:

$(\mathbf{I} - A)X = Y$, where, A - matrix of input output coefficients

If $|\mathbf{I} - A|$ is not equal to zero, $(\mathbf{I} - A)^{-1}$ can be determined.

Therefore, $X = (\mathbf{I} - A)^{-1} Y$

Here $(\mathbf{I} - A)^{-1}$ is known as the LEONTIEF INVERSE.

Example

Consider two hypothetical sectors

		To Processing Sectors		Final Demand	Total Output
		1	2	(Y_i)	(X_i)
From Processing Sectors	1	150	500	350	1000
	2	200	100	1700	2000
Payments (value added)		650	1400		
Total Outlays	(X_i)	1000	2000		

Since X = (I-A)$^{-1}$Y, we can describe how sector outputs, X's, will change when Y changes.

Example (cont.)

Input output coefficients:

a_{11} = 150/1000 = 0.15

a_{12} = 500/2000 = 0.25

Therefore, $\mathbf{A} = \begin{bmatrix} 0.15 & 0.25 \\ 0.20 & 0.05 \end{bmatrix}$ **&** $\mathbf{Y} = \begin{bmatrix} 350 \\ 1700 \end{bmatrix}$ **,** $\mathbf{X} = \begin{bmatrix} 1000 \\ 2000 \end{bmatrix}$

Analyze how sector 1 & 2 outputs are affected if final demand for sector 1 is increased from $350 to $400 and that of sector 2 is reduced from $1700 to $1600.

Example (cont.)

According to the problem, $\mathbf{Y} = \begin{bmatrix} 400 \\ 1600 \end{bmatrix} \sim \mathbf{Y} = \begin{bmatrix} 50 \\ -100 \end{bmatrix}$

Also, $(\mathbf{I} - \mathbf{A}) = \begin{bmatrix} 0.85 & -0.25 \\ -0.20 & 0.95 \end{bmatrix}$ **and** $(\mathbf{I} - \mathbf{A})^{-1} = \begin{bmatrix} 1.254 & 0.33 \\ 0.264 & 1.122 \end{bmatrix}$

$$\mathbf{dX} = (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{dY} = \begin{bmatrix} 1.254 & 0.33 \\ 0.264 & 1.122 \end{bmatrix} \cdot \begin{bmatrix} 50 \\ -100 \end{bmatrix} = \begin{bmatrix} 29.7 \\ -99 \end{bmatrix}$$

The change in demand produces an increase in sector 1 output of \$29.7 and a decrease in sector 2 output of \$99.0.