Measuring Utilization Efficiency of Foreign Aid in Asian Countries – DEA Approach

Seungkee Baek, Tone Kaoru

National Graduate Institute for Policy Studies

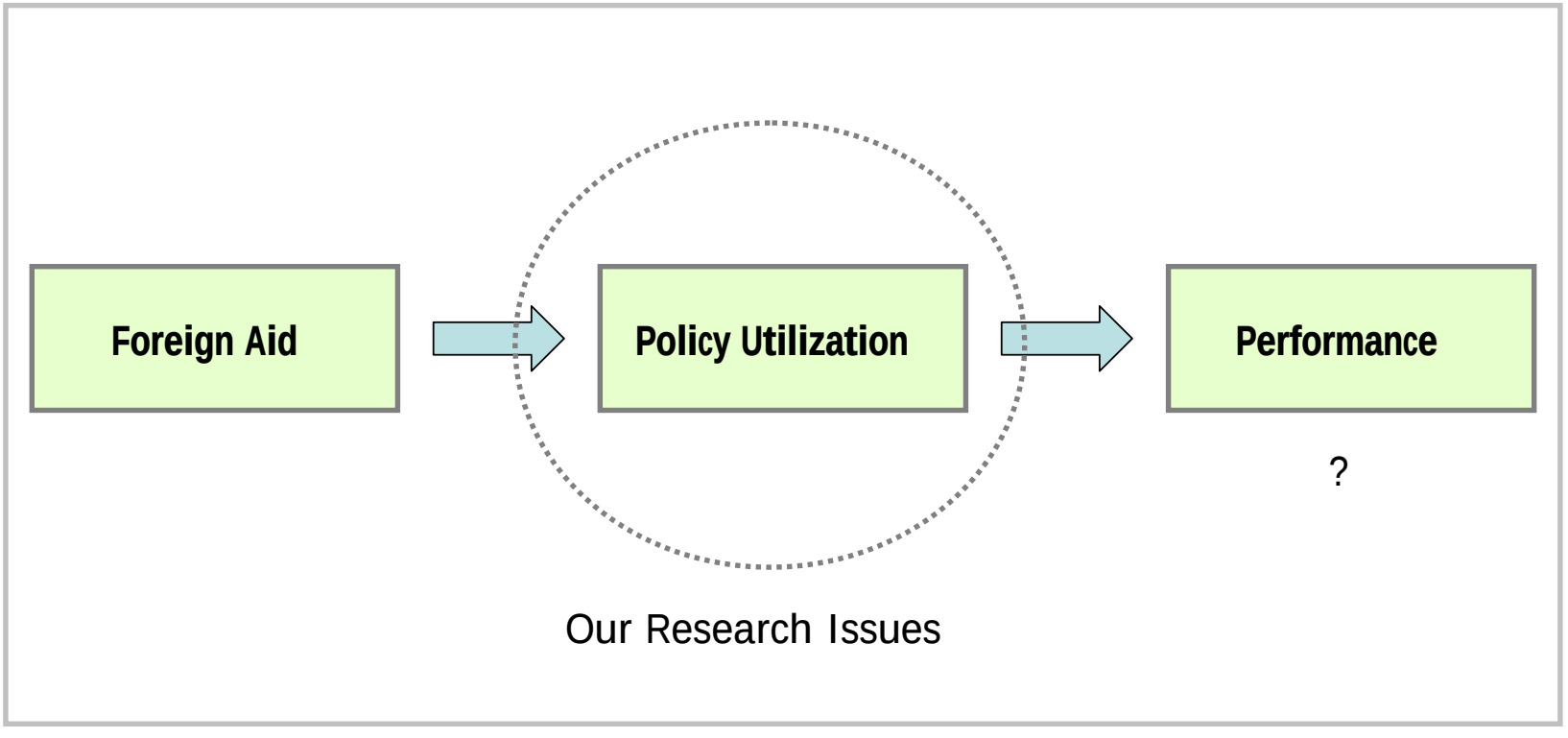
0. Objectives and Motivation

- Today, this presentation will explain how to analyze policy utilization using data envelopment analysis (DEA).

Objectives	• **Provide brief introduction of data envelopment analysis** • **Explain definition and role of foreign aid policy and its utilization** • **Suggest methodology for analyzing policy using DEA**
Motivation	• **During economic development from 1960s to 1970s, foreign aid plays an critical role as a source of seed money in Korea.** • **We should make full use of good successful case of other Asian countries to obtain an idea for economic policy**

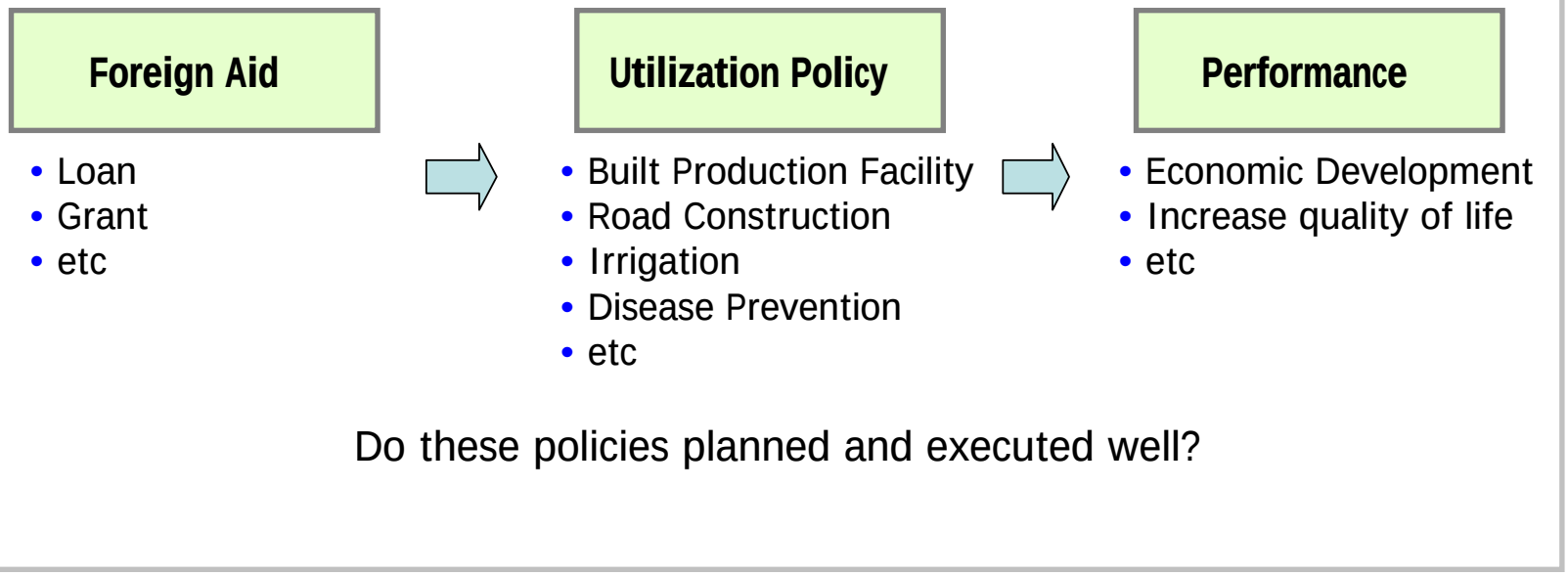
1. Research Issue

- Even though heavy amount of foreign aid invested in Asian countries, it still remains as in question that the economical status of receiving countries are really improved.



1. Research Issue

- We evaluate the efficiency of foreign aid utilization policy of aid receiving countries and provide a strategy for improvement.



2. What is Efficiency?

- Efficiency can be easily defined by the ratio of output over input
- However, when many factors are included in input or output and different units are used, we need weight for each factor to measure the efficiency

$$\text{Efficiency} = \frac{\text{output}}{\text{Input}}$$

When input and output are composed of multiple factors, i.e.

Input = input 1 + … + input *m*, and output = output 1 + … + output *s*

How can we measure the efficiency?

2. What is Efficiency?

- We measure weighted efficiency by assigning weight for each input and output.
- Using weighted efficiency, we can easily compare and analyze the efficiencies of each receiving countries

$$\text{Weighted Efficiency} = \frac{\text{weight 1*output 1 + … + weight s * output s}}{\text{weight 1*input 1 + … + weight m * input m}}$$

Where, input is composed of *m* input factors and output is composed of *s* factors

Q1. What is the maximum value of efficiency ?

3. Why Weighted Efficiency?

- Weighted efficiency provides ‘normalized’ measurement of performance.
- Using ‘normalized’ efficiency, we can easily compare the efficiency and find inferior members

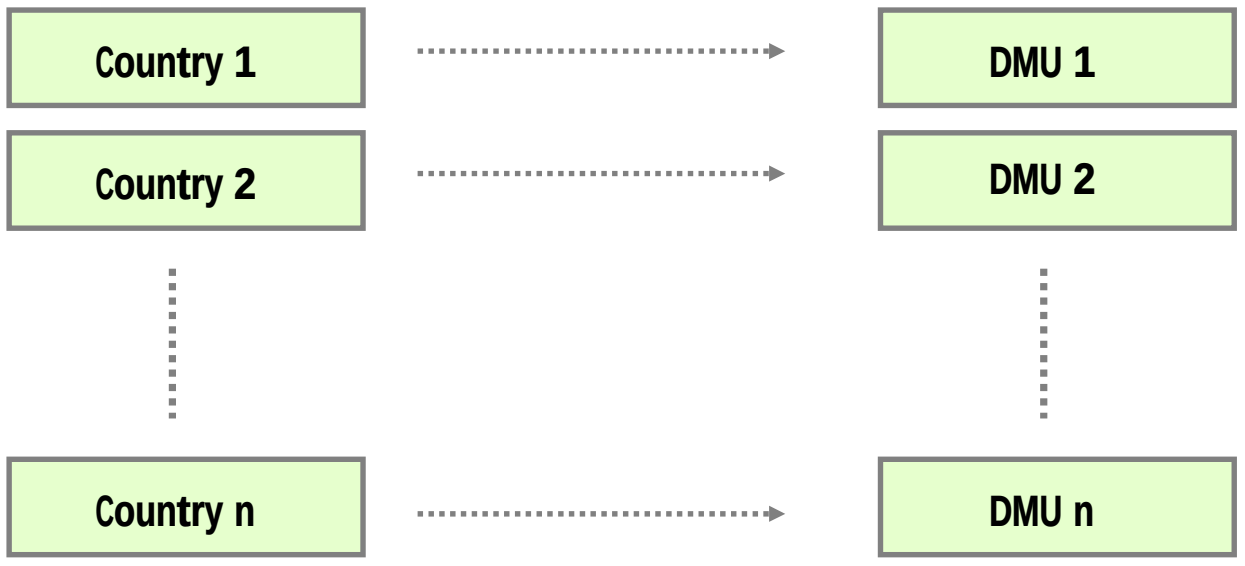
$$0 \leq \text{Weighted Efficiency} \leq 1$$

When weighted efficiency equals to 1, it means ‘really’ efficient, but weighted efficiency less than 1, it means that some of input or output includes waste.

4. Decision Making Unit

- We assumes multiple ‘units’ are need to be measured the efficiency.
- We define basic unit of efficiency measurement as ‘decision making unit (DMU)’ in DEA

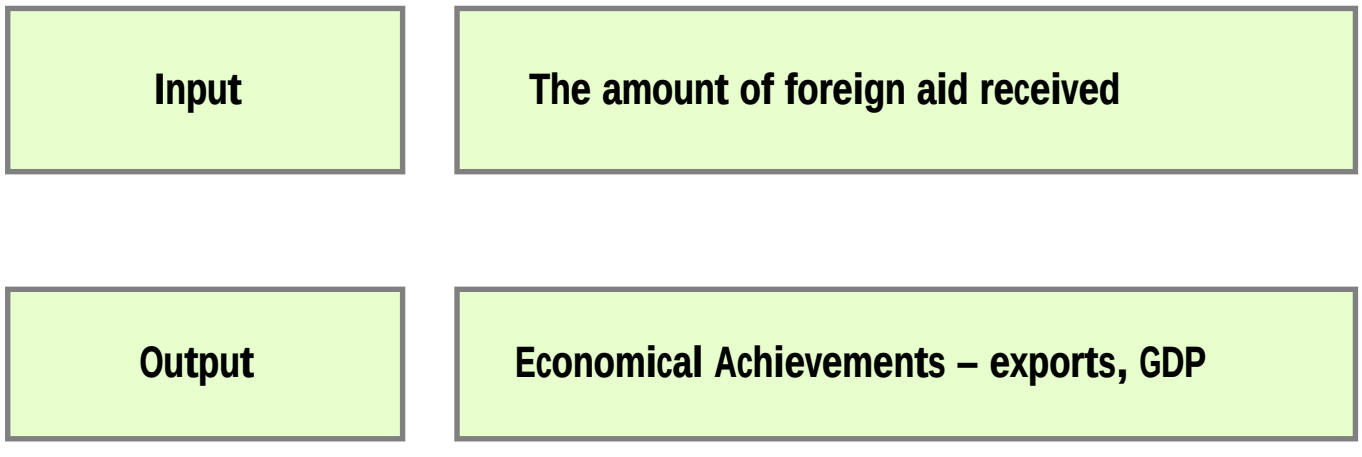
Assume that there exist n number of foreign aid receiving countries.



5. Structure of DMU in This Study

- Since we analyze the efficiency of foreign aid utilization policy among Asian countries, we define DMU as each government of these countries
- Also, we define input as the amount of foreign aid, and output as economic performance

Structure of DMU



6. Measuring Efficiency

- Assume that there exist *m* inputs(x_1, x_2, ..., x_m) and s outputs(y_1, y_2, ..., y_s).
- We need to determine weight for each input and output before measuring 'normalized' efficiency.

Efficiency of DMU i

$$= \frac{u_1 \times y_1 + u_2 \times y_2 + \cdots + u_s \times y_s}{v_1 \times x_1 + v_2 \times x_2 + \cdots + v_m \times x_m} = \sum_{r=1}^{s} u_r y_r \Big/ \sum_{j=1}^{m} v_j x_j$$

where
u_r : weight for output r
v_j : weight for input j

6. Measuring Efficiency

- Every DMU make an effort to maximize their ‘normalized’ efficiency while the amount of weighted output should not exceed the input
- We can formulate above situation using mathematical programming - DEA

$$Max \sum_{r=1}^{s} u_r y_{ir} \Big/ \sum_{j=1}^{m} v_j x_{ij}$$

$$s.t.$$

$$v_1 x_{11} + v_2 x_{12} + \cdots + v_m x_{1m} \geq u_1 y_{11} + u_2 y_{12} + \cdots + u_s y_{1s}$$

$$\vdots \qquad\qquad\qquad\qquad\qquad\qquad \vdots$$

$$v_1 x_{n1} + v_2 x_{n2} + \cdots + v_m x_{nm} \geq u_1 y_{n1} + u_2 y_{n2} + \cdots + u_s y_{ns}$$

$$u_r, v_j \geq 0$$

7. Data Envelopment Analysis

- From seminal work of Charnes et al. (1978), DEA have emerged as a major tool for analyzing efficiency.
- We usually use envelopment form of DEA model which enforce nominator or denominator to 1

Input Oriented Model

$$Max \sum_{r=1}^{s} u_r y_{ir}$$

$$s.t.$$

$$\sum_{j=1}^{m} v_j x_{ij} = 1$$

$$-vX + uY \geq 0$$

$$u_r, v_j \geq 0$$

Output Oriented Model

$$Min \sum_{j=1}^{m} v_j x_{ij}$$

$$s.t.$$

$$\sum_{r=1}^{s} u_r y_{ir} = 1$$

$$-vX + uY \geq 0$$

$$u_r, v_j \geq 0$$

8. Example

- Both A and B company produce same product, and they implement same technology
- How company A improve efficiency?

	Company A	Company B
Workers	10	8
Machines	5	4
Production	100	150
DEA Efficiency	0.53	1

9. Slacks

- We explain why inefficiency occurs using concept of slacks
- Slack means shortfall in output or excess in input

$$\text{Efficiency} = \frac{\text{OUTPUT + Shortfall}}{\text{INPUT + Excess}}$$

When DMU have no shortfall and excess in output and input, it becomes an efficient DMU

10. Measuring Slacks

- The function of slacks is to make inequality equality
- We denote slack for input as s^- and output as s^+

$$y_0 > y_1 \quad \Longrightarrow \quad y_0 = y_1 + s^+$$

$$x_0 < x_1 \quad \Longrightarrow \quad x_0 = x_1 - s^-$$

11. Slacks in Example

- Company A need to remove waste in 2 workers, 1 machines and increase 50 units of product, for example

	Company A	Company B
Workers	10(2)	8
Machines	5(1)	4
Production	100(50)	150

12. Slack Based Measurements (SBM)

- Tone (2001) proposed slack based measurement model, which measures the amount of input, output slacks

$$Min \quad \rho_1 = 1 - \sum_{i=1}^{m} w_{i0} \frac{s_{i0}^-}{x_{i0}}$$

$$s.t.$$

$$x_{10} = \sum_{j=1}^{n} x_{1j}\lambda_j + s_{10}^-$$

$$\vdots \qquad\qquad \vdots$$

$$x_{m0} = \sum_{j=1}^{n} x_{mj}\lambda_j + s_{m0}^-$$

$$y_0 \le Y\lambda$$

$$e\lambda = 1$$

$$\lambda, s_i^- \ge 0$$

where,

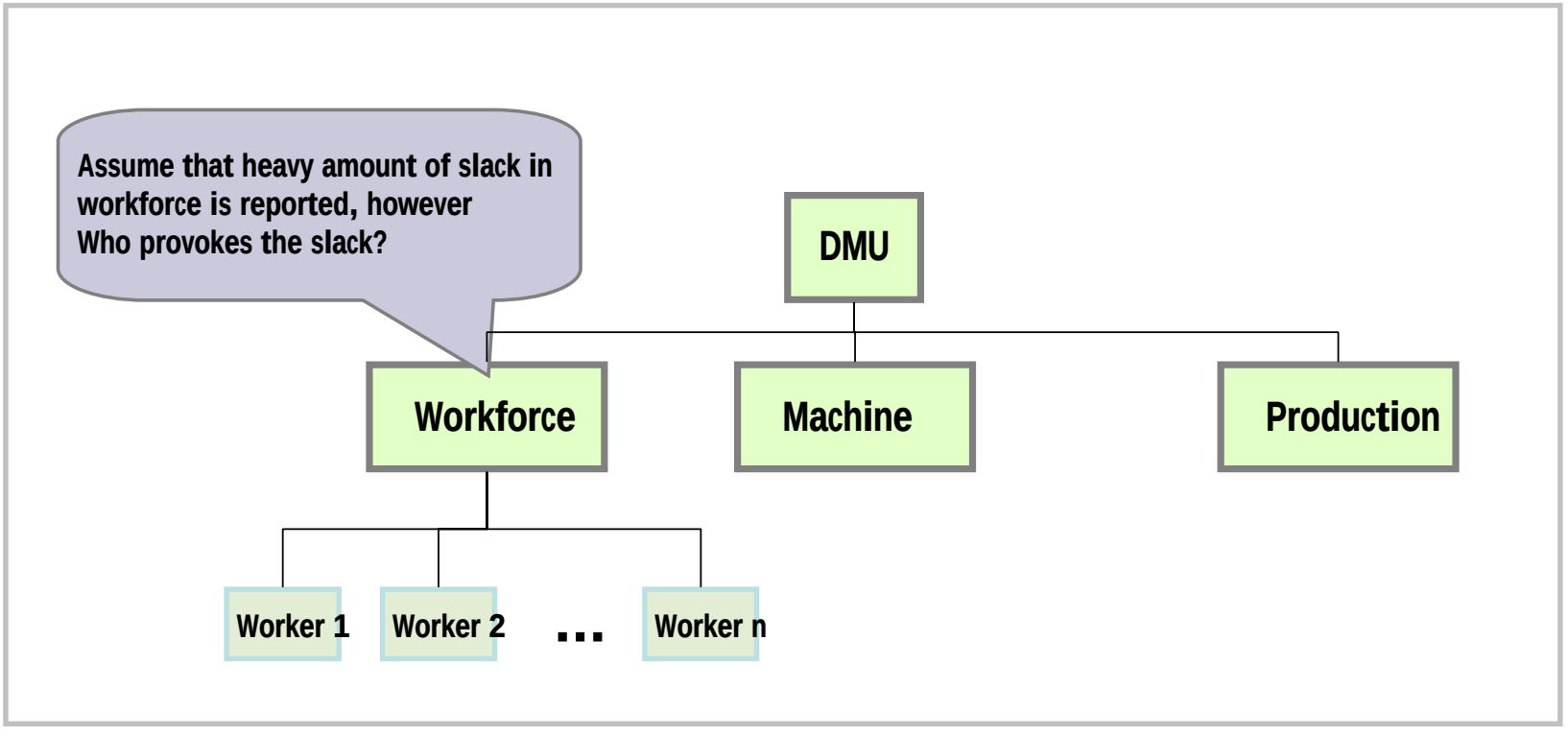
i **: index for input resources and slacks (*i*=1,…, *m*)**

w_{i0}**: weight for each input resources *i***

$$\left(w_{i0} = x_{i0} \Big/ \sum_{l=1}^{n} x_{il} \right)$$

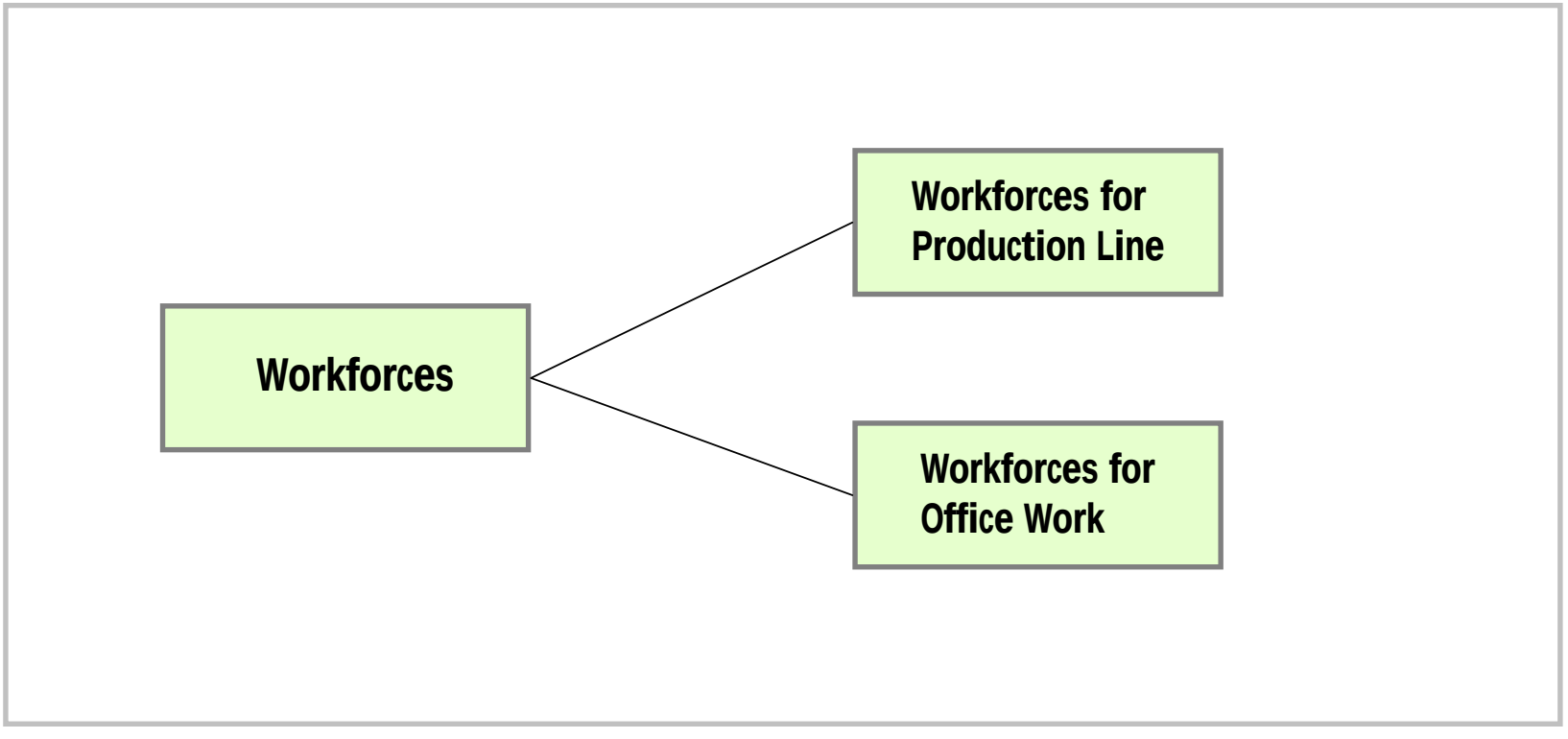
13. Pitfalls in Slack

- However, slacks only shows overall waste of input resources. Thus the slack itself can not provide an pin point advice of removing wastes



14. Slack Decomposition

- We need detailed slack information for inefficiency improvement.
- To measure the detailed slack, we divide input resource.



15. Additional Information of Resource Mix

- We introduce additional information of resource mix to decompose the slacks
- Using additional information of resource mix, we can divide the input resource and obtain detailed input slacks.

$$x_{ij} = \sum_{k=1}^{i_K} x_{i_k j}$$

where,
***i*: index for input resources (*i*=1,…, *m*)**
***j*: index for DMU (*j*=1,…, *n*)**
***k*: index for detailed-input resources for input resource *i* (*k*=1,…,i_K)**
x_{ij}: input resource *i* for DMU *j* before applying additional information
x_{ikj}: detailed input resource *k* for DMUj after applying additional information

16. Measuring Detailed Slack

- We measure detailed slack by applying the additional information of resource mix.

$$Min \quad \rho_2 = 1 - \sum_{i_k \in IS} w_{i_k 0} \frac{s^-_{i_k 0}}{x_{i_k 0}}$$

$$s.t.$$

$$x_{i_k 0} = \sum_{j=1}^{n} x_{i_k j} \lambda_j + s^-_{i_k 0} \quad (i_k \in IS)$$

$$y_0 \le Y\lambda$$

$$e\lambda = 1$$

$$\lambda \ge 0, s^-_{i_k 0} \ge 0 \quad (i_k \in IS)$$

where,

IS : index set for the second stage, $\left(IS = \{1_1, \cdots 1_{1_K}, \cdots\cdots, m_1, \cdots m_{m_k}\}\right)$

i **: index for input resources and slacks (*i*=1,…, m)**

k **: index for detailed input resources and slacks (*i*=1,…,*iK*)**

$w_{i_k 0}$**: weight for detailed input resources where,**

$$\left(w_{i_k 0} = x_{i_k 0} \Big/ \sum_{o=1}^{m} \sum_{p=1}^{o_K} x_{o_p 0} \right)$$

17. Case – Data Collection

- We collect data of 13 countries from 1999 to 2001

Input			Output
	Additional Information 1	Additional Information 2	GDP Export
Loan	Social Infrastructure Economic Infrastructure Production Facility	Material Service	
Grant	Social Infrastructure Economic Infrastructure Production Facility	Material Service	

17. Case – Result before applying AI

- Below Table shows an overall wastes in foreign aid utilization
- From the result, heavy portion of slack is measured both loan and grant

DMU	% of slack in		Efficiency
	Loan	Grant	
DMU1	N/A	86.4%	0.2374
DMU2	N/A	84.2%	0.2379
DMU3	N/A	83.1%	0.2121
DMU4	54.2%	0.0%	0.4829
DMU5	50.7%	13.3%	0.5190
DMU6	0.0%	0.0%	1.0000
DMU7	96.0%	84.2%	0.0818
DMU8	97.3%	86.6%	0.0593
DMU9	99.2%	79.9%	0.0205

17. Case – Result after applying AI (1)

- We analyze the origin of inefficiency by applying the additional information of resource mix
- We can find some exceptional case which is heavily decreased slacks when the effect of the AI does not applied.

DMU	Loan				Grant			
	1st Phase	2nd Phase			1st Phase	2nd Phase		
	amount of slack	%			amount of slack	%		
		S*	E**	P***		S*	E**	P***
DMU1	0.00	N/A	N/A	N/A	12.32	17.1%	82.9%	N/A
DMU2	0.00	N/A	N/A	N/A	19.62	N/A	0.0%	N/A
DMU3	0.00	N/A	N/A	N/A	32.07	21.9%	78.1%	N/A
DMU4	921.70	84.2%	6.2%	9.7%	10.68	0.0%	N/A	N/A
DMU5	919.77	44.6%	55.4%	N/A	7.06	0.0%	N/A	N/A
DMU6	0.00	0.0%	0.0%	N/A	0.00	0.0%	N/A	N/A
DMU7	690.86	0.0%	N/A	N/A	65.59	59.7%	40.3%	N/A
DMU8	964.76	60.3%	39.7%	N/A	65.88	60.7%	N/A	39.3%
DMU9	2344.79	79.8%	20.2%	N/A	86.56	53.0%	1.8%	45.2%

17. Case – Result after applying AI (2)

- We analyze the origin of inefficiency by applying the additional information of resource mix
- We can find some exceptional case which is heavily decreased slacks when the effect of the AI does not applied.

DMU	1st Phase	2nd Phase	
		Loan Expand	Grant Expand
DMU1	0.2374	0.2374	0.2374
DMU2	0.2379	0.2379	1.0000
DMU3	0.2121	0.2121	0.2121
DMU4	0.4829	0.4829	1.0000
DMU5	0.5190	0.5190	1.0000
DMU6	1.0000	1.0000	1.0000
DMU7	0.0818	1.0000	0.0818
DMU8	0.0593	0.0593	0.0593
DMU9	0.0205	0.0205	0.0205

18. Concluding Remarks

- The contribution and further research issue of this presentation can be summarized as follows

- **We would emphasize that DEA is effective tool for analyzing efficiencies of policy**
- **We need to conduct further research on how decisions are made with regard to the selection of projects using foreign aid – Is it transparent and open ?**
- **We need further research about the relation between the change of efficiency score and the expansion of the production possibility set in field of slack based measurement.**