Incorporating Sustainable Outcomes into Productivity Assessments

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Productivity and Performance

- It is common both in the academic literature and the trade literature to compare the performance of various organizations on the basis of productivity.
- A productive organization is one that can produce the most output with the least inputs.
- In the transportation field, productivity comparisons have been conducted between seaports, airports, and transportation carriers.
Importance of Productivity

• It is important for an organization to be productive, because a productive organization can operate with lower costs.

• If two organizations have the same factor costs (i.e., wage rates, capital costs, etc.), the productive organization will have a competitive advantage over other firms.

• For example, a port that can move more containers per hour with fewer workers will likely have a cost advantage over other competing ports.
Productivity and Wealth Improvements

• From an economic perspective, productivity improvements increase the wealth of the people living in a country.
• If a country can produce more outputs with fewer inputs, then the GDP of the country will increase.
• China is becoming a wealthier country because its industry and workers are becoming more productive.
Assessing Productivity Across Firms

• There are many different ways to assess productivity.
• Some simple measures often used in the trade literature include *output per worker* and *output per man-hour*.
• These are known as partial productivity measures, since they only assess output against one factor of production – labor – ignoring potential trade-offs with other inputs, such as capital.
Total Factor Productivity

- More sophisticated methodologies to measure productivity, often used in the academic literature, examine how multiple inputs are used to measure multiple outputs.
- For example, for seaports, these measures may assess how several inputs – labor, container cranes, dock space, etc. – are used to produce multiple outputs – container movements, breakbulk tonnage, bulk freight, etc.
- Popular examples of these types of measures include Total Factor Productivity (TFP), which is an indexing technique and Data Envelopment Analysis (DEA), which is a linear programming technique.
Issues With Productivity Assessments

- In order to compare productivity across organizations, researchers have had to develop many procedures to properly control for differences between the organizations.
- For example, some of the techniques will control for the size of the organizations, recognizing that there may be economies of scale in production, and that large organizations may be inherently more productive than small organizations.
- Researchers have also recognized how the various inputs and outputs are combined to create composite productivity measures is very important, especially since the organizations will use the inputs and produce the outputs in different combinations.
Incorporating Sustainable Outcomes into Productivity Comparisons

- An important issue that has not received much attention when comparing productivity across transportation organizations is how to properly incorporating “sustainable outcomes” into the productivity analysis.
Productivity Comparison Example

**Black Airline**
- Output – 100,000 RTK per year
- Labor Input – 5,000 man-hours
- Capital Input – 5 Airbus 320s

**Green Airline**
- Output – 80,000 RTK per year
- Labor Input – 5,000 man-hours
- Capital Input – 5 Airbus 320s

Which airline is the most productive?
Productivity Comparison Example

Black Airline

- Output – 100,000 RTK per year
- Labor Input – 5,000 man-hours
- Capital Input – 5 Airbus 320s
- Pollution – 2 million tonnes of carbon

Green Airline

- Output – 80,000 RTK per year
- Labor Input – 5,000 man-hours
- Capital Input – 5 Airbus 320s
- Pollution – 1 million tonnes of carbon

Which airline is the most productive?
Production Possibilities

Normally, in business, the goal is to move out on the production possibility frontier as far as possible in order to produce the most outputs with the least amount of inputs.
But, if the increased production is accompanied by increased pollution or any other "negative output", then maybe more production is not better.
An Important Issue

• How to compare productivity across organizations after properly considering both positive and negative outputs.

• I will report findings from a study conducted at the University of Maryland by four researchers (Pathomsiri., Haghani, Dresner, and Windle).
Study Setting

• Fifty-six airports in the United States during the period 2000-2003.
• Our goal was to compare the productivity across the airports after considering both positive and negative outputs.
• Negative outputs that could be considered – several possibilities including carbon emissions and noise pollution.
Negative Output Incorporated in Analysis

• The negative output that we actually incorporated into our productivity comparison between airports was flight delays.
• Flight delays not only inconvenience passengers but impose a cost on airlines (e.g., extra labor and capital requirements).
• Delays are a negative output that tend to get produced jointly with positive outputs; that is, as an airport increases its passenger and freight traffic (positive outputs), it gets increasingly congested and more delays are also produced.
• A recent study for the Federal Aviation Administration estimated that airport flight delays cost the United States $32.9 Billion per year (Nextor 2010).
• The same methodology we used can also be used to incorporate the cost of carbon emissions, noise pollution, or any other measurable negative output.
Methodology

- The simplest way to consider negative outputs, such as airport flight delays, is to treat the negative outputs as inputs.

- Using this methodology, the goal is to minimize all regular factor inputs plus the negative outputs, subject to maintaining the positive outputs (or to maximize the positive outputs subject to minimizing the regular inputs plus the negative outputs).
Example of Considering Negative Outputs as Inputs

Inputs and Negative Outputs
- Airport Land Area
- Number of Runways
- Runway Area
- Number of Delayed Flights
- Time Delay in Minutes

Positive Outputs
- Passenger Throughput
- Cargo Throughput
- Number of Non-Delayed Flights

Objective: Maximize positive outputs subject to maintaining inputs and negative outputs (or minimize inputs and negative outputs subject to maintaining positive outputs.
Problem with Considering Negative Outputs as Inputs

• This simple methodology (considering negative outputs as equivalent to factor inputs) has a major flaw. If a negative output is a byproduct of the positive outputs or is jointly produced with the positive outputs, then it will not be possible to minimize the negative output without also minimizing the positive outputs.

• From our example, delayed flights and non-delayed flights are linked as joint products. One cannot be increased or decreased without affecting the production of the other.
Problem With Treating the Negative Output as an Input

Goal: Maximize non-delayed flights, subject to maintaining inputs and delayed flights.

But more non-delayed flights result in more delays. It may be impossible to increase non-delayed flights while holding delayed flights steady.
Non-Parametric Directional Output Distance Function

- A number of researchers (Chung et al. 1997; Färe and Grosskopf 2004) have developed an alternate approach to incorporate undesirable outputs into a DEA-type linear programming model, known as the non-parametric directional output distance function.
Airport Example

Assuming all airports employ the same inputs, A and B are airports on the production possibility frontier while Airport D is clearly inefficient since it is producing too much undesirable output relative to desirable output. It needs to reduce its undesirable output by moving towards the AB production frontier.
Variables and Data

- In order to compare the productivity across the 56 US airports in our dataset, we collected information on three inputs – land area, number of runways, and runway area, three positive outputs – non-delayed flights, passengers, and cargo throughput, and two undesirable outputs – delayed flights and time delays.
- According to the Federal Aviation Administration rules, a flight is considered delayed if it arrives more than 15 minutes behind schedule. This definition was used to calculate delayed flights.
- We also calculated actual delay time to use as our second undesirable output.
- Data on all variables was collected for a four year period from 2000 to 2003.
Analysis

• In order to fully examine the impact of delays on our results, we estimated our model first with only the inputs and desirable outputs.

• Next we estimated the model again by including both the desirable and undesirable outputs.
Results (1)

- Without considering delays, “efficient airports” are generally the very busy airports, such as Atlanta Hartsfield-Jackson (ATL) and Memphis (MEM), FedEx’s cargo hub.

- When delays are considered, smaller airports are actually the best performers.
Efficiency Comparison by Airport Size

Lower scores imply higher efficiency.

Both desirable and undesirable outputs included in productivity calculations.
• When delays are not included in the model, the level of inefficiency (relative to the efficient frontier) is generally higher.
• For example, our results using the model with only desirable outputs suggest that Albuquerque International Airport (ABQ) should accommodate 257% more passengers in order to be efficient.
• However, when undesirable outputs are also considered, our results suggest that only 15% more passengers are needed for ABQ to be efficient.
• These results suggest that if delays are considered as an undesirable output, less passenger growth (i.e., a more sustainable outcome) is desirable.
• When only desirable outputs are considered, the level of delays is strongly correlated with efficiency scores.
• This result suggests that when delays are not included in the productivity calculations, the “best practice”, most efficient airports are also the ones providing the poorest quality service (i.e., most delays).
• When delays are considered in the calculation of productivity, the correlation between delays and efficiency is much lower.
Results (4)

• When undesirable outputs are included in the model, the number of airports on the efficient frontier increases.

• As more measures are included, there is increasing likelihood that an airport will perform well on at least one of the measures, thus more airports are found to be efficient.
Conclusions

• In the past, we have equated productivity with producing more output for a given level of input.
• However, this output is not always desirable.
• Therefore, to properly assess efficiency, one should consider both desirable and undesirable outputs.
• After properly accounting for both desirable and undesirable outputs, we are likely to find that the best “sustainable” outcomes result in comparatively less output being produced.
Thank you very much!