Introducing a New DEA Methodology for Environmental Inputs

Education and healthcare are two critical sectors of the economy, both because they account for a large portion of expenditures and because they feed back into the efficiency of labor in the economy. Unfortunately, the efficiency of schools and hospitals is hard to measure. Data Envelopment Analysis, or DEA, is commonly used to measure this efficiency, but the traditional methodology does not formally account for non-discretionary or environmental inputs.

PERC Research Fellow Timothy Gronberg, Jordan Professor of Economics Dennis Jansen, and Norabajra Asava-vallobh propose a new method for estimating a DEA model that accounts for non-discretionary inputs in PERC Working Paper 1307. Simulation evidence is provided to show that their method out-performs other models.

Data Envelopment Analysis is a nonparametric method that can calculate the proportional reduction in inputs that is possible for a firm while maintaining a level of output. This method relies on the comparison of peer firms, or more generally production units.

Peer comparison is an informative way of measuring efficiency, but it relies on the assumption that firms only differ in their inputs and efficiency. If firms differ in non-discretionary inputs, they may wrongly seem more or less efficient due to them. For example, school administrators can control things like classroom size and teachers’ educational training, but they cannot control parental involvement in schooling or neighborhood characteristics.

The authors’ strategy for including these inputs in estimation is to control for them directly in a three stage process. The first stage is identical to the traditional one stage input-oriented DEA model. Using input and output data from a set of firms, a set of most efficient firms is determined. All other firms are then measured against the efficiency standard of these benchmark firms based on the amount of inputs they used and the amount of output they generated.

The method generates an estimate of how much each firm could reduce its inputs and still have the same output. The ratio of the calculated efficient input level to the actual input level is called the firm’s “technical efficiency score.” Efficient firms receive a score of one, and a completely inefficient firm would receive a score of zero.

The authors’ second stage seeks to explain the inefficiency measured in the first stage caused by environmental factors. They do this by treating the non-discretionary factors as the output, and a measure of inefficiency (1 – the efficiency score) as the input. An efficiency score is generated by the same empirical process as in the first stage. The second stage efficiency score indicates how much of the first stage inefficiency can be explained by environmental factors. A score of one indicates that all first stage inefficiency was caused...
The third step combines the first and second stage efficiency scores for each firm into a combined score that indicates the efficiency of each firm, given its non-discretionary inputs. Importantly, a firm can receive the maximum efficiency score of one if its first stage score is one or if its second stage score is one. A firm in a less ideal environmental setting will not be wrongly penalized because of factors that it cannot control. This difficulty in comparing firms with different environmental conditions is a known shortcoming of DEA, and methods have been suggested to deal with this issue. The most successful method was suggested by Ruggiero in 1998. He compares each firm the most environmentally similar firms. Restricting the sample in this way introduces bias, especially in small samples. The authors support this claim using simulations. Each firm is assigned a set of discretionary and non-discretionary inputs and an efficiency score. Firm outputs are generated according to a production function and scaled by the efficiency score. The traditional one-stage DEA method, Ruggiero’s method and the authors’ method are all used to estimate the efficiency using just the inputs and outputs. The authors vary the number of discretionary and non-discretionary inputs and outputs simultaneously from 1 to 4 and consider sample sizes of 50, 100 and 150 firms. The more complex settings with more than one output, input and environmental input, are where the authors’ method outperforms the existing methods. For all sample sizes tested, it is more accurate in predicting both the efficiency ranking of the firms and the efficiency scores for simulations with more than one output, input and environmental input. A primary advantage of Data Envelopment Analysis is that it handles multiple inputs and multiple outputs quite well, so the fact that the authors’ model outperforms the other models in these settings is important.

Firms within industries differ in critical environmental ways. DEA analysis provides a flexible framework for measuring relative efficiency of firms, but the standard model does not account for these uncontrollable factors. Comparing firms to environmentally different peers can generate misleading relative efficiency measures. Asava-valloobh et al. propose an alternative methodology that accounts for this problem in a similarly flexible manner and utilizes the full set of firms, making it a valuable tool.

### The On-Budget Effects of Trust Funds Surpluses

Surpluses and deficits in the federal budget drive public debt. The federal budget (or formally the “unified budget”) has two components. The first is called the “on-budget” because it is primarily decided by spending bills and tax laws created by Congress. Conversely, the “off-budget” is largely driven by economic conditions. While the on- and off-budgets are designed to be separate, there is evidence that they interact. Surpluses in the off-budget (from trust fund surpluses) represent opportunities to retire public debt by increasing unified budget surpluses. For example, the Social Security trust fund was devised as a way to increase the federal government’s ability to finance future retirement benefits. If there is a Social Security surplus in a year and there is no resulting increase in the on-budget deficit, then the surplus could be used to retire federal debt. Conversely, if the on-budget deficit increases by the amount of the surplus, then the Social Security surplus cannot be used to reduce the federal debt. If the trust funds do not contribute to saving, then alternative saving mechanisms need to be considered.

Both theoretical and empirical models are developed by PERC Research Scientist Liqun Liu, Executive Associate Director Andrew J. Rettenmaier, Director Thomas R. Saving and PERC Research Scientist Zijun Wang in PERC Working Paper 1308. First, they examine two different methods by which budgeting decisions could be made in a theoretical model and then verify their predictions empirically. By estimating an array of empirical models they are able to speak to causes of the incon-
sistent findings in the existing literature, and they propose a model that is a compromise between the established methods.

The authors’ theoretical models both find that an off-budget surplus will lead to an on-budget deficit, but the deficit will not increase dollar-for-dollar. In their model, they allow the trust fund surplus to be put to three uses: increasing on-budget spending, decreasing on-budget revenue (tax cuts) or increasing the unified budget surplus (debt reduction). They model the decision-making process two ways.

First, they assume that a single decision-making authority that gains utility from on-budget spending and unified budget surpluses, but loses utility from taxation, allocates the off-budget surplus across the three uses. They solve a constrained optimization problem where the unified budget surplus is the constraint and is equal to the difference between combined off- and on-budget revenues (trust fund surpluses and taxes, respectively) and expenditures (spending and interest payments on federal debt). They find that the decision-maker will allocate some of the surplus to each of the three uses, so that the unified budget surplus will go up, but not by the entire trust fund surplus quantity.

The other model assumes that two groups with somewhat opposing preferences split the decision-making authority. Party D likes on-budget spending and unified surpluses and is indifferent to taxes; it chooses on-budget spending. Party R dislikes taxes, likes unified surpluses and is indifferent to on-budget spending; it chooses the tax level. Each chooses according to its preferences and subject to the same constraint as in the single decision-maker model. The two parties make these choices simultaneously and with regard to the decision being made by the other party, leading to a Nash equilibrium solution.

The solution to this dual optimization problem is the same qualitatively as the solution to the single decision-maker problem – that not all of the trust fund surplus will be transferred into unified budget surplus because some will be diverted to pay for additional on-budget spending and tax cuts.

Empirically, these results have mixed support in the literature. The predictions are supported by the small cross-sectional literature, but time series studies have found that trust fund surpluses lead to increases in on-budget deficits that are actually larger than the surpluses. Conversely, in time series studies that control for serial correlation, there is no significant effect.

The authors work to reconcile these differences across methods by estimating their empirical models a number of ways. They first estimate time series models that do not account for serial correlation and obtain results that are consistent with the literature in that they predict that an additional dollar of trust fund surplus increases the on-budget deficit by over two dollars. As in the literature, once they control for serial correlation by first-differencing, they obtain results that are statistically insignificant and indicative of trust fund surpluses causing decreases in on-budget deficits.

Because the first-difference estimates may be subject to over-differencing, they may underestimate the true effect of the policy. As a compromise, the authors run two models in which they first-difference the variables with a two- or three-year lag. These specifications control for serial correlation, but are less likely to be subject to problems caused by over-differencing. The results are more reasonable. For the three-year lag, they find that a one-dollar increase in the trust fund surplus causes the on-budget surplus to decrease by $0.62 - $0.79.

The results from the multi-year lag specifications are consistent with the predictions of the theoretical models for budgetary decision-making and the cross-sectional literature. An increase in the trust fund surplus will cause the on-budget surplus to decrease (or alternatively, the on-budget deficit to increase), but less than dollar-for-dollar. This implies that trust fund balances only partially represent savings and should not be relied upon for debt reduction.
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