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Japanese banking inefficiency and shadow pricing☆

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ABSTRACT

We estimate Japanese banking inefficiency and the shadow price of problem loans by treating problem loans as a jointly produced undesirable by-product of the loan production process. Our method uses the directional output distance function of Färe et al. [R. Färe, S. Grosskopf, D.-W. Noh, W.L. Weber, Characteristics of a polluting technology: Theory and practice, Journal of Econometrics 126 (2005) 469–492] and seeks the maximum expansion of desirable outputs, such as loans and securities investments, and the simultaneous contraction in undesirable outputs, such as problem loans. The directional output distance function is estimated using data envelopment analysis and a parametric linear programming method. While the two methods give similar estimates of inefficiency, the shadow price estimates for the two methods diverge.

1. Introduction

From 1980 to 1990 the Japanese money supply grew at an annual 9.1% rate. The increased money supply prompted Japanese banks to ease lending and resulted in a stock and real estate price bubble. In 1989, the Nikkei Index peaked at 38,916. However, by the early 1990s, the stock price and real estate bubble had burst leaving Japanese banks with high levels of non-performing loans on their balance sheets. As a percent of GDP, bank loans in Japan are more than double those of US banks making the Japanese economy highly susceptible to problems in the banking industry. From 1990 to 2000 Japanese bank loan losses grew from less than 1% of bank assets to more than 2.5% of bank assets. (Weber and Devaney [1]) Although nonperforming loan problems have recently eased, the balance sheets of both small banks and large banks are still plagued by the inability of borrowers to pay interest and repay principal. Any attempt to measure the performance of banks in response to policy reforms or merger activities must account for problem loans. Drake and Hall [2] and Altunbas et al. [3] treat problem loans as an exogenous factor influencing bank technical efficiency or bank costs. Hughes and Mester [4] and McAllister and McManus [5] also control for problem loans in their cost/scale efficiency estimates for U.S. banks. Fukuyama and Weber [7,8] control for bank risk via a bank equity capital constraint in a DEA (Data Envelopment Analysis) model, so that banks with similar risk profiles are compared with each other.

Following Berger and Humphrey's [6] discussion concerning bank risk and non-performing loans on bank efficiency, Drake and Hall [2] treat problem loans as a fixed input in their DEA efficiency analysis. However, non-performing loans are a by-product of the loan production process and do not occur until after a loan has been made. Therefore, non-performing

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loans are more accurately modeled as an undesirable or bad output, rather than as an input. Moreover, from a technical modeling stand point, if bad outputs are treated as inputs, the resulting output possibility sets are unbounded.

To measure efficiency we use the directional output distance function which was introduced by Chambers, Chung, and Färe [9] in production theory as an extension of Luenberger's [10] benefit function. This function serves as an inefficiency measure as it seeks the maximum simultaneous expansion of good (desirable) outputs and contraction of bad outputs. Decision-making units are efficient if they cannot simultaneously expand good outputs and contract bad outputs, given inputs. For the Japanese bank production process we explicitly model problem loans as the bad output that is a joint by-product of the loan production process. Park and Weber [11] measured Korean bank efficiency during 1992–1997 using the directional output distance function. We extend their work by estimating the shadow price of problem loans. Färe et al. [12] were the first to use the directional distance function to measure environmental efficiency and estimate the shadow price of an undesirable polluting output (sulfur dioxide emissions). We use the method of Färe et al. [12] and estimate the shadow price of problem loans via a parametric directional distance function. We also estimate the shadow price of problem loans by solving a dual DEA directional distance function.

Shadow pricing models have at least two uses. First, if all outputs have observable market prices, a shadow pricing model can be used to determine if the mix of outputs is consistent with revenue maximization. However, market prices for undesirable outputs are frequently unobserved. In these cases a second use of shadow pricing is to infer the unobserved price from the market price of a desirable output and knowledge of the physical tradeoff between the desirable and undesirable output. We pursue this second case as we show that the shadow price of problem loans equals the decline in value of a desirable output needed to reduce the undesirable output by one unit. As such, the shadow price measures the opportunity cost of reducing the bad output by one unit.

The purpose of this paper is four-fold. First, we present a directional DEA (data envelopment analysis) framework where the term "DEA" was coined by Charnes, Cooper, and Rhodes [13] and Banker, Charnes, and Cooper [14] as an extension of Farrell's [15] original efficiency analysis. Second, we present and estimate a parametric LP model (linear programming) using the loss minimizing procedure of Aigner and Chu [16]. In this step we estimate the quadratic directional output distance function introduced by Chambers [17]. Third, we present an empirical illustration of our two methods using data on Japanese banks that operated in fiscal years 2002 through 2004. We choose this period because data on non-performing loans are available for most Japanese banks. Fourth, we compare our estimates of the shadow price for problem loans that are found for the DEA and parametric LP specifications of the directional distance function. In this step we relax a monotonicity condition for the bad output in order to identify the region of the output possibility frontier where each bank operates. Our model allows for the possibility of output congestion in that banks can operate along either an upward-sloping, flat, or downward sloping portion of the output possibility frontier. While the deterministic quadratic directional distance function yields a point estimate of the shadow price for a given bank, our DEA method provides a range of shadow price estimates for that same bank.

2. Characterizing the bank technology

2.1. The directional distance function and derivation of shadow prices

Let $y \in \Re^M_+$, $b \in \Re^J_+$, and $x \in \Re^N_+$ denote vectors of M good (desirable) outputs, J bad (undesirable) outputs, and N inputs. The production process is modeled from Shephard's [18,19] production theory with bad outputs. The underlying technology is defined by the bank output possibility set:

$$P(x) = \left\{(y, b) : x \in \Re^N_+ \text{ can produce } (y, b) \in \Re^M_+ \times \Re^J_+\right\}, \tag{1}$$

which is the set of all good and bad output vectors that are producible from a fixed level of input. In addition to the standard regularity assumptions, the bank technology (1) satisfies strong disposability of good outputs:

$$y \geq y' \in \Re^M_+ \quad \text{and} \quad (y, b) \in P(x) \quad \text{for } x \in \Re^N_+ \Rightarrow (y', b) \in P(x). \tag{2}$$

Eq. (2) states that if the good output vector is decreased it is still producible for a given level of inputs and bad outputs. We also assume that inputs are strongly disposable:

$$x' \geq x \in \Re^N_+ \Rightarrow P(x') \supseteq P(x). \tag{3}$$

Strong disposability of inputs states that if inputs are increased from x to x', the resulting bank output possibility set $P(x')$ is no smaller than the original output possibility set $P(x)$.

While good outputs and inputs satisfy strong disposability, we assume the vector of bad outputs and good outputs satisfies only joint weak disposability:

$$(y, b) \in P(x) \quad \text{and} \quad 0 \leq \theta \leq 1 \Rightarrow (\theta y, \theta b) \in P(x). \tag{4}$$

Weak disposability implies that there is an opportunity cost of reducing bad outputs in that some good output must be foregone. Finally, good and bad outputs are null-joint if

$$(y, b) \in P(x) \quad \text{and} \quad b = 0 \Rightarrow y = 0. \tag{5}$$