An illustration of dynamic network DEA in commercial banking including robustness tests

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A R T I C L E  I N F O

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A B S T R A C T

The main motivation of this article is to illustrate dynamic network data envelopment analysis (DN-DEA) in commercial banking with emphasis on testing robustness. To this end, sixteen foreign banks in China are benchmarked against thirty-two domestic banks for the post-2007 period that follows major reforms. When network and dynamic dimensions are brought together, a more comprehensive analysis of the period 2008–2010 is enabled where divisional and between-period interactions are reflected in efficiency estimates. Weighted, variable returns-to-scale, non-oriented dynamic network slacks-based measure is used within the framework of the intermediation approach to bank behavior. A bank network (i.e., a decision-making unit, DMU) is conceptualized as comprised of two divisions or sub-DMUs, namely, interest-bearing operations and non-interest operations linked by number of referrals. Undesirable outputs from sub-DMUs 1 and 2 (non-performing loans, and proportion of fruitless referrals, respectively) are treated as carry-overs that impact the efficiency of the following periods. Under robustness testing, the illustrative application discusses discrimination by efficiency estimates, dimensionality of the performance model, stability of estimates through re-sampling (leave-one-out method), and sensitivity of results to divisional weights and returns-to-scale assumptions. The results based on Chinese commercial banks are illustrative in nature because of simulated data used on two of the variables.

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1. Introduction

While the first published application of standard data envelopment analysis (DEA) in banking can be traced back to Sherman and Gold [22], application of dynamic network DEA (DN-DEA) in banking is still in its infancy, e.g. Fukuyama and Weber [15] provide an example in the context of Japanese banks; Kao and Liu [18] examine Taiwanese commercial banks; and, Wang et al. [27] measure the efficiency of a small number of Chinese commercial banks. The current article argues that continuing this line of research will bring greater confidence to the application of DN-DEA for assessment of performance in financial institutions, in particular where greater attention is paid to robustness testing. Thus, the article continues with a demonstration of DN-DEA in the Chinese commercial banking sector – one of the most talked about economies in the world – where results are illustrative because of simulated data used with two of the variables.

China has been further opening up its domestic financial markets to foreign financial institutions by implementing reforms that expanded services in foreign exchange and renminbi (RMB). Effective as of 11 December 2006, domestic and locally incorporated foreign banks engage in such services as loans, deposits from the general public, negotiable instruments, trading bonds, letters of credit and guarantees, domestic and foreign settlements, bank cards, interbank lending, etc.1 In other words, foreign banks are permitted to offer the same types of RMB services/products as their domestic counterparts. According to Xu [28] foreign banks have been granted equal status as of December 2006 – a turning point that marks five years of liberalization in Chinese banking. Thus, the main motivation of this article is to illustrate DN-DEA in the context of Chinese commercial banking for the post-2007 period. Key research design choices made are carefully justified for the benefit of the DEA student and an extensive discussion of robustness is also included.

1 See 'Regulations of the People's Republic of China on Administration of Foreign-funded Banks' ([11]). The same regulations also apply to the banking institutions established on Chinese mainland by financial institutions originating from the Hong Kong Special Administrative Region, the Macao Special Administrative Region, or Taiwan. For example, in our sample, Hang Seng bank (China) Ltd., and CITIC Ka Wah Bank (China) Ltd. with home groups from the Hong Kong Special Administrative Region are treated as foreign banks rather than Chinese domestic banks (see Article 72).
The rest of the article continues with an explanation of the conceptual framework behind measuring relative bank performance. The method section begins with an introduction to dynamic network DEA and proceeds to a description of data. The section on results includes an extended discussion on robustness testing. The article ends with concluding remarks.

2. Conceptual framework for measuring the relative performance of banks

While there is no there is no universally agreed approach to modeling bank behavior, particularly in the context of evaluating technical efficiency. Applications of efficient frontier methods in banking normally begin with a bank behavior model guiding the selection of inputs and outputs under the production, intermediation or value-added approaches (see [1]). An investigation of major DEA applications in banking literature in top journals across 2004–2009 reaches the conclusion that, “...there is no clear agreement amongst the selection of inputs and outputs beyond the general observance of the intermediation approach to bank behavior” ([3], p. 326).

In this study, costs are not attached to input variables and prices are not associated with output variables because the main focus is on measuring technical efficiency, rather than cost or allocative efficiency. The traditional intermediation executed by banks as part of their regular operations include incurring various interest and non-interest expenses to generate deposits and writing loans to generate interest income, alongside non-interest income mainly comprised of service fees and sales commissions. Therefore, in the current article’s performance benchmarking the objective of banks is implementing the above-mentioned inter-division or value-added approaches (see [1]).

Fig. 1 depicts the conceptual framework of the current article’s efficiency analysis for banks or decision-making units (DMUs). Interest-bearing operations and non-interest operations are treated as the two core divisions or sub-DMUs in banks’ operations. These divisions are not of physical nature but reflect the concentration of a commercial bank’s related operations (see [2] for a similar approach to divisions in banking). That is, lending is the main activity in sub-DMU 1 and the referrals generated here create the potential for business in sub-DMU 2; thus, number of referrals is the intermediate product connecting the two divisions. For example, customers taking out a loan could be encouraged to sign up for a credit card as well, or business borrowers could be encouraged to set up a foreign currency facility, letter of credit facility, or an overdraft facility that generate fees and commissions. Such cross-selling activities or referrals represent intermediate outputs from sub-DMU 1 that become intermediate inputs to sub-DMU 2. For sub-DMU 1 to produce interest income, the division needs to employ people (captured by personnel expense) and incur interest expense as it pays depositors. Those loans written by sub-DMU 1 that become impaired are captured by the non-performing loans ratio (i.e. impaired loans-to-gross loans) and treated as an undesirable output in efficiency analysis. Sub-DMU 2 also needs to employ people in order to generate non-interest income mainly in the form of fees and commissions but not every referral from sub-DMU 1 results in a sale for sub-DMU 2. Thus, the failure to convert referrals to fees and commissions is regarded an undesirable output for sub-DMU 2 and it is captured under the heading of ‘proportion of fruitless referrals’.

3. Method

3.1. Measuring technical efficiency with dynamic network DEA

The technical efficiency analysis in the current study is a prerequisite to cost efficiency analysis (i.e., a technically inefficient unit cannot be cost efficient). In the bank network setting depicted in Fig. 1, the ‘black box’ a. phrase used by [14], in the context of

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2 “Loan impairment” refers to a borrower no longer making the contracted repayments on a loan, or making repayments not in accordance with agreed frequency or amounts. Under the IFRS (International Financial Reporting Standards, [http://www.ifrs.org]), ‘impaired loans’ are considered to be the best measure of problem loans. A loan is considered ‘impaired’ if there is objective evidence of impairment (i.e. a “loss event”), and that loss event (or events) has an impact on the estimated future cash flows from the loan that can be reliably estimated ([20]).

A non-performing loan normally appears in a period following writing of that loan.
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