An Analysis of Korean Bank Performance Using a Double Bootstrapped DEA Analysis

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Abstract

The purpose of this study is to analyze the efficiency of Korean banks using a two-stage DEA (data envelope analysis) bootstrap procedure suggested by Simar & Wilson (2007). The study comes approximately two decades after the Korean financial crisis which had a devastating impact on the Korean banking sector and economy. The crisis exposed the underpinnings of extremely liberal lending policies which prompted numerous banking reforms by the government. In the first stage of the two-stage DEA procedure, the relative efficiency scores of Korean banks are estimated. Then, in the second stage, the effect of certain environmental variables is estimated using a truncated regression model. The results of this paper suggest a continuing tension between Korean bank profitability and bank revenue.

1. Introduction

Korea is one of the original modern economic miracles, increasing GDP by almost 7% annually over the 30 years (1965 to 1995) leading up the Asian Financial Crisis in 1997. This is more than China, Hong Kong, and Taiwan over the same period, and is comparable to the city-state of Singapore. Korean banks in combination with Korean business conglomerates known as Chaebol, were a critical component of this growth. However, the Korean financial crisis had a devastating impact on the Korean banking sector, and exposed several deficiencies which were contributing factors to the financial crisis. In response to the crisis, numerous significant banking reforms were implemented by the government.

This study comes approximately 20 years after the Korean financial crisis and both assesses the current levels of efficiency of Korean banks and identifies factors that currently influence Korean bank efficiency. The efficiency of Korean banks is assessed using a two-stage DEA (data envelope analysis) bootstrap procedure suggested by Simar & Wilson (2007). In the first stage the relative efficiency scores of Korean banks are estimated. Then, in the second stage, the effect of certain environmental variables is estimated using a truncated regression model. The two-stage DEA bootstrap procedure used in this paper increases the efficiency of estimates of the determinants of Korean bank efficiency relative to prior two-stage methods utilized to measure efficiency.

This study updates and improves upon past research on Korean bank efficiency. Following the Korean/Asian financial crisis in 1997, several authors studied Korean bank efficiency both leading up to and following the crisis. Gilbert and Wilson (1998) analyzed the effects of Korean banking liberalization efforts (privatization and deregulation) on 24 Korean banks (14 nationwide and 10 regional) during the 1980-94 time period. Malmquist indexes were used to decompose productivity changes into changes in efficiency and changes in technology. The authors found that during the 1980-94 time period of deregulation and privatization, banks significantly changed their mix of inputs and outputs. The changed mix of inputs and outputs resulted in increases in both productivity and potential output.

Hao, Hunter, and Yang (2001) also analyzed effects of Korean banking liberalization efforts. Their focus was on the productive efficiency of a sample of private banks (9 nationwide and 10 regional) over the 1985-95 period. The authors used a stochastic frontier cost function approach

to measure efficiency scores for the banks in their sample. In a second stage efficiency regression the authors identified important drivers of operating efficiency. Their results indicate that the most efficient banks were those with higher rates of asset growth, lower expense ratios, larger amounts of core deposits, and few employees per mission won of assets. They also found that the financial deregulation of 1991 did not have a significant effect on bank efficiency.

Park and Weber (2006) estimated Korean bank inefficiency and productivity changes over the 1992-2002 period. Estimates of inefficiency were derived from the directional technology distance function. The authors aggregated individual bank inefficiency and productivity growth to the industry level. They found that technical progress during the 1992-2002 period outstripped efficiency declines to produce a net increase in banking industry productivity.

Sufian (2011) analyzed the sources of inefficiency in the Korean banking sector over 1992-2003 time period. Three different approaches were used to measure how efficiency scores vary with changes in inputs and outputs: an intermediation approach, a value-added approach, and an operating approach. Using multiple approaches allowed the author to determine if different definitions of inputs and outputs affect the measured efficiency levels. Technical efficiency was sensitive to the definition of inputs and outputs – with efficiency levels highest using an operating approach and lowest using an intermediation approach. The decline in Korean bank efficiency over the period was found to be due to scale, with banks either too small to benefit from economies of scale or too large to be scale-efficient.

The paper proceeds as follows. Section 2 of the paper discusses the history of the Korean banking sector. Due to the integral nature the banking sector played in growth of the Korean economy, the banking sector review largely summarizes the Korean Miracle economic growth story while discussing the close connection between banks, the government, and the large business conglomerates known as Chaebol. Section 3 of the paper describes the DEA technique for identifying bank efficiency and also the bootstrapping and double bootstrapping processes utilized to improve the estimate of banking sector efficiency. Section 4 of the paper discusses the results of the double bootstrapped estimates of Korean bank efficiency and identifies the most important contributors to Korean bank efficiency. Section 5 concludes the paper by discussing the key insights from the empirical analysis.

2. History of the Korean Banking Sector

Since 1945, the Korean banking sector has undergone significant changes. At the end of the Japanese occupation (1910-1945), Korea inherited a few modern commercial banks from the Japanese colonial era. Although political instability prior to the establishment of the Republic of Korea in 1948 resulted in severe dislocation of the financial system (Gilbert & Wilson, 1998), by 1950, several central bank and general banking statutes were passed by the newly formed National Assembly. These statutes included the Bank of Korea Act of 1950, which led to the creation of a central bank. Shortly afterwards, the Bank of Korea enacted several policy measures that laid the foundation for sound banking guidelines (Park & Weber, 2006) and provided the basis for the reorganization and nationalization of the privately-held colonial-era commercial banks under the General Banking Act of 1950 (Gilbert & Wilson, 1998). However, implementation of the act was delayed by the Korean War (1950 – 1953). After the 1954 signing of the Korean War Armistice, existing privately-held commercial banks were nationalized for the purpose of reconstruction and redevelopment of industries which suffered during the war. (Park & Weber, 2006)

In 1960, a newly elected government began privatization and autonomy efforts through divestment of ownership interest in the commercial banks. However, by 1961 a military coup and regime change headed by President Park Chung-hee resulted in the end of privatization

efforts and the renationalization of five nationwide banks. (Park & Weber, 2006) After two years of lackluster economic performance, in 1963 the Park government instituted the first of a series of five-year government plans that "reflected a strong commitment to industrialization and an important role for the state in this process." (Noland, 1996)

The next approximate 35 years were marked a period of heavy government intervention into the banking sector, including the establishment of several categories of banks/financial institutions with varying roles in the financial industry (nationwide commercial banks, regional commercial banks, specialized banks, and non-bank financial institutions), specifying the business scope of the various financial institutions (Lee, 2000), appointing top managers at banks (Gilbert & Wilson, 1998), setting interest rates on loans and deposits at banks (Gilbert & Wilson, 1998; Hao et. al., 2001), targeting certain industries and firms as recipients of loans (Hao et al., 2001; Noland, 1996; Park & Weber, 2006) while restricting loans to other firms/industries (Banker et al., 2010), subsidizing loans to targeted industries, firms, and projects (Gilbert & Wilson, 1998; Noland, 1996), promoting consumer savings via national saving campaigns and control of interest rates (Banker et al., 2010; Noland, 1996), restricting shareholder influence over banks (Lee, 2000), and limiting foreign involvement in Korean banking market through such means as imposing currency exchange controls (Gilbert & Wilson,1998), limiting foreign investment in Korean banks (Noland, 1996), limiting entry into the Korean market by foreign banks, and limiting foreign borrowing by Korean firms through loans (Gilbert & Wilson, 1998) or bond sales (Noland, 1996).

Over this approximate 35 year period, the Korean banking system and Korean savings were essentially used by the government as a vehicle by which it implemented the national industrial policy delineated in its five-year plans. (Banker et al., 2010; Borensztein and Lee, 1999) Due to the essential nature of the banks to Korea's industrial policy, in particular, to the success of large conglomerate companies called chaebols (see discussion below), the government provided an implicit safety net for Korean banks. (Lee, 2000)

In the 1960s, following the nationalization of five existing commercial banks and the first five-year government economic plan, several new banks were developed or allowed to form. Specialized banks were established by the government to finance government targeted industries. (Park & Weber, 2006) In the late 1960s, in an attempt to stimulate and balance local and regional economic development, privately owned regional commercial banks which were only allowed to operate within their own provinces were developed. (Gilbert & Wilson, 1998) Then, during the 1970s, tightly regulated nonbank financial institutions were introduced in an effort to attract funds and introduce competition into the market by diversifying financing sources. (Hao et al., 2001)

During the 1960s and 1970s, national and regional commercial banks, through the provision of financing to specific industries targeted for economic development, were the primary tool used by the government to institute its five-year economic plans which defined Korea's industrial policy aimed at rapidly developing and industrializing the Korean economy. (Park & Weber, 2006; Ji and Park, 1999) "Toward the latter part of the 1970's, policy loans, i.e., loans which supported government programs, accounted for nearly 80% of domestic credit extended during the period." (Hao et al., 2001)

Much of the financing provided by Korean banks to targeted industries, particularly during the 1970s, occurred via large industrial groups, or conglomerates, known as chaebols. As a result of the government's five-year economic plans, chaebols were given government protections, special privileges, access to capital, and subsidized loans in order to help nascent Korean

industries develop and compete internationally and hence accelerate Korea's economic growth. (Borensztein and Lee, 1999; Lee, 2000)

During the 1970s, a close relationship developed between the chaebols, the Korean banking sector, and the government, giving the chaebols privileged access to capital. The chaebols, in combination with "the government-controlled banking system which channeled consumer savings" to the chaebols, are felt to have been critical to the successful and rapid growth in the Korean economy during the industrialization period leading up to the Asian financial crisis. (Banker, Chang, & Lee, 2010) However, after industrialization, that same close relationship is considered by many to have become a hindrance to future economic growth. (Lee, 2000) This was an opinion even expressed by government of Korea. (Leipziger and Petri, 1993; Yoo, 1998; Borensztein and Lee, 1999)

In the 1980s, the Korean government began to loosen its tight grip over the banking industry with the reforms aimed at deregulation and privatization. Many of these reforms were brought about by the 1982 General Banking Act and a new five-year economic plan. During this time period, all remaining nationalized nationwide commercial banks were privatized, six new nationwide commercial banks came into existence as restrictions on the formation of new banks were removed, banks were given more discretion over their internal affairs as numerous regulations governing the internal management decisions and restrictions on business activities were abolished or simplified, controls over interest rates on loans (and deposits) were loosened or removed as the government increasingly relied on reserve requirements and monetary aggregates to reach its goals, entry barriers to non-bank financial institutions were reduced, loan regulations shifted from policy preference loans (for example, to chaebols) to minimum loan amounts for small to medium sized businesses (Noland, 1996), and exchange controls and restrictions effecting foreign ownership of Korean firms were relaxed. (Gilbert & Wilson, 1996) Perhaps most importantly of these reforms during this period was that "the government shifted its policy from supporting large companies to restricting chaebols' economic power and enforcing competition policies." (Lee, 2000)

In the 1990s the Korean government engaged in another round of bank reforms – this time promulgated by pressure from the Organization of Economic Cooperation and Development and United States to open its financial markets. The result was two revisions to the General Banking Act with the first occurring in 1991 and the second in 1997. The result of these changes in the 1990's was that "interest rates were deregulated, policy loans and other credit controls were eliminated, reductions in non-performing loans were targeted, foreign exchange market transactions were deregulated, and bank ownership was restructured to allow individual shareholders up to a 12% equity stake." (Park & Weber, 2006) Additionally, during the 1990s, the government instituted a deposit insurance program for Korean banks. (Kataoka, 2001)

Despite the financial sector reforms of the 1980s and early to mid-1990s, many felt that by the advent of the Korean financial crisis in 1997, the government still exerted heavy influence over the banking industry. One of the most important ways the government continued to exert its influence was by impacting which firms/industries received loans. (Banker et al., 2010; Borensztein and Lee, 1999; Gilbert & Wilson, 1998; Lee, 2000; Noland, 1996)

A primary source of the government influence over who received loans was its influence over the appointment of top managers at banks and other financial institutions. (Borensztein and Lee, 1999; Gilbert & Wilson, 1998; Kataoka, 2001; Lee, 2000; Noland, 1996; Park & Weber, 2006). It is perhaps not surprising that bank lending continued to be aggressive and high-risk during the 1980s and early to mid-1990s, with little attention paid to the creditworthiness of borrowing

firms. (Banker et al., 2010; Borensztein & Lee, 1999; Gilbert & Wilson, 1998; Kataoka, 2001; Lee, 2000; Park & Weber, 2006; Corsetti et al., 1999)

Aggressive and high-risk bank lending was reflected in the poor balance sheets of Korean banks (Banker et al, 2010), the low average rate of return on Korean bank assets, a rate which was among the lowest in the emerging economies at the time (Goldstein & Turner, 1996, Table 5), the extremely low profit margins in the Korean manufacturing sector (Borensztein and Lee, 1999), the extremely low return on invested capital (ROIC) for chaebol (Corsetti et al., 1999), the high ratio of corporate interest payments to sales (Gobat, 1998), the low ratio of corporate operating income to interest payments, or interest coverage ratio (ICR) (Corsetti et al., 1999), and the weak relationship between the allocation of credit and the profitability of investment (Borensztein and Lee, 1999).

Ironically, some recent financial reforms leading up to the Korean financial crisis - allowing entry into the banking market (thus promoting competition) and significantly lifting restrictions on foreign borrowing (Chang et al, 1998) – contributed towards the 1997 crisis. These financial reforms did so by operating complementarily with the tight bank-chaebol-government relationship, the moral hazard problem (Hahm & Mishkin, 2000) created by the government's previous "too big to fail" policy for chaebols (Borensztein & Lee) and banks (IMF, 1988), and lax government banking supervision of financial institutions (Hahm & Mishkin, 2000) to produce excessive risk-taking which ultimately resulted in wide scale corporate failure in the Korean economy.

The Korean government's financial reform of allowing nonbank financial institutions (NBFIs) to enter into market beginning in the 1980s, particularly the proliferation of merchant banks in the 1990s, resulted in heavy ownership of the NBFIs by chaebols. (Hahm & Mishkin, 2000) This cross ownership, combined with low government restrictions and oversight of lending to chaebols by these new financial institutions compared to traditional banks, resulted in the NBFIs increasingly funneling loans to chaebols compared to traditional banks. (Kihwan, 2006). By the late 1990s, the debt to equity ratio of most chaebols was extremely high, exceeding 400 percent. (Baek et al., 2004; Banker et al., 2010; Gobat, 1998)

Meanwhile, both the merchant banking industry and the traditional Korean banks/financial institutions increasingly utilized short-term foreign debt to finance their investments, chiefly loans to chaebols. The extremely high debt levels in the late 1990s were exacerbated by the fact that the share of short-term debt in total debt was also high. (Chang et al, 1998; IMF, 1998)

When chaebols had problems paying their debt, the government broke from prior policy of bailing out or restructuring the chaebols or their lenders (Gobat, 1998) due to the excessive perceived costs of a bailout compared to prior debt-crisis bailouts in 1972, 1979-83, and 1984-88. (Joh, 2004) By 1997, "creditors realized that the government was willing to break from past policy and let poorly managed big businesses fail." (Gobat, 1998) The result was that "foreign banks demanded repayment of the short-term loans given to Korean financial institutions rather than rolling them over to the following year, which had been the usual practice." (Joh, 2004) "Due to their size and importance in subcontracting, the failure of these chaebols had a devastating impact on the economy …" (Joh, 2004) "The string of bankruptcies and financial distress that affected the Korean corporate sector in 1997 translated into serious financial difficulties for the banking system…" (Corsetti et al., 1999) Ultimately, "high leverage and excessive short-term debt [held by foreign countries] ma[de] Korean companies vulnerable to economic downturns, changes in financing costs, and changes in creditor perceptions" (Gobat, 1998), thus precipitating the 1997-1998 Korean financial crisis.

"In early December 1997, when the IMF announced its US$ 57 billion bailout package for South Korea, the Korean banking sector was on the verge of collapse." (Cho & Kalinowski, 2010)

While the inexorable expansion of size/scale and market share of the chaebols at the expense of profit through the use of Korean financial system was arguably effective at helping promote Korean economic growth up to the 1990s, with the advent of the Korean financial crisis it became increasingly clear that in order for the Korean economy to remain successful, significant further and real banking reform would have to be instituted to reduce the influence over the financial sector by the government and the chaebol.

Perhaps the most important post-crisis Korean banking industry reform measure insofar as breaking the tie between the government/chaebol and the banking industry was the increase in foreign access to the Korean banking market: "In May 1998, the government abolished the remaining barriers to foreign entry into the domestic financial markets … The market share of foreign-owned banks including foreign bank branches, measured in assets, increased from 8.1 percent in 1997 to 31.1 percent at the end of 2005… [Meanwhile,] the average ratio of foreign equity shares in the Korean banking sector accounted for 55 percent as of end-2005, the sixth highest in the world. This was a dramatic change compared with the closed banking market before the 1997 crisis." (Cho & Kalinowski, 2010)

Other important reforms instituted in the aftermath of the financial crisis included strengthening prudential regulation of banks by bringing them into line with international best practice, improving transparency by introducing new disclosure requirements, and legislative provisions to promote the development of financial holding companies to strengthen financial institutions' competitiveness through an increase in the scale and scope of their business. (Kim et al., 2006)

These post-crisis reforms occurred concurrently with a government led restructuring of the banking sector. "The first phase between 1998 and 2000 was dominated by the government efforts to avert the systemic failure of the banking sector through nationalization and the injection of massive public funds. The second phase, after basic banking stability was restored in 2001, can be characterized by" re-privatization and then strategic mergers that resulted in a massive consolidation of the Korean banking sector. (Cho & Kalinowski, 2010)

In the wake of the Korean financial crisis the Korean financial sector has been characterized by an increase in the quality of assets, increased profitability, an increased share of the financial market by banks, increased market concentration, and an increased market share for foreign banks. (Kim et al., 2006)

This current study allows us to assess the efficiency of Korean banks approximately 20 years after the Korean financial crisis and approximately 10 years after completion of the most significant reforms and banking industry restructuring following that crisis.

3. Bootstrapping Process

3.1 Obtaining Efficiency Scores Using the DEA Technique

Data Envelope Analysis (DEA), which takes a non-parametric approach, is a very widely used method of gauging the productivity of firms. Since our study aims to identify the environmental components that might have an impact on the efficiency of Korean banks through a truncated regression analysis, we must first conduct a traditional DEA analysis to obtain the dependent variable utilized for the advanced investigation in the bootstrapped regression analysis. Even though there have been many developments and variants of the DEA model

since the inception of the CCR model, we will anchor our initial analysis to the original CCR input-oriented model due to its conciseness and clarity of the theoretical background.

The model is expressed as follows:

$\min \theta$

$s.t.$

$Y\lambda \geq y_0$

$\theta x_0 - X\lambda \geq 0$

$e\lambda = 1$

$\lambda \geq 0, (j = 1,2,3,...,J)$

3.2 Smoothed Bootstrapping

Despite the great feature of the theoretical background in its own support, the DEA model still suffers from the fact that the model, deterministic in nature, is sensitive to the sampling variation in obtaining the true frontier since the outcome (i.e. efficiency scores) is derived from the limited samples (Simar and Wilson, 1998, 2000). In order to circumvent the issue, Simar and Wilson (1998) proposed applying the bootstrapping technique introduced first by Efron and Tibshirani (1993), which might mitigate the sensitivity of the sampling variation. Hence, before moving forward to the next phase of our analysis, we have implemented the smoothed bootstrap of Simar and Wilson (1998) to further our understanding of the statistical sensitivity of the DEA model. The algorithm for deriving several bootstrap replications with respect to DEA efficiency is as follows:

Step 1: Compute the original efficiency scores for each of seventeen Korean banks, θ_i , which are greater than or equal to the one from the CCR input model.

Step 2: Conduct the naive bootstrap estimates to obtain β_i from the sample with replacement.

Step 3: Construct a pseudo-data set as $\{x_i^*, y_i^* = y_i * (\theta_i / \tilde{\beta}_i)\}$,

where,

$$\tilde{\beta}_i = \begin{Bmatrix} \beta_i + h\varepsilon_i \, if \, \beta_i + h\varepsilon_i \geq 1 \\ 2 - (\beta_i + h\varepsilon_i) \, otherwise \end{Bmatrix}$$

h = bandwidth parameter, one of which could be h= $0.9An^{-1/5}$ used by Silverman (1986), Desli and Ray (2004), and Lothgren (1998)

ε_i = random error i drawn from standard normal deviation

A= min (standard deviation of θ, interquartile range of θ/1.34)

σ_θ^2 = variance of initial DEA efficiency score

Step 4: Repeat step 3 B times, typically 1,000 times, to compute β_{Bi}^* as follows:

$$\beta_{Bi}^* = \overline{\beta} + \left[(\tilde{\beta}_{Bi} - \overline{\beta}) / (1 + h^2 / \sigma_\theta^2 \right]^{1/2}$$

where,

$$\overline{\beta} = \frac{\sum \tilde{\beta}_{Bi}}{n}$$

Step 5: Obtain $\beta StarAvg_i = \frac{\beta^*_{Bi}}{B}$.

Step 6: Compute necessary statistics such as bias or confidence intervals.

3.3 Double Bootstrapping

Simar and Wilson (2007) argued that previous studies that employed a two-stage approach for DEA were flawed in two ways. First, the studies did not take account of the date generating process (DGP), which is a mimicking process to simulate the sampling distribution of interest, leaving suspicion on the accuracy of the estimation of productivity. Particularly when a study uses a small sample size, the basic assumption of independence in the censored (Tobit) regression analysis without proper statistical underpinning is violated.

The second issue, which is more serious, is that DEA scores tend to be correlated since a score of one data making unit (DMU) is the product of the other ones within the same data set. The correlation effect might result in second stage estimates which are inconsistent and biased.

To circumvent these dependency issues, Simar and Wilson (2007) proposed a new algorithm of double bootstrapping and advocated using the truncated regression model instead of the censored (Tobit) model in the second stage.

Regarding usage of the truncated regression model, Simar and Wilson (2007) argued that it is preferable to the Tobit model since the Tobit model accommodates truncation for the dependent variable below zero, but allows the dependent variable to go to infinity in the positive direction. On the other hand, the truncated model defines the domain of the dependent variable only between zero and one, as the DEA index structure cuts off other regions in both directions.

Addressing the two flaws, the Simar & Wilson algorithm entails the following seven steps:

1. Calculate $\hat{\delta}_i$ for each bank using the original data.
2. Apply Maximum Likelihood estimation in the truncated regression of $\hat{\delta}_i$ on z_i, to obtain an estimate $\hat{\beta}$ of β and an estimate $\hat{\sigma}_\varepsilon$ of σ_ε.
3. Repeat B_1 times to yield seventeen sets of bootstrap estimates $\left\{\hat{\delta}_{i,b}^* \quad b = 1,...B_1\right\}$.

   a) Draw ε_i from the $N(0, \hat{\sigma}_\varepsilon^2)$ distribution with left-truncation at $(1 - \hat{\beta} z_i)$.

   b) Compute $\delta_i^* = \hat{\beta} z_i + \varepsilon_i$.

   c) Reconstruct a pseudo data set (x_i^*, y_i^*), where $x_i^* = x_i$ and $y_i^* = y_i \hat{\delta}_i / \delta_i^*$.

   d) Obtain a new DEA estimate $\hat{\delta}_i^*$ using the new data (x_i^*, y_i^*).
4. Compute the bias-corrected estimator $\hat{\hat{\delta}}_i$ as follows:

$$\hat{\hat{\delta}}_i = \hat{\delta}_i - \hat{bias}_i$$

where $\widehat{bias}_i = \left(\frac{1}{B_1} \sum_{b=1}^{B_1} \hat{\delta}_{i,b}^{*} \right) - \hat{\delta}_i$.

5. Use the Maximum Likelihood method to estimate the truncated regression of $\hat{\hat{\delta}}_i$ on z_i, yielding an estimate $\hat{\hat{\beta}}$ of β and an estimate $\hat{\hat{\sigma}}$ of σ_ε.
6. Loop over the next three steps (a-c) B_2 times to acquire a set of B_2 bootstrap estimates $\left\{ (\hat{\hat{\beta}}_b^{*}, \hat{\hat{\sigma}}_b^{*}) \quad b = 1,...,B_2 \right\}$.

   a) For each bank i=1,…n, ε_i is drawn from the $N(0, \hat{\hat{\sigma}})$ distribution with left truncation at $(1 - \hat{\hat{\beta}} z_i)$.

   b) For each bank i=1,…n, $\delta_i{**} = \hat{\hat{\beta}} z_i + \varepsilon_i$ is computed.

   c) Use the Maximum likelihood method for the truncated regression of $\delta_i{**}$ on z_i, obtain an estimate of β, $\hat{\hat{\beta}}^{*}$ and an estimate of σ_ε, $\hat{\hat{\sigma}}^{*}$.

7. Finally, using the estimate $\hat{\hat{\beta}}^{*}$ of β and $\hat{\hat{\sigma}}^{*}$ of σ_ε, construct $(1-\alpha)$ percent confidence intervals of the *j*-th element β_j of the vector β.

4. Empirical Results

4.1 Analysis of Bootstrapped DEA Indices

In the initial analysis of our study we derive efficiency rates for each of the seventeen Korean commercial banks in year 2014. The data set included outputs of interest revenue and non-interest revenue, and inputs of deposits, number of employees, and capital. The data were acquired from the Financial Supervisory Service (FSS) in Korea which releases bank statistics once a year. The original data contains some negative values for non-interest revenue. Hence, we added a certain number to all non-interest revenue data so that all values were above zero based on the translation invariance theorem, which denotes that translation of the original observations results in a new problem that has the same optimal solution for the envelopment form as the old one (Cooper et al. 2007).

We used the 'rDEA' package embedded in R to implement the algorithms. However, we additionally had to code up in R since the package was not sufficient to conduct all necessary analyses in our study.

In order to provide an overview the variables employed in this study we start our analysis by presenting the descriptive statistics for the original data set in Figure 1.

Figure 1: Descriptive Statistics

	Interest revenue	Non-int. revenue	Deposit	Number of employees	Capital
Mean	20292	3043	801874	6922	88590
Median	12571	1876	374337	3478	60429
Max	50830	9402	2368266	21283	211559
Min	924	19	29821	416	3342

Figure 2 presents both the smoothing and double bootstrapped efficiency scores along with the original DEA index for Korean banks that are classified as three different types: national, local, and specialized banks. The original mean DEA scores for national banks, local banks, and specialized banks are 0.786, 0.947, and 0.951, respectively. This implies that specialized banks -- banks that target specific customer groups such as those engaged in agricultural or ocean production or small to medium sized businesses -- and local banks, targeted to serve regional customers, are more productive than other bank groups.

Figure 2 also shows that overall specialized banks are very efficient, with two specialized banks, Development and Industrial, lying on the efficient frontier of the estimated DEA model. Local banks also demonstrate a high performance rate, also having two banks on the efficient frontier, Cheju and Jeonbuk.

On the other hand, the national banks are the least efficient in their operations, due possibly to their larger size. When the business size is large, the magnitude of operational profit might be greater than that of the smaller banks. However, a firm's productivity does not necessarily increase proportionately to the size of the firm. Hence, the national banks in Korea might have large room for improvement in their operational efficiency.

Figure 2 also illustrates the bias in estimates of DEA efficiency for each bank from the smoothed bootstrap technique, with an average bias of 0.102. This bias estimate gauges the sensitivity of the measurement of productivity in Korean banks arising largely from the sampling differences. Even though specialized banks are the most efficient in their productivity among the three bank groups, the average bias for specialized banks is the largest, followed by local banks. This might imply that the sampling instability is relatively high with the specialized banks compared to other groups. Based upon the new scores after adjusting the bias, local banks were deemed overall most efficient.

Figure 2 also illustrates that the double bootstrapping method produces similar outcomes to the smoothed bootstrapping technique in terms of the order of mean values of bias corrected efficiency indices among the three bank groups -- the local bank group was the highest, followed by specialized banks and then national banks. However, all the three groups are consistent in that the bias corrected scores from the double bootstrapped technique tend to be closer to the original DEA indices compared to those obtained from the smoothed bootstrapped technique. This implies that the second bootstrapping resulted in a higher smoothing effect as deviations from the original scores decreased.

Despite the tendency of the second bootstrapping to yield estimates closer to the original values in biased corrected scores, they still reveal quite a large difference compared to the original scores. For example, the national bank group has a difference of 0.048, local group of 0.042,

specialized group of 0.092, and overall of 0.055. Additionally, the measured bias (the difference between the original values and bias corrected scores) is positive for all bank banks. This observation is consistent with the previous literature, for instance, Halkos and Tzeremes (2013) and Roman et al (2014).

Figure 2: Smoothed and Double Bootstrapped Efficiency Scores

Type	Bank	DEA	B. corrected		Bias		Lower Bound		Upper Bound	
			S.	D.	S.	D.	S.	D.	S.	D.
	Woori	0.756	0.703	0.733	0.053	0.023	0.684	0.714	0.739	0.761
	K. SC	0.803	0.704	0.727	0.098	0.076	0.645	0.695	0.793	0.748
	Hana	0.774	0.716	0.743	0.057	0.031	0.694	0.725	0.757	0.768
	Exchange	0.747	0.677	0.702	0.070	0.045	0.642	0.689	0.721	0.719
Nat.	ShinHan	0.776	0.704	0.726	0.072	0.05	0.667	0.713	0.749	0.742
	K.City	0.955	0.840	0.867	0.115	0.088	0.770	0.814	0.933	0.906
	Kookmin	0.693	0.629	0.668	0.064	0.025	0.597	0.654	0.683	0.694
	Mean	**0.786**	**0.710**	**0.738**	**0.076**	**0.048**	**0.671**	**0.715**	**0.768**	**0.763**
	Std. dev.	**0.081**	**0.064**	**0.061**	**0.022**	**0.025**	**0.054**	**0.049**	**0.080**	**0.068**
	Daegu	0.954	0.869	0.919	0.084	0.035	0.830	0.897	0.938	0.953
	Busan	0.977	0.903	0.950	0.074	0.027	0.873	0.926	0.955	0.987
Local	Kwangju	0.895	0.800	0.862	0.095	0.033	0.748	0.838	0.870	0.897
	Cheju	1.000	0.814	0.942	0.185	0.058	0.677	0.896	1.059	1.001
	Jeonbuk	1.000	0.830	0.959	0.169	0.041	0.707	0.924	0.976	1.020
	Kyongnam	0.858	0.783	0.831	0.074	0.027	0.748	0.814	0.839	0.858
	Mean	**0.947**	**0.833**	**0.911**	**0.114**	**0.042**	**0.764**	**0.882**	**0.940**	**0.953**
	Std dev	**0.058**	**0.045**	**0.052**	**0.050**	**0.011**	**0.074**	**0.046**	**0.078**	**0.063**
	Develmt	1.000	0.815	0.812	0.184	0.188	0.679	0.770	1.072	0.858
Spec.	Industrial	1.000	0.832	0.871	0.167	0.129	0.714	0.813	0.990	0.916
	Ag. Coop.	0.853	0.779	0.826	0.074	0.027	0.744	0.807	0.848	0.857
-	Suhyup	0.953	0.847	0.929	0.105	0.024	0.788	0.908	0.928	0.965
	Mean	**0.951**	**0.819**	**0.859**	**0.132**	**0.092**	**0.731**	**0.824**	**0.959**	**0.899**
	Std. dev.	**0.068**	**0.029**	**0.052**	**0.051**	**0.081**	**0.046**	**0.058**	**0.095**	**0.052**
O.all	**Mean**	**0.882**	**0.779**	**0.827**	**0.102**	**0.055**	**0.718**	**0.800**	**0.873**	**0.862**
	Std. dev.	**0.106**	**0.076**	**0.095**	**0.045**	**0.054**	**0.070**	**0.090**	**0.120**	**0.106**

The last two columns in the Table 2 construct the upper bond and lower bound of the estimated values.

Simar and Wilson (2000) suggested the following way of constructing the estimated $(1-\alpha)$ percent confidence interval of the *j*-th element β_j of the vector β:

$$\text{Prob}\left(Lower_{\alpha,j} \le \beta_j \le Upper_{\alpha,j}\right) = 1-\alpha,$$

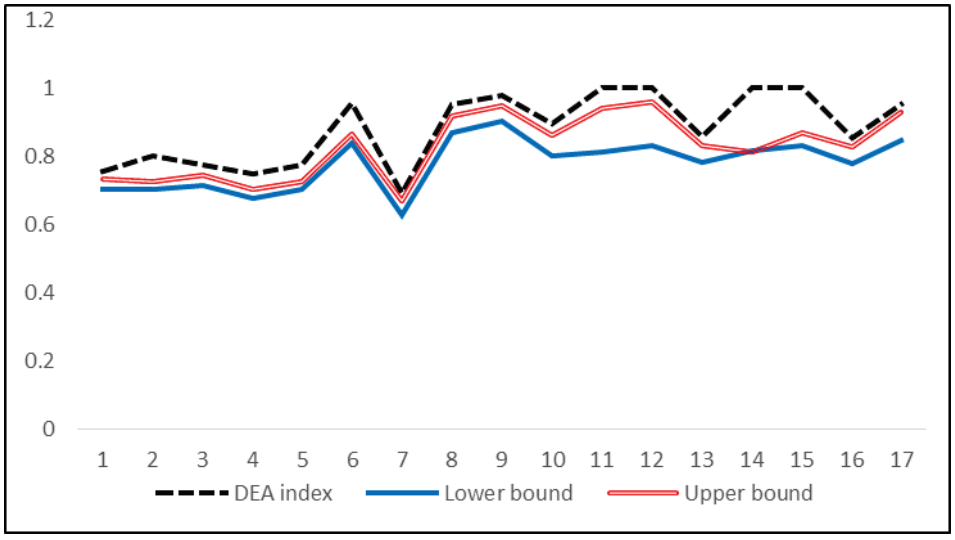
where α is some small value denoting the probability of committing type 1 error (we used the α level of 0.05 in our study). $Lower_{\alpha,j}$ and $Upper_{\alpha,j}$ are calculated using the empirical intervals obtained from bootstrapped results. Thus,

$$\text{Prob}(-\hat{b}_\alpha \le \hat{\hat{\beta}}_j^* - \hat{\hat{\beta}}_j \le -\hat{a}_\alpha) \approx 1-\alpha$$

where $Upper_{\alpha,j} = \hat{\hat{\beta}}_j + \hat{b}_\alpha$ and $Lower_{\alpha,j} = \hat{\hat{\beta}}_j + \hat{a}_\alpha$.

Figure 3 displays the lower and upper confidence interval bounds for the double bootstrapped DEA estimates among the seventeen Korean banks. The confidence intervals displayed suggest some interesting observations. First, the 95% confidence intervals generally display a narrow gap (interval) for the DMUs in the national group (numbers 1-7). Meanwhile, the gap (interval) for the specialized banks (numbers 8-13) is wider, while the gap (interval) for the local banks (14-17) is the widest. Second, the double bootstrapped DEA scores (center of the gap / confidence interval) for the national banks are closer to the original DEA scores than both the local and specialized banks indicating a lower degree bias in the original estimates for the national banks. Despite the larger 95% confidence intervals for local and specialized banks, the confidence intervals do not include the original DEA score estimate. Hence, for every bank, a hypothesis test that the double bootstrap estimate equaled the original DEA score estimate would be rejected at the 5% significance level.

Figure 3: Bias Corrected Double Bootstrapped Index



4.2 Truncated Regression Analysis

The major purpose of this study is to identify the impacts that external environmental variables have on the productivity of seventeen Korean banks. This is done by regressing the efficiency scores derived from the double bootstrap algorithm proposed by Simar and Wilson (2007) on environmental variables. The environmental variables employed in our work are ROA (Return

on Assets), Age (number of years in operation since the bank was first established), securities, and type (national banks and local banks are treated as binary variables). Thus, the second stage regression model can be expressed as follows:

$$\delta_i ** = \hat{\hat{\beta}} z_i + \varepsilon_i$$

Or, equivalently:

$$\delta_i ** = \beta_0 + \beta_1 (ROA)_i + \beta_2 (Age)_i + \beta_3 (Security)_i + \beta_4 (TypeNational)_i + \beta_5 (TypeLocal)_i + \varepsilon_i$$

Figure 4: Truncated Bootstrapped Regression Output

	Estimate	Std. Error	t-value	Pr (>|t|)
Constant	1.0471e+00	7.2855e-02	14.3723	2.2e-16 ***
ROA	-1.5783e-01	9.4841e-02	-1.6642	0.09607 *
Age	-7.2862e-04	1.0190e-03	-0.7150	0.47460
Securities	6.4225e-07	1.2259e-07	5.2390	1.615e-07 ***
Type National	2.7127e-01	6.1948e-02	4.3790	1.192e-05 ***
Type Local	1.4422e-01	5.9591e-02	2.4202	0.01551 **
Sigma	6.9622e-02	1.3196e-02	5.2761	1.320e-07 ***

***: 0.01 significance level, **: 0.05 significance level, *: 0.1 significance level

From Figure 4 it can be observed that securities and bank type were significant variables; securities at the level of 0.01, type National at 0.01, and type Local at 0.05. This implies that the securities of each bank and bank type are likely important determinants of efficiency scores for each bank (DMU). However, the variables ROA and age were either weakly significant or insignificant. Thus, the ROA and age variables are not important environmental factors in determining the operational efficiency of Korean banks.

A more detailed discussion on each variable follows. First, the estimated coefficient on ROA was negative and barely significant at the level of 0.1. In the Korean banking sector history section of this paper, there was a discussion on aggressive and high-risk bank lending leading up to the financial crisis being associated with low measures of profitability, including return on assets (ROA). Thus, excessively large loan portfolios of Korean banks which generate large revenues (our measure of output in the DEA analysis) have traditionally resulted in lower measures of returns (e.g., ROA) for Korean banks. Hence, the negative sign on ROA may be indicative of the inverse relationship between profitability measures (like ROA) and efficiency measures based on revenue per unit of deposits, employees, or capital.

The second variable, age, has a negative coefficient but is insignificant. Meanwhile, the estimated coefficient on the third variable, securities, is highly significant. The securities variable largely represents non-loan assets on the balance sheet of banks which is generally highly correlated with the size of bank. Hence, the positive coefficient on securities likely represents the increased efficiencies of larger banks due to economies of scale.

Next, the estimated coefficients on type-national and type-local were positive and highly significant. This implies that area coverage and target customers might be critical factors in

determining Korean bank efficiency. This is not surprising given that specialized banks "were established to provide funds to particular sectors whose supply of funds through commercial banks was insufficient due to limited availability or low profitability." (Bank of Korea, 2008) Thus, the positive coefficient on type-national and type-local likely indicates their greater efficiency compared to specialized banks due to specialized banks focus on targeted industries which have been traditionally neglected by national and local banks because they are less financially appealing loan recipients. Currently Korea has seven national banks, six regional or local banks, and five specialized banks.

5. Managerial Insights and Conclusion

We have examined the efficiency level of 17 Korean commercial banks using the DEA methodology and also identified the components that influence bank efficiency in a second stage truncated regression analysis. Three key managerial insights can be derived from the results in our study.

First, this is the first study to employ a two-stage DEA bootstrap procedure based on the work of Simar and Wilson (2007) to increase the efficiency estimates of the determinants of Korean bank efficiency. Hence, this work builds on prior two-stage methods utilized to analyze the determinants of efficiency in the Korean banking sector – in particular, the work of Hao, Hunter, and Yang (2001).

In the second stage of the DEA bootstrapping process, we conducted a truncated regression analysis to determine the impact of environmental variables on bank efficiency. Among others, we singled out the variables return on assets (ROA), age, securities, and bank type (national, local, or specialized). The results revealed that securities, bank type, and ROA were significant.

A second key insight of this paper relates to the sign of the coefficient on ROA in the regression for the second stage analysis. In that regression, Korean bank efficiency was the dependent variable. Following popular convention in DEA banking sector papers, efficiency (the relationship of outputs to inputs) was measured using outputs focused on revenue generation – specifically, interest and non-interest revenue.

While one might expect a positive relationship between ROA and bank efficiency, the negative relationship is not surprising given the discussion in the Korean banking sector history portion of this paper: Leading up to the 1997 Korean financial crisis, aggressive and high-risk bank lending was reflected in numerous weak measures of profitability of Korean banks. While banks were effective at making a great number of revenue increasing loans throughout the post-World War II period leading all the way up to the financial crisis, the impact of those loans on Korean banks income statements was dubious, with across the board profitability measures at extremely low levels by international standards by the eve of the financial crisis.

While the efforts of the Korean government to expand the Korean economy in the decades leading up the financial crisis by strongly promoting loans to Korea Chaebol and other firms appear to have been successful at expanding loans and potentially increasing economic growth, these accomplishments came at the expense of bank profitability. Specifically, the negative coefficient on ROA shows the inverse relationship between loan revenue and our measure of bank profitability (ROA).

In the years between the end of World War II and the 1997 financial crisis, Korea rapidly converged on the levels of GDP per capita seen throughout the economically developed world. Korea is now one of the wealthier countries in the world with GDP levels just below that of the U.K., France, Japan, and Italy. However, Korea's rate of convergence on the United States has

greatly slowed since the 1997 financial crisis - in 1996 Korea's per capita GDP in U.S. $'s was just below ½ of the United States, while in 2017 it remains at just below ½ of the United States. (https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=KR-US)

Additionally, a 2016 McKinsey & Company research report revealed that Korean banks still have very low levels of profitability compared to much of the rest of the world – with returns on equity that are the lowest by far among the 14 Asian countries included in the regional report. (HV, 2016, Exhibit A)

The results of this paper, specifically the negative coefficient on ROA in the loan revenue regression, reveal the continuing tension between bank profitability and bank revenue. The Korean government may still be influencing Korean bank lending practices to this day. Meanwhile, the slowing rate of convergence of Korean GDP to that of the United States suggests that the optimal strategy for growth may change depending on where one is on the development path. That is, once a country is on the cusp of GDP levels seen in the most economically advanced countries, a change in banking policies may be called for to sustain convergence on the most advanced economies.

As a developed country, it may be time for a reassessment of the influence of the Korean government on Korean bank lending practices with a close eye to the optimality of such a strategy once a country has significantly narrowed its GDP gap relative to the rest of the economically developed world.

A third key insight in the paper relates to the implied coefficient on specialized banks in the second stage regression. Since both the national and regional/local bank binary variables had positive coefficients, the implication is that specialized banks had lower levels of efficiency compared to national and regional/local banks. The Korean government originally regulated banks to serve different target customers by diving them into three categories - national, regional/local, and specialized. In one sense, this is an encouraging policy since different group of customers receive better customized services from the specialized bank group. But the specialized bank category was specifically developed to serve sectors of the economy that were receiving insufficient funds according to government officials. The Korean government has pointed out that one reason for the lack of funds was the reduced profitability of investments (loans) in these neglected sectors. (Bank of Korea, 2008) However, as with the Korean government's industrial policy aimed at increasing bank loans across the banking industry (national, regional/local and specialized banks), the industrial policy of increasing bank loans specifically to neglected sectors may be a policy worth assessing now that Korea's rate of convergence on the most developed countries in terms of GDP per capita has slowed.

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