

Evaluating the Costs and Risks of Development Banks:
Theory and Case Studies

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1. Introduction

Development banks (DBs) play a significant role in capital allocation in the developing world. The combined assets of major multilateral development banks exceeded \$1.5 trillion in 2018. For single country DBs, assets totaled more than twice that of the multilateral banks.

Although the pros and cons of DBs have been widely debated in the literature, a critical piece of missing information has been the value of subsidies conferred by governments to the banks.¹ To begin to fill that gap, we develop a methodology to comprehensively evaluate subsidy costs and risk exposures for DBs. We plan to apply the approach in three case studies: (1) Korea Development Bank (KDB); (2) Brazilian Development Bank (BNDES); and (3) Agricultural Bank of the Republic of Turkey (Ziraat). Considering a variety of applications will illustrate how the basic methodology can be modified to accommodate unique features of different institutions. To date we have only done a comprehensive analysis of the KDB, and this draft reports on those results.

The methodology uses a contingent claims approach to estimate the subsidy costs of DBs on a fair value basis, and to quantify the associated financial risks. The application to the KDB demonstrates how the method can be implemented, some of the challenges involved, and the sensitivity of the results to variations in key assumptions. It also illustrates the significant

¹ La Porta et. al. (2002) and Caprio et. al. (2005) examine the performance of government-owned banks and their economic effects using a variety of metrics. A number of World Bank studies examine various aspects of these institutions (Luna-Martinez and Vicente, 2012 and references therein), and several case studies also shed light on their practices (e.g., Lazzarini et. al., 2011). There is disagreement about whether the activities of DBs are on net beneficial or deleterious to economic growth. Proponents argue that the investments provide vital infrastructure that otherwise would not be built, particularly in developing countries (e.g., Rodrik, 2004), and that DBs play an important countercyclical role (e.g., Griffith Jones et. al., 2010). Opponents contend that the DBs are often conduits of cheap and opaque loans to politically-connected firms. La Porta et. al. (2002) present evidence that higher rates of government ownership of banks is associated with slower subsequent financial development. Bulow and Rogoff (2005) suggest that direct grants are a more transparent way subsidize favored investments.

difference between official cost estimates and what is obtained using a market or fair value approach to subsidy estimation, which tends to produce much higher cost estimates. The analysis contributes to a growing body of literature aimed at increasing the transparency of government credit and other financial subsidies, and at better informing public investment decisions by applying the methods of financial economics to improve measurement of costs and risks (see Lucas, 2012 and 2014).

Governments primarily subsidize DBs via commitments to provide capital infusions should a bank experience financial distress, often at no cost to the DB. Those commitments effectively guarantee the debt and deposits of the DBs, which in turn allows them to borrow at low rates. Valuing these government capital commitments requires modeling the capital structure of the DBs and the decision rules of their managers, as well as taking a stand on the risk and returns of their investment portfolios. Other forms of assistance may include interest savings from government deposits or forced savings deposits, tax advantages, and other cash transfers. In return, governments may receive dividend payments and derive benefits from influencing investment decisions. The main focus here is on properly measuring the prospective cost of the capital infusions net of any dividend payments.²

Although DBs provide some information from which to infer subsidy costs in their financial reports, official subsidy estimates systematically understate the full cost of support. As discussed at length in Lucas (2014), the main reason for the understatement of subsidies is that taxpayer equity—typically for development banks in the form of paid-in and “callable capital” from governments—is effectively treated as requiring a zero rate of return, rather than a return

² The issue of subsidized deposits and forced investments also will be addressed in the BNDES case study because both are significant there.

that is commensurate with the cost of the risk ultimately borne by taxpayers. This is part of a broader mispricing phenomenon that arises from the fact that governments treat their cost of capital as their borrowing rate instead of a rate commensurate with the risk of the investment made.

Under the structural approach proposed here, DBs do not solve an explicit optimization problem. Instead, DB managers rebalance assets and liabilities according to adjustment rules that are calibrated to maintain a stationary target capital structure over time and that are consistent with regulatory directives, and with observed behavior and outcomes. Specifically, the model is parameterized to reproduce the value of certain observable outcomes such as the historical frequency of government capital infusions. There are at least two advantages of this approach relative to an explicit maximization framework: (1) The motivations of DBs go beyond profit maximization, for instance including industrial policy or development objectives, and it would be hard to know or accurately encapsulate those objectives in a model. (2) Specifying fixed adjustment rules allows valuations to be produced using Monte Carlo methods, whereas jointly solving for an optimal policy and the value of financial derivatives is computationally much more complex and limits the detail with which other important features of bank policy can be incorporated.

Technically the approach taken here builds on the foundational ideas in Merton (1974) and (1977) on valuing risky debt, and on extensions to more general capital structures in the spirit of Leland (1994), Leland and Toft (1996) and Collin-Dufresne and Goldstein (2001). It is most closely related to Lucas and McDonald (2006) and (2010), which develop models with a stationary mean-reverting capital structure to value government guarantees of Fannie Mae and Freddie Mac, and to Lucas (2014) which applies a closely related approach to the European Bank

for Reconstruction and Development. The model presented here differs from most of the earlier literature by replacing bankruptcy as the endpoint with the possibility of multiple capital infusions over a long horizon, by explicitly modeling risk differentials between asset classes, and by taking into account rebalancing between safe and risky asset classes.

The application to the KDB illustrates the significant magnitude of the differences between fair value and official subsidy cost estimates, and some of the practical challenges of implementing the proposed methodology. Under our preferred parameterization, we find that the prospective subsidy cost to the Korean government of providing contingent claims on government capital to the KDB over a 20-year period starting in 2013 is KRW 36 trillion (\$33 billion), or 25 percent of the bank's initial asset value. Annuitizing the cost over the 20 years at a 4 percent rate implies an annual cost of KRW 2.4 trillion, which can be interpreted as a fair insurance premium that the KDB would have to pay to the government annually if it were required to pay for the capital subsidy that it receives. If the bank had paid for that insurance, the expenditure would have more than doubled the KDB's reported losses in 2013.

Sensitivity analysis reveals the extent to which the estimated subsidies vary with assumptions about asset volatility, exogenous asset growth rates, the market risk premium on risky assets, the trigger rules for capital infusions, and so forth. For a wide range of plausible parameterizations the subsidy costs are significant. Importantly for transparency and informed decision-making by policymakers, recognizing those costs would reverse the KDB's self-assessment of being profitable in most years. Although it's very possible that those costs are outweighed by the (here unmeasured) benefits produced, the perception of a free lunch is contradicted by this new evidence on cost.

The rest of the paper is organized as follows. Section 2 provides background information on development banks and the structure of their financing. Section 3 describes the proposed methodologies for valuation and risk assessment. Section 4 applies the methodologies to the KDB. Section 5 concludes.

2. Background on Development Banks

Governments use DBs as instruments to promote economic growth by providing credit and advisory services that support the provision of infrastructure and other private and public investment projects. Credit is extended to small and medium sized enterprises, to large corporations, and to other financial institutions. DBs also hold cash and marketable securities for liquidity, and make a limited number of equity investments.

DBs alter the allocation of capital through at least distinct two channels:³ First, they provide access to capital for some projects that would not receive funding from the private sector, thereby increasing borrowing on the *extensive margin*. For instance, DBs may alleviate credit rationing and redlining that can arise for reasons related to asymmetric information (Stiglitz and Weiss, 1981) or contractual incompleteness. Some authors also point to the countercyclical role of DBs in providing financing. As public institutions, they also may fund projects that are politically but not economically justifiable. Second, DBs increase investment on the *intensive margin* by providing credit on more favorable terms than what would be offered by private sector banks. That effect causes some projects to be undertaken on a larger scale than they otherwise would have been.

³ See Lucas (2016) for a model of the effects of government credit support along the extensive and intensive margins, and an analysis that suggests the greater importance of the extensive margin.

DBs can be divided into two broad categories, multilateral and single country banks. Another major distinction between different DBs is the entities they lend to: some lend money only to other financial institutions, whereas most lend directly to end-borrowers, or to a combination of financial institutions and other borrowers.

Multilateral DBs are owned by large groups of countries. For instance, the Asian Development Bank has 67 member countries, of which 48 are from within Asia and the Pacific. Typically, members are obligated to commit equity capital to the bank up to an agreed-upon subscription amount, with the largest pledges coming from larger and richer countries. A portion of the pledged capital is paid into the bank up front, and the rest is callable, giving rise to the term “callable capital.” Calls occur when a DB requires additional equity, for instance because it experiences loan losses that increase leverage to unacceptably high levels. Capital, once called, generally is retained by the DB. However, DBs main source of funds is from issuing debt securities such as bonds and notes in public markets. DB debt issues tend to carry a high credit rating because of the protection provided by callable capital. As shown in Table 1, in 2018 the asset holdings of the largest multilateral DBs exceeded \$1.5 trillion.

Single country DBs also provide capital for infrastructure and other investments to a variety of borrowers that include private firms of various sizes, financial institutions and individuals. A survey sent to the 280 members of the World Federation of Development Banks by the World Bank yielded 90 responses about their activities, structure and challenges (Luna-Martinez and Vicente, 2012). The results indicate that 12 percent of the DBs were established before 1946, 49 percent between 1946 and 1989, and 39 percent between 1990 and 2011. At the end of 2009, survey respondents reported total assets of \$2 trillion, of which \$1.59 was in loans. Five were classified as megabanks, with assets over \$100 billion. The two largest respondents,

China Development Bank and the Brazil Development Bank (BNDES), together are larger than the World Bank Group. Most DBs are much smaller, controlling only a small share of assets in their country's banking system.

Single country DBs are funded in various ways, including taking deposits from the public, borrowing from other financial institutions, and issuing bonds in domestic or international capital markets. Equity capital is obtained through retained earnings and in some cases from explicit transfer arrangements with the government. Although a formal callable capital agreement is generally not in place for single-country banks, DBs benefit from implicit or explicit guarantees and periodic infusions of cash from the government that allow them to borrow on favorable terms that can be passed through to borrowers. Those commitments from the governments of single country DBs are economically similar to the capital commitments that support multilateral DBs, and can be valued using an identical approach.

3. Modeling the costs and risks to governments of development banks

In this section we describe a contingent claims pricing model designed to capture the salient features of multilateral and single country DBs, and the costs and risks they impose on governments via callable capital or debt guarantees. The model captures the fact that the sponsoring government(s) are exposed to losses when the leverage ratio of a DB falls enough to trigger an infusion of equity capital, usually in the form of a cash payment. Those equity infusions tend to occur during bad economic times that have high "state prices." Hence callable capital entails significant market risk, the cost of which is inferred from market data on the risk and returns of publicly traded financial institutions that engage in similarly risky investment

activities. Conceptually, the subsidy cost is then the present value of the cash flows associated with the commitment to infuse equity, net of any revenues collected, using market rates for discounting.

3.1. Valuation model

The stochastic cash flows between DBs and government sponsors are projected in two ways: using an actual or physical probability distributions and under a risk-neutral measure. The physical probability distribution is tracked in order to compute statistics related to the government's risk exposure. It is also essential for verifying that the calibration reproduces observed outcomes. A corresponding "risk-neutral" version of the model is used for valuation. Variables superscripted with " N " denote the risk-neutral representation, those with a superscript " P " denote the physical representation. The superscript is omitted for rules, variables and parameters that are identical in both cases. The risk neutral pricing approach used here differs from standard applications where market prices are available. Because shares in development banks are not publicly traded, the market cost of risk is inferred from an asset beta for the industry rather than from a market price of the underlying assets.

The assets of DBs are divided into two broad groups: risky and liquid. Risky assets include primarily loans, and also any investments in equity or other risky securities. Liquid assets include holdings such as short-term government securities. The DB's risky assets, A , evolve over time according to a discretized log-normal process, augmented to include the possibility of downward jumps, and of growth arising from exogenous adjustments in asset holdings by DB managers. Shocks to risky assets are the only source of uncertainty in the model. The actual and risk neutral processes respectively for risky assets are:

$$(1) \quad A_{t+h}^P = (1 - J \cdot I_J) A_t^P e^{(1+r_A + J \cdot p_J - .5\sigma_{A,t}^2)h + \sigma_{A,t}\varepsilon\sqrt{h}} + \Delta_{A,t}^P$$

$$(2) \quad A_{t+h}^N = (1 - J \cdot I_J) A_t^N e^{(1+r_f + J \cdot p_J - .5\sigma_{A,t}^2)h + \sigma_{A,t}\varepsilon\sqrt{h}} + \Delta_{A,t}^N$$

where h is the time step, t subscripts represent time, r_A is the expected rate of return on risky assets, r_f is the risk-free rate, $\sigma_{A,t}$ is the volatility of risky assets, J is the size of downward jumps, I_J indicates if a jump has occurred, p_J is the probability of a jump, ε is a draw from a standard normal distribution, and $\Delta_{A,t}$ is a discrete change in risky assets due to management or government decisions that exogenously affect balance sheet growth. The volatility parameter may be time-varying. The corresponding risk-neutral evolution of risky assets in equation (2) follows the same process, but with their r_A in place of r_f .

The evolution of liquid assets, B , is determined by the return on those assets and by exogenous adjustments by bank managers. The actual rate of return, r_B , is taken to be deterministic but slightly higher than the risk-free rate. The positive spread over the risk-free rate on liquid assets is included in order to make the assumed rates of return on the bank's liquid asset portfolio more realistic. The actual and risk neutral processes respectively for liquid assets are:

$$(3) \quad B_{t+h}^P = B_t^P e^{r_B h} + \Delta_{B,t}^P$$

$$(4) \quad B_{t+h}^N = B_t^N e^{r_f h} + \Delta_{B,t}^N$$

DBs finance asset-holdings primarily using debt liabilities that earn interest at a rate only slightly above a risk-free or government rate. Assets are financed with retained earnings and with capital provided by the government.

The evolution of liabilities, L , is similarly determined by their rate of return, which is paid out of new issuances, and by exogenous adjustments to liabilities by bank managers, $\Delta_{L,t}$. The actual and risk neutral processes respectively for liabilities are:

$$(5) \quad L_{t+h}^P = L_t^P e^{r_L h} + \Delta_{L,t}^P$$

$$(6) \quad L_{t+h}^N = L_t^N e^{r_f h} + \Delta_{L,t}^N$$

As for liquid assets, the actual return on liabilities is generally higher than the risk-free rate although default risk is minimal.

Equity is then the difference between assets and liabilities:

$$(7) \quad E_t^P = A_t^P + B_t^P - L_t^P$$

$$(8) \quad E_t^N = A_t^N + B_t^N - L_t^N$$

As elaborated on below, asset returns are reinvested or used to pay down liabilities. Exogenous changes by managers to assets and liabilities are subject to the natural adding up constraints. The government, which is assumed to be the only equity holder, receives no dividends but makes periodic cash infusions.⁴

3.1.1 Triggers for cash infusions and rebalancing

In the model, capital calls are triggered when large losses on risky assets that push a DB's leverage ratio over a fixed threshold. Less severe shocks, along with the differential returns on

⁴ Some DBs are partially owned by private investors and may pay dividends. The equations can be easily adjusted to accommodate that case.

assets and liabilities, cause deviations from other target ratios to open up over time. To avoid moving too far from target ratios, and consistent with observed behavior, managers are assumed to periodically rebalance assets and liabilities. Technically the rebalancing is important to maintain stationarity and to be able to align model and observed outcomes.

Specifically, capital is called and there is an infusion of cash from the government when the ratio of liabilities-to-equity, L_t/E_t , exceeds a fixed trigger value, L/E_{max} . The trigger is only checked periodically (e.g., quarterly or annually), to reflect that monitoring and the release of new balance sheet information is infrequent, for instance coinciding with quarterly financial reporting. For the purpose of calibrating the model, L/E_{max} can be based on the statutory rules governing leverage when they exist, or on the historical pattern of cash infusions when there is not a stated or binding policy rule.

When capital is called, it is in an amount that restores the target liability-to equity ratio, L/E^* . Similarly to the trigger value, the target ratio is fixed at a constant value based on statutory rules when they exist, and on available data about historical bank behavior when there is no formal policy rule. We assume that cash infusions are initially invested entirely in liquid assets. The adjustments to equity and liquid assets when there is a capital call are given by:

$$(9) \quad \Delta_{E,t} = (1 + 1/(L/E^*))L_t - A_t - B_t$$

$$(10) \quad \Delta_{B,t} = \Delta_{E,t}$$

The trigger and target ratios and adjustment rules are identical in the risk-neutral and actual implementations, but that the trigger is hit more frequently in the risk-neutral representation because equity is on average lower.

DB managers are assumed to be able to gradually adjust over time the mix of risky and liquid assets, and to issue or repay liabilities, in order to move toward stationary targets for the ratios of the various quantities. To capture that rebalancing between risky and liquid assets is not instantaneous, the model incorporates a periodic partial adjustment towards the target asset mix, $(A/B)^*$, at an adjustment rate $\gamma_{A/B}(i)$, i =high or low. The adjustment rate is asymmetric, with increases in risky asset holdings occurring more rapidly than decreases. As for cash infusions, adjustments occur only periodically, with the interval between adjustments a choice variable. When an adjustment to the asset mix is triggered, the changes in risky and liquid assets are given by:

$$(11) \quad \Delta_{A,t} = \gamma_{A/B}(i) \left[\frac{(A/B)^* B_t - A_t}{1 + (A/B)^*} \right]$$

$$(12) \quad \Delta_{B,t} = -\Delta_{A,t}$$

where i =low if $A/B^* < A_t/B_t$ and i =high otherwise. The size of any adjustment is further limited by non-negativity constraints on assets and liabilities.

The asymmetric adjustment rates capture the idea that it is fairly easy to sell liquid assets and reinvest them in riskier ones, but there may not be enough desirable risky projects available to immediately restore the target asset mix. The rate of downward adjustment is much slower because of the difficulty of liquidating risky and opaque bank loans. Because data to inform the choice of adjustment speed is generally unavailable, the sensitivity analysis explores the sensitivity of estimated subsidy costs and risks to variations in those parameters.

A similar asymmetric adjustment process is used to rebalance firm liabilities and liquid assets so as to move the ratio of liabilities to total assets towards a target ratio $(L/TA)^*$. Desired

increases in liabilities may occur more rapidly than desired decreases due to the costs of liquidating assets rapidly. Changes in liabilities are absorbed through corresponding changes in liquid assets. As for cash infusions and adjustments to the asset mix, adjustments occur only periodically, with the interval between adjustments a choice variable. Furthermore, reduction in liquid assets takes place if the ratio of risky to liquid assets exceeds the target ratio. That restriction avoids adjustments to liabilities that would cause the DB to move further away from its desired asset mix. When an adjustment to liabilities is indicated, the changes in liabilities and liquid assets are given by:

$$(13) \quad \Delta_{L,t} = \gamma_{L/TA}(i) [(L/TA)^* (A_t + B_t) - L_t]$$

$$(14) \quad \Delta_{B,t} = \Delta_{L,t}$$

where the rate of adjustment is $\gamma_{L/TA}(high)$ when the target ratio L/TA^* exceeds $L_t/(A_t+B_t)$ and it is $\gamma_{L/TA}(low)$ otherwise. The money is invested or subtracted initially from liquid assets because it is assumed it takes some time to adjust risky assets. As above, the rules and triggers are identical in the risk-neutral and actual implementations, but the behavior of assets and liabilities differs because of the differentials in returns.

3.3 Implementation

To find the present value of government cash infusions to DBs over a horizon of T years, and to characterize the distribution of those infusions, the models can be implemented using Monte Carlo simulation. Simple Monte Carlo methods are applicable because the behavioral

rules for infusing cash and adjusting assets and liabilities depend only on current state variables and are not forward-looking.⁵

At the beginning of each Monte Carlo run, the values of risky and liquid assets and liabilities are reset to base-year values. Each period (e.g., monthly), a draw from a standard normal distribution, scaled by σ_A , determines the lognormal component of the evolution of risky assets. A draw from a uniform distribution determines whether there is a jump down in the value of risky assets. Risky assets, safe assets, liabilities and equity evolve according to equations (1) to (8).

The conditions for rebalancing the mix of risky assets, and for adjusting the ratio of liabilities to total assets, are checked periodically (e.g., quarterly). If the conditions are met, adjustments are made according to equations (11) to (14), which feed back into equations (1) to (8).

Also at preset intervals (e.g., quarterly), L_t/E_t is compared to the trigger value for a cash infusion. If the trigger is tripped, the infusion restores L_t/E_t to its target ratio according to equation (9), and the cash is invested in liquid assets according to equation (10). Along each Monte Carlo path, the amount and timing of each cash infusion is recorded, and the payments are discounted to time 0 using the risk-free rate in the risk-neutral representation of the model.

⁵ By contrast, in traditional structural models used to value derivatives on firm assets, no capital structure adjustments are made (e.g., Merton (1974 and 1977) and closed form solutions are obtainable. In fully optimizing models such as Leland (1994) or Leland and Toft (1997), capital structure adjustments are based on solving a simple forward-looking optimization problem. For complex financial institutions, specifying a plausible constrained optimization problem and solving for the optimal policy would greatly complicate the analysis relative to the approach taken here.

The present value of the cash infusions, which is the cost of the government subsidy over the chosen horizon, is found by averaging across a large number of Monte Carlo runs. The physical distribution of cash infusions over various horizons can be computed by tracking those amounts in the physical representation of the model, and those are the basis for value at risk calculations.

4. Case Study #1: Korea Development Bank

Implementing the model for the KDB illustrates some of the possible approaches to calibration, the magnitude of the subsidies and distribution of future costs, and the sensitivity of those results to key assumptions. Notably, the estimated subsidy cost significantly exceeds the costs reported by the KDB.

4.1 Background

The KDB was established in 1954, at the end of the Korean War that had devastated Korea's economy and industrial base. In accordance with the Korea Development Bank Act of 1953 (KDB Act), its purpose was to spur industrialization and economic development by providing financing to private firms. The KDB is a subsidiary of KDB Financial Group and is entirely owned by the Korean government.

In the 1950s, the KDB financed basic industry such as the coal and electric power industries. As the policy of the government shifted to transforming the economy into an export shop in the 1960s and 1970s, KDB turned to financing heavy and chemical industries to boost exports. Then, the national economy switched gear toward focusing on high value-added products, which led to KDB's financing of the automobile and electronics industries in the 1980s and of advanced technology industries such as the semiconductor industry in the 1990s.

The KDB has also played an important role in Korea's economy during more recent crisis periods. It was involved in the acquisition and debt-equity swap of Daewoo during the Asian currency crisis in the late 1990s and took part in the management and oversight of LG Card during the credit card crisis in the early 2000s, two events that led to massive shocks to the domestic economy.

4.1.1 Operations, assets and funding sources

In recent years the KDB has provided funding to a cross-section of Korean businesses, ranging from SMEs to large industrial groups. Its departments include corporate finance, investment, international finance, project finance, and risk management. It also operates a private equity fund. The KDB is funded using a combination of deposits, bond issuance, and borrowings from other institutions.

The KDB operates as a hybrid commercial/investment bank. Its main functions include making loans to Korean businesses for domestic and foreign operations, buying and underwriting stocks, guaranteeing and buying debt securities, and evaluating the economic and technological feasibility of industrial projects. Loans comprise the largest part of its portfolio, followed by liquid assets, and investments in marketable securities (Table 2).

The KDB invests in debt and equity to diversify its loan holdings and as a secondary source of liquidity. The bank also trades and holds positions in interest rate derivatives and foreign exchange derivatives, primarily for hedging purposes.

The main way the KDB finances its operations is by issuing bonds known as Industrial Finance Debentures (IDBs), which constituted 2.2 percent of the Korean bond market in 2013. IDB maturities range from 1 to 5 years. The government guarantees that the IDBs will be repaid,

and interest on the bonds is not taxable. The main holders of the bonds are pension funds, insurance companies, securities companies, and trust companies. The KDB also borrows from the central government, the Bank of Korea, and foreign investors, and issues deposits. In 2013, liabilities consisted of 57 trillion KRW of bonds, 23 trillion KRW of loans from other institutions, and 38 trillion KRW of deposits.

Because the KDB is fully owned by the government, issuing public equity is not an option for raising capital. However, it also uses retained earnings and occasional capital infusions from the government as a funding source.

4.1.2 Loan pricing

KDB provides subsidies to its borrowers primarily through the pricing and terms on the loans it makes, which tend to be more favorable than what would be obtainable from private financial institutions. Whereas most loans involve some concession relative to what would be obtainable elsewhere, so-called “preference rates” provide additional discounts on loans made to small and medium-sized enterprises or companies doing business in industries the central government tries to foster.

According to KDB disclosures, its lending rates reflect current market interest rate conditions and an evaluation of the risk and other characteristics of a specific loan. A lending rate is determined by adding a credit risk premium, adjustment rate, and margin to a base rate and subtracting any preference rate. The base rate is the Certificate of Deposit, Industrial Finance Debentures, or LIBOR rate; the credit risk premium takes into account an internal credit ratings and the associated default probability; the adjustment rate takes into consideration a liquidity premium and maturity spread; and the preference rate provides a discount to some borrowers.

4.1.3 Risk assessment and risk management

KDB uses a combination of external and internal ratings to assess credit risk and assign risk weights for purposes of pricing and setting reserves. Exposures to governments, public institutions, and banks are evaluated using credit ratings from external credit rating agencies when available. For its exposure to large companies, SMEs, and ABS, KDB uses its own rating system, which complies with the requirements set by the Financial Supervisory Commission. Internal ratings range from AAA to D. A typical rating for KDB's loan portfolio is BBB, but it holds loans with ratings that span almost the entire spectrum (Table 3).

KDB bears concentration risk that arises because its loan portfolio is skewed towards large companies and the manufacturing sector. That increases the likelihood of large losses, particularly during economic downturns. On its outstanding loans of 96 trillion KRW in 2013, 25 percent were made to SMEs and 75 percent to large corporations. The top 20 loans accounted for 32 percent of total loans. The manufacturing sector received 58 percent of loans.⁶ Its concentrated strategy proved costly when STX, one of its largest clients, defaulted on loans of 3.6 trillion KRW. To avoid such losses in the future, the bank has since adopted a policy that no additional loan can be made to the top 20 conglomerates with loans outstanding already exceeding 1 trillion KRW.

The KDB computes and monitors other risk metrics to manage other sources of risk. For example, for trading assets it calculates 1-day VaR over the historical 250 trading days. In

⁶ These statistics are consistent with the observations of Jo and Jung (2008) on the composition and quality of KDB loans.

addition, the KDB monitors its liquidity ratio, which is defined as the ratio of liquid assets to short-term liabilities.

4.1.4 Cash injections

The Korean government subsidizes the KDB through periodic cash injections that are provided free of cost. This arrangement with the government closely resembles the callable capital agreements in effect at multilateral development banks with member countries.

The KDB Act states that the government guarantees the repayment of principal and interest on the outstanding Industrial Financial Debentures and foreign currency-denominated debt. The Act also specifies a limit on the size of capital injections KDB can receive from the government. At year-end 2013, the authorized capital stood at 20 trillion KRW, of which 9.3 trillion KRW had already been paid. Covering losses above that amount would presumably require lawmakers to authorize additional funds.

The government has injected cash into the KDB quite frequently over the last two decades, as shown in Table 4. As far as we can ascertain, there is no explicit rule that determines the timing or size of the injections. However, some of the largest injections occurred at times when the KDB's financial health deteriorated following adverse shocks to the Korean economy. In the late 1990s and early 2000s following the Asian crisis the Korean economy was stagnant. The KDB depleted its retained earnings in 2000, which led to an infusion of over 3 billion KRW the next year. In 2003, the credit card crisis hit the economy, and Korea Electric Power Corporation and K-Water, non-financial government corporations in which KDB had equity ownership, experienced serious financial problems. To help KDB survive the turmoil as well as to finance these two companies, the government provided another 1 trillion KRW in 2004.

During the recent global financial crisis, although the financial health of KDB appeared to be relatively good, the government provided as precautionary capital another 500 billion KRW in both 2008 and 2009.

4.2 Parameterizing the model

In this section we present the parameters used to implement the model, and describe the data and reasoning behind those choices. For some parameters there is considerable uncertainty and we indicate a plausible range to use in sensitivity analysis. All monetary values are in Korean won (KRW) unless otherwise stated. Table 5 summarizes the base case assumptions.

4.2.1 Initial assets and liabilities

Initial values for assets and liabilities are taken from KDB's 2013 balance sheet. For the purposes of the model, the many asset classes that the KDB invests in have to be divided between risky and liquid assets. In the base case analysis, we classify as liquid assets the 15.3 trillion in assets classified as liquid, plus 20 trillion of the 27 trillion in debt securities. The remaining 108.3 trillion in investment assets—which includes all loans, all equity, and 7 trillion in debt securities—are counted as risky assets.

Liabilities, which are comprised of a blend of industrial finance debentures (IFDs), deposits, borrowing from government agencies, borrowings from foreigners, and other miscellaneous liabilities total 127.3 trillion.

Conceptually, the KDB's derivative positions could be consolidated onto their balance sheet and incorporated into the totals for assets and liabilities. Because the KDB's derivative positions appear to be primarily to hedge interest rate and currency risk, which we do not consider, it seems reasonable to treat them as supporting the assumption that it is not necessary

to incorporate those risks explicitly into the model. It should be noted that the methodology implicitly includes all sources of risk via the volatility of asset returns parameter.

Ideally initial assets and liabilities would be set to their market values, or estimates thereof. Because KDB does not have publicly traded equity, those quantities cannot be estimated by reference to market data and we use book values as a starting point. KDB's auditor produces a fair value balance sheet that shows values for the various categories of assets and liabilities that are quite close to KDB's reported book values.

4.2.2 Expected rates of return on assets and liabilities

The expected return on liabilities is set at 3 percent, which is the rate reported by KDB on both deposits and IFBs for 2013, which account for 74 percent of total liabilities. KDB reports a lower borrowing rate of about 1.5 percent on other liabilities.

The expected return on liquid assets is set at 3 percent as well, consistent with the logic that those assets are similar in risk and liquidity to the deposits and IFBs that the bank issues. The KDB's reported returns on securities held for trading and securities available for sale also are consistent with the 3 percent assumption for liquid asset returns.

It is difficult to identify a truly risk-free rate in Korea. However, reasonable proxies include short-term government borrowing rates or high quality bank borrowing rates. Reference rates in 2013 include a 91-day CD rate of 2.7 percent and a 3-year Treasury rate of 2.8 percent. The risk-free rate is set to 2.5 percent in the model to correct for the likely presence of a small risk premium and term premium in those reference rates. A risk-free rate that is 50 bps lower than the expected return on liquid assets and low-risk liabilities also seems reasonable.

The expected return on risky assets represents a weighted average of the expected return on loans, equity, and the riskier portion of security holdings. Loans constitute about 90 percent of risky assets. KDB reports a weighted average loan rate of about 4.8 percent. Non-performing loans over the 2004 to 2013 ranged from 0.8 percent to 1.4 percent of the loan portfolio, some fraction of which will be recovered. Adjusting the promised loan rate down by 50 bps for default losses implies a 4.3 percent expected return on loans. The expected return to equity investments is taken to be 8.5 percent, based on the 2.5 percent risk-free rate plus an equity premium for the Korean stock market which a number of authors have suggested is about 6 percent. The expected return to the riskier portion of securities holdings is taken to be the same as for bank loans. Taking a weighted average implies an expected return on risky assets of 4.5 percent.

4.2.2 Volatility of risky assets

The value of the bank's assets will vary over time with changes in default rates, recovery rates, the pricing of market risk, interest rates, and other market conditions. For the purposes of this calibration, the relevant components of volatility are primarily those associated with credit risk. Interest rate risk appears to be limited as the duration of assets and liabilities are similar.

One way to estimate the volatility of assets is to consider the volatility of each major asset class and value-weight them. The volatility of the Korean stock market (the KOSPI index) is about 28 percent, based on historical returns from 1990 to 2013. The KDB's stockholdings are less diversified than the overall market and hence likely to be more volatile all else equal. Because bank loans are not marked to market it is difficult to directly estimate their volatility. Historical data on high-yield bonds (albeit U.S. bonds) indicate volatility on order of 11 percent per year. However, a portion of that volatility arises from changes in the base level of interest rates, which is assumed to be mostly hedged for the KDB. Assuming that the relevant portion of

the volatility is 3 percent for loans and risky debt securities, and taking equity volatility to be 30 percent, a point estimate for risky asset volatility is 4.2 percent.

Another approach to estimating asset volatility is to equate it to a typical value for large banks. On his website, Professor Damodaran's reports that for money center banks the average debt-to-equity ratio is 218 percent and that bank equity volatility is 37 percent. Setting the volatility of bank debt to 3 percent implies an asset volatility of 13.7 percent. Because this is a weighted average of the volatility on risky and liquid assets, it suggests a very high volatility for risky assets.

In the base case the volatility of risky assets is set to 4.2 percent, as suggested by consideration of the Korean asset market. This is a key parameter and clearly there is considerable uncertainty surrounding its true value. The effects of lower and higher volatility are considered in the sensitivity analysis.

4.2.3 Trigger and target for cash infusions

The KDB does not have an explicit capital requirement. However, inferences about capital infusion triggers and targets can be gleaned from historical experience. In the model, capital infusions are triggered by the ratio of liabilities-to-equity exceeding a trigger level, L/E_{max} . Table 6 shows the ratio of liabilities-to-equity (in book value terms) from 1999 to 2013. It averaged 8.7 over the period, with a standard deviation of 3.9, a minimum of 5.3, and a maximum of 20.4. We set the target ratio to 7.3, which is somewhat below the historical average but consistent with the last five years. We set the trigger ratio to about 5 percent above the target at 7.6 in the base case analysis, and look at the effects of varying these assumptions in the

sensitivity analysis. The target ratio of liabilities-to-total assets is chosen to be consistent with the target liabilities-to-equity ratio. .

The KDB announced in 2014 that it would operate in compliance with Basel III, which requires banks to maintain a ratio of Tier 1 capital to risk-weighted assets of 4.5 percent. In 2013 a rough estimate of that ratio for KDB based on setting the risk weight to one for all risky assets and to zero for all other assets suggests this is far from being a binding constraint. Hence it is not used to set the trigger rule.

4.2.4 Adjustments in asset mix and leverage

Because of the differential average returns on risky assets, safe assets and liabilities, their relative proportions will change over time unless there is some exogenous rebalancing towards target ratios. For example, without rebalancing cash infusions shrink over time because the ratio of assets to liabilities increases exponentially.

The ratio of risky-to-liquid assets held by the KDB has varied considerably over time, as shown in Table 6, presumably both because of policy choices and changes in risky asset values. The ratio of A/B averages 7.7 over the 1999 to 2013 period, and we set the target A/B^* to that average value. We assume that the rate of upward adjustment towards the target is 50 percent on an annual basis, and that the rate of downward adjustment is 10 percent on an annual basis. The asymmetry reflects the relative ease of selling liquid assets and replacing them with risky loans rather than vice versa.

The ratio of liabilities to total assets reported by KDB was very stable over the 1999 to 2013 period, hovering around 0.9 in most years, and ranging from 0.8 to 1. The target ratio is set to 0.88 (which is consistent with the assumption about the target for the liability-to-equity ratio).

The adjustment rates for increases (decreases) in that ratio are set to 90 percent (25 percent) on an annual basis, reflecting the greater difficulty of reducing leverage when it is excessive than the ease of increasing it in good times by issuing additional debt. This adjustment helps to keep the leverage ratio stationary over time, although there is still some drift in the base case parameterization towards less risk over time.

The sensitivity analysis explores the effects of faster or slower adjustments to both of these targets.

4.2.5 Other parameters

The time step in the calibration is monthly. Once a quarter there is a check of whether there is a cash infusion, and there are quarterly adjustments in asset mix and leverage. The effects of changing monitoring frequency are explored in the sensitivity analysis.

The jump parameter is set to zero in this preliminary version of the paper. We will use it to explore the effects of financial crises and other sources of discrete falls in asset values in the next draft.

As its liquidity ratio for KRW-denominated assets and short-term liabilities was 1.6 and that for foreign currency-denominated assets and short-term liabilities was 1.1 in 2013, short-term liabilities are fully covered by its current assets, and there is little concern over liquidity risk.

4.3 Cost estimates and sensitivity analysis

Under the base case parameterization, the model implies that the subsidy cost to the Korean government of its contingent cash infusions to the KDB over a 20-year period starting in 2013 is KRW 36 trillion (\$33 billion), or 25 percent of the bank's initial asset value. Annuitizing the cost over the 20 years using a 4 percent interest rate implies an annual cost of KRW 2.4 trillion. Had the government charged the KDB that amount as a premium for its contingent capital, it would have more than doubled the KDB's reported losses in 2013.

As discussed earlier, many of the parameter choices are subject to considerable uncertainty. The sensitivity analysis illustrates how the present value subsidy cost changes, varying just one parameter at a time and leaving the rest as in the base case. We consider changes to asset volatility; the liability-to-equity target; the liability-to-equity trigger; the up and down adjustment speeds for the ratio of risky-to-liquid assets and liabilities-to-total assets.

The results of the sensitivity analysis are summarized in Table 7. The estimates are sensitive to asset volatility, the target ratio of liabilities-to-equity, and the speed of upward adjustment in liabilities. They are relatively insensitive to the other variables considered.

As expected, an increase in asset volatility increases the subsidy cost because it increases the likelihood of equity shortfalls. The sensitivity to this parameter, and the difficulty of calibrating it, motivates looking more closely at the KDB's internal risk weightings as an indicator of the credit risk in their loan portfolio and working with a more micro-level model that incorporates that information (as described in section 3.2). Those results will be added in the next draft.

The effect of decreasing the target ratio of liabilities-to-equity that triggers an equity infusion is to increase costs. That might seem counterintuitive because adding more equity

reduces risk. However, the offsetting factor is that the target ratio of liabilities-to-total assets is left at its base case value, which causes the lower trigger to be hit more frequently. The results are quite sensitive to varying the relative values of those two parameters.

The sensitivity to the speed of upward adjustment in liabilities is explained by scale. When those adjustments are more rapid the DB grows more quickly over time, which increases the scale of the subsidies.

4.4 Value at risk

The parameter choices for the base case were also tempered by consideration of the predicted distribution of cash infusions and how they compared with historical infusions. For example, the relation between the trigger level for cash infusions and the target ratio of liabilities-to-equity was chosen to allow the possibility of fairly small infusions in some years.

Capital infusions are predicted to take place in 33 percent of years under the base case parameters. That is lower than the frequency since 1999 (see Table 7). However, the occurrence of several unusually large crises during that period may have led to a higher rate of infusions than would be seen over longer horizons.

The predicted annual average size of the infusions, contingent on a positive infusion, is xx. Figure 1 shows the distribution of cash infusions over 5 years and over 20 years. The probability of large losses increases over the longer horizon primarily because there is a positive drift in the scale of the bank. From those distributions, the VaR over (20 years) at the 95 percent confidence level is about KRW 6.8 trillion.

5. Conclusions

Accurate cost estimates are a prerequisite for informed public investment choices, yet that information is typically unavailable to policymakers. The costs of contingent claims are particularly opaque and generally underreported. In this paper we propose, and then implement for the KDB, an approach to evaluating the cost to governments arising from their sponsorship of development banks, institutions that in many countries play a central role in capital allocation. It is a significant first step towards providing comprehensive estimates of the costs and risks of DBs around the world, and illustrates the challenges of financially assessing these opaque and often complex institutions.

A technical issue we plan to address in subsequent drafts is how to model more explicitly the relation between the shadow market value of the bank, which is the focus here, and reported accounting measures of value. We are also working on applying this approach to BNDES, one of the largest financial institutions in Brazil, and to Ziraat in Turkey. It is hoped that the methodology will eventually be applied to additional national and multilateral DBs around the world, so as to provide new and more accurate information about their costs and risks to bank managers, the public and governments.

Table 1: Assets of Selected Multilateral Financial Institutions, 2018 (\$ billions)	
African Development Bank	34
Asian Development Bank	192
European Bank for Reconstruction and Development	68
European Investment Bank	607
Inter-American Development Bank	130
Int'l Development Assoc., World Bank Group	189
Asian Infrastructure Investment Bank	20
Islamic Development Bank	19

Sources: Investopedia and Annual Reports

Table 2: Balance Sheet of KDB in 2013 (trillions of KRW)	
Liquid Assets	15.3
Debt Investments	27.0
Equity Investments	5.0
Loans	96.3
Total Assets	143.6
Liabilities	127.3
Equity	16.4

Table 3: Distribution of Internal Loan Credit Ratings in 2013	
	Number of Loans
AAA	27
AA	149
A	715
BBB	1,452
BB	1,369
B	554
CCC	72
CC	13
C	-
D	460
NR (Not Rated)	1,201
Total	6,012

Table 4: Increases in Paid-in Capital by Year (billions of KRW)

1996	1997	1998	1999	2000	2001	2002	2003	2004
N/A	1,160	1,199	800	0	3,043	0	80	1,000

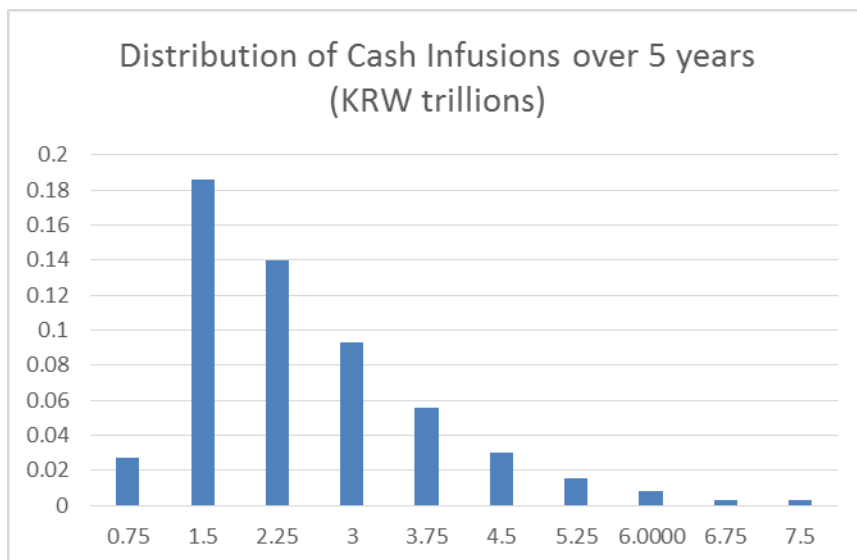
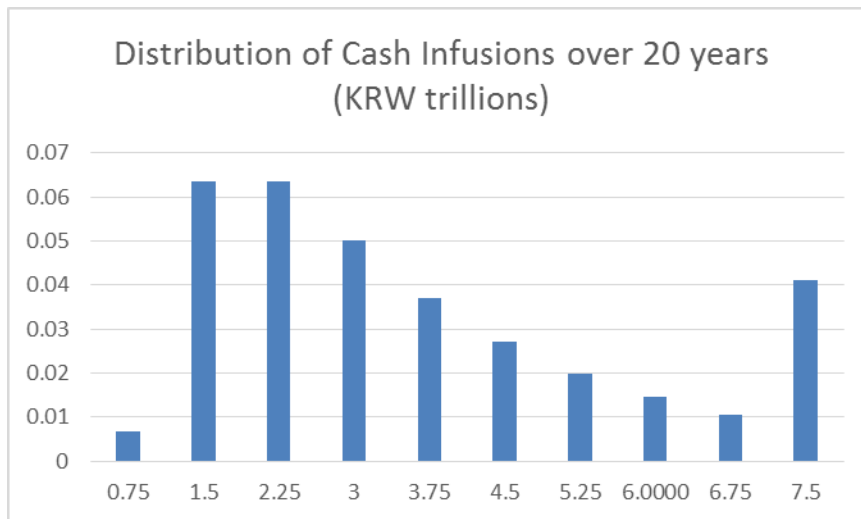
2005	2006	2007	2008	2009	2010	2011	2012	2013
0	0	0	500	500	10	0	0	10

Table 5: Base Case Parameters for Two-Asset Model for KDB	
Number Monte Carlo runs	10,000
Time horizon	20 years
Risk-free rate, r_f (annual)	.025
Return on liquid assets, r_B (annual)	.03
Return on liabilities, r_D (annual)	.03
Expected return on risky assets, $E(r_A)$ (annual)	.045
Initial liquid assets, B_0 (KRW trillions)	25.3
Initial risky assets, A_0 (KRW trillions)	108.3
Initial liabilities, L_0 (KRW trillions)	127.3
Normal shock volatility risky assets, σ_A	.042
Jump probability	0
Jump size	0
Liability-to-equity trigger, L/E_{max}	7.6
Liability-to-equity target, L/E^*	7.33
Frequency of monitoring L/E	quarterly
Target risky asset-to-liquid asset ratio A/B^* for rebalancing asset mix	7.7
Annual adjustment rate to target when $A_t/B_t > A/B^*$	.1
Annual adjustment rate to target when $A_t/B_t < A/B^*$	.5
Frequency of monitoring A/B	quarterly
Target liability-to-total-assets ratio for rebalancing liabilities	.88
Annual adjustment rate to target when $L_t/(A_t+B_t) > \text{target}$	.25
Annual adjustment rate to target when $L_t/(A_t+B_t) < \text{target}$	.9
Frequency of monitoring $L/(A+B)$	quarterly

Table 6: Select Ratios for the KDB (shaded years indicate cash infusions)			
	Risky Assets/Liquid Assets	Liabilities/Equity	Liabilities/Assets
1999	6.8	11.1	0.9
2000	5.8	20.4	1
2001	7	10.8	0.9
2002	9.5	10.4	0.9
2003	5.5	11.1	0.9
2004	6.2	8	0.9
2005	10.7	5.5	0.8
2006	12.7	5.3	0.8
2007	9.6	5.6	0.8
2008	4.6	9	0.9
2009	6.7	7.1	0.9
2010	6.5	6	0.9
2011	8.6	6.2	0.9
2012	6.5	6.8	0.9
2013	8.4	7.8	0.9
Avg	7.7	8.7	0.9
Std	2.2	3.9	0
Min	4.6	5.3	0.8
Max	12.7	20.4	1

Table 7: Sensitivity of Subsidy Estimates to Parameter Changes			
(subsidies in KRW trillions)			
asset vol	0.032	0.042	0.052
subsidy	26.3	36.0	46.6
L/E target	6.33	7.33	8.33
subsidy	46.8	36.0	24.0
L/E trigger	7.1	7.6	8.1
subsidy	35.5	36.0	34.5
L/(A+B) adjustment speeds down	.5x base case	base case	2x base case
subsidy	36.3	36.0	35.3
L/(A+B) adjustment speeds up	.5x base case	base case	2x base case
subsidy	25.7	36.0	55.5
A/B adjustment speeds down	.5x base case	base case	2x base case
subsidy	36.0	36.0	36.0
A/B adjustment speeds up	.5x base case	base case	2x base case
subsidy	34.1	36.0	36.8
monitoring frequency	monthly	quarterly	yearly
subsidy	37.2	36.0	37.9

Figure 1



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