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A real options model for loan portfolios of actively traded Philippine universal banks

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Abstract

This study applies Real Options Theory to banking in the environment of actively traded Philippine Universal Banks. These banks exist in an environment of imperfect information with regard to lending, and a country where credit scarcity impedes the growth and performance of entrepreneurial activity. We investigate the option premiums of loan portfolios that depict managerial flexibility with investment strategy. A Real Options Model that considers both the strategies to lend and to idle shows that smaller lending institutions will value loans higher than their larger competitors. From the model, the need to maintain smaller variances in loan portfolio returns constrains manager flexibility. Option premiums in the Philippines exhibit sensitivity to information asymmetries. In these findings, this discussion forwards three propositions and their implications. Furthermore, this paper discusses the value of a hedging portfolio to counter risks from information asymmetry. Hence, this paper differs from many models in the existing literature that focus just on the value of the call option, the value of expansion or growth.

Keywords: Real options theory, Banking, Loan portfolio, Valuation, Strategy, Lending

Background

Actively traded, Philippine Universal Banks engage in strategies of continuous industry reallocation, and loan diversification in order to compete for profitable investments in a highly competitive market. Since the Global Recession from 2008 to 2009, loan portfolio book values continue to exhibit significant growth. From annual reports covering an eight-year window of observation from 2008 to 2015, loan portfolio book values show an average geometric growth of 20.28% a year. Yet, from the Global Entrepreneurship Monitor (GEM) 2014 Philippine country report, inadequate access to credit from formal financial establishments presents an impediment to entrepreneurial activity growth and performance (Velasco et al. 2016). In 2017, the Doing Business report ranks the Philippines in the lower 38th percentile of participating countries in attaining credit. The World Bank Group report attributes this inadequate access to credit as partly due to the absence of a collateral registry (World Bank 2017).

The level of information asymmetry or imperfect information augments the value of the loan portfolio. In Real Options Theory, imperfect information degrades option values (Scherpereel 2008). From Smith and Thompson (2008), the difference in the profits between an expanded portfolio and the original portfolio serves as the value of learning information from a new prospect. Accounts where the principal or interest

remains unpaid for a period of 30 days or longer, classify as Non-Performing Loans (NPLs). As a result of this condition, banks in the country must consider the outstanding balance as non-performing (*Bangko Sentral ng Pilipinas*, Circular 772, Series 2012). Since banks cannot predict with certainty those loans that will degrade to a non-performing state, this study views NPLs as a measure of information asymmetry. Since 2008, subjects in this study report declines on an order of 2.86% per annum in Non-Performing Loans (*Bangko Sentral ng Pilipinas* 2008 to 2015, Published Balance Sheets). This study finds that as the information asymmetry value changes, we see the economic benefits or losses from expanding the portfolio.

Philippine Universal Banks serve a greater purpose to the country beyond matching the funds of savers to the needs of borrowers. According to Republic Act 8791, Chapter IV, Article I, Section 23, along with the powers of commercial banks and investment houses, Universal Banks have the power to invest in unrelated enterprises. Commercial banks are corporations with the power to accept drafts; issue letters of credit; provide discounting facilities; accept deposits; accept or create demand deposits; buy and sell currencies, as well as gold and silver bullion; acquire debt securities; and provide credit in accordance with Monetary Board policies (An Act Providing for the Regulation of the Organization and Operations of Banks, Quasi-Banks, Trust Entities and for Other Purposes, 2000). As Section 6 of Republic Act 8791 defines, only the *Bangko Sentral ng Pilipinas* (BSP) bestows authority for an institution or individual to conduct banking functions, these institutions must forward the mandate of the Central Bank to support price and monetary stability, along with peso exchangeability. Thus, the activities of banks and quasi-banks must sustainably grow and balance the national economy (The New Central Bank Act 1993).

This study forwards a model that values the strategies to lend or to idle a loan portfolio in a system where business practices produce asymmetric information, and income volatility. Determining the loan portfolio option value of a Philippine Universal Bank that results from managerial flexibility, in an environment of volatility and imperfect information, is the first objective of this paper. The importance of determining the option value for a loan portfolio is that this information guides investment policy, as to the level of expansion a loan portfolio may undertake, or the amount necessary to hedge downside risks from idling or lending. As such, these option values provide insight with regard to the future value of strategies and resources in Capital Budgeting and Rationing decisions. Unlike much of the extant Real Options literature, this paper will discuss both the put and call option values Philippine Universal Banks face. This follows the methodology and concepts of Real Options Valuation by Bellalah (2001); Dixit (1989a, 1989b, 1992); McDonald and Siegel (1986); Pindyck (1988); Tsai (2008); and van Putten and MacMillan (2004).

Since this study examines investment strategy from the use of a Partial Differential Equation, the second objective of this paper will further discuss the concepts behind the Value of Waiting and the Optimal Trigger by Dixit (1989a) as the Philippine setting affects them. More specifically, this study seeks to address how volatility, and imperfect information affect these variables. In turn, this second objective seeks to address how the Value of Waiting affects both put and call options in the theory.

The sequence of this paper is as follows. In the second section, we discuss the theoretical background of our study. The third section will describe the econometrics in the

model and conceptual framework. The fourth section discusses the model and salient assumptions. The fifth section will present the values for the variables, and numerical analyses of this model. In the sixth section, we offer a discussion of the implications from the findings. The final section will conclude with main points from this study, along with directions for future research.

Theoretical background

Taught in many programs of business administration and commerce, the Net Present Value (NPV) offers managers a tool by which to value resources and strategies. The concept of discounting an expected future inflow to the present time serves as the basis for the NPV technique of analysis. To determine the Present Value of an income stream, the discounting method requires a factor by which to bring future inflows to the present. This present value discounting factor requires the interest rate, and the number of discounting periods, to reduce the future inflow to reflect its worth in the present time. The Net Present Value decreases the value of future inflows by the amount necessary to acquire a particular resource or strategy. From this relationship between future income and any expenditure, the decision rule to accept a project requires that the NPV is positive. On the other hand, to reject a project the NPV must be negative (Vernimmen et al. 2009).

Volatility or measures of uncertainty receive no explicit treatment in the NPV technique. Hence, the method provides values under the assumption of a static and certain world (McSweeney 2006). McCloskey (1991) raises caveat over the seeming sureness and precision of economic models. The article suggests that the inevitability with which such models determine economic values do not account for shocks exogenous to the model constructs, these are influences of genuine and Newtonian uncertainty (McCloskey 1991). As the NPV technique bases decision on a binary rule set, either accept or reject, the method does not address issues such as strategies for waiting or learning. Jensen (1993) highlights the multiple points of failure in corporate internal control mechanisms from the selection of the Board of Directors, to valuation practices. The article indicates that despite the simplicity of the rule for project acceptance or rejection by the NPV technique, many American Chief Officers accept negative NPV projects (Jensen 1993). This brings into question if the NPV reflects value as practitioners rationally assess a project, or if hubris plays a more significant role in project acceptance. In examining the banking industry, Nordal (2009) uses a Real Options Model to assess the required level of reserve capital for banks. The study forwards that valuation of assets from the NPV method requires banks to provide higher levels of reserve capital. With a Real Options Valuation Model, the paper shows the presence of a waiting value affects asset assessments, in turn requiring a lower reserve capital level (Nordal 2009). Supporting the position that deterministic methods of valuation may improperly value a strategy or resource, Thompson and Barr (2014) compare values from a Real Options model to those from traditional methods of valuation in an ore mining operation. The use of a Real Options model indicates that using traditional valuation methods may create more wasted ore than is optimal (Thompson and Barr 2014).

In a discussion extending the cost of capital concept to capital budgeting decisions, Lintner (1965) posits that a firm will accept a new project in consonance with the goals of its investors as long as doing such will increase the equity value of the firm. Hence,

adjusting for the market price of risk, and variance in currency returns from the portfolio, the incremental change in returns must equal the returns of the proposed project, adjusting for the same market price of risk and variance in returns, all to accept a new project. It is with emphasis that the resulting values must be greater than zero. Essentially, the risk-adjusted returns from a proposed project must be equal to risk-adjusted returns for the portfolio of assets in order to consider a project (Lintner 1965). This alludes to a level of indifference between accepting, or rejecting a project that Dixit (1989a) introduces 24 years later. Furthermore, the value of a proposed project results from the difference between project inflows, and the opportunity costs (outlays), to gain access to the project (Lintner 1965). It is of note that the inflows from a project, at this stage of Portfolio Theory, already consider project income as resulting from the incremental currency return, adjusting for risk through the variance in its returns. Thus, the article mathematically establishes the general form of an option value for a capital project (Lintner 1965).

For both financial and real options, assessing project specific inflows to a contingent claim (the cost to acquire rights to an opportunity, or maintaining the existing investment portfolio) involve comparisons in a state of equilibrium. From Black and Scholes (1972), the value of an option results from the underlying asset inflows, and the costs to acquire the right to access the opportunity. The Black-Scholes Option Pricing Model (BSOPM) establishes a relationship of contingent claims by which to assess asset returns (Black and Scholes 1973). In Real Options Theory important variables to value an opportunity are the level of project specific inflows (the underlying asset value), value of the investment to gain access a project (the exercise price), the time to maturity, the discounting rate, and variances in the value of project specific inflows (Frayer and Uludere 2001; Mauboussin 1999; Trigeorgis 1991).

A Real Option examines a potential resource or strategy exclusive to a going concern that imbues an organization with particular advantages, or enhances its existing state. Two important factors in a real option are its exclusivity to the organization, and the prospect for subsequent opportunities (McGrath et al. 2004). Real Options may come from within the firm, or its external environment (Bowman and Hurry 1993). Investments in product development, human capital abilities, as well as fixed assets serve as examples of internal cradles of Real Options. External sources from the business landscape may embody aspects of industrial organization, political, environmental, socio-cultural, and economic influences.

As much of the extant literature applies Real Options Theory to capital expenditure projects, often with regard to the energy and real estate sectors, a collection of papers in the extant literature explicitly apply this theory to the banking industry. Yoon and Smith (2002) examine the Real Options based impetus of American banks to lend. The paper forwards that variance in interest income increases the Value of Waiting, especially after a bank experiences losses to the loan portfolio. As such, greater variances cause banks to wait on investing. From the paper, a hedging portfolio that lowers lending deferral as a result of uncertainty is possible (Yoon and Smith 2002). Gu (2002) examines the option value of subsidy loans for mortgages in a Chinese housing program. The put option premium of the mortgage subsidy is positive as long as the present value of the loan amortization is greater than that of the savings account. As such, the value of the house (net the amount in savings) is the value of the put option (Gu 2002).

Tsai (2008) considers the value of equity in a venture to an entrepreneur with exclusive information not available to a lender. According to the paper, inside information (asymmetric information) affects the discount rate of a venture, effectively distorting the value of equity lowering its value in the eyes of external investors (Tsai 2008). More recently, Elfenbein and Knott (2015) apply Real Options Theory to the American banking industry, looking for factors influencing bank exit. From the article, profit volatility, and cost dispersion attribute to a delay from exit in the banking industry (Elfenbein and Knott 2015).

Conceptual framework

This study will determine the values of options for lending and idling by the use of a Real Options Model. Inputs to the model are the inflows from the loan portfolio, ϖ ; the exercise price, χ or k ; uncertainty (volatility), σ ; a growth rate, μ ; the discounting rate, ρ ; and the level of information asymmetry, ζ . Income Inflows from the loan portfolio consist of interest income, and service charges, as well as fees and commissions. These accounts represent the capital gain from loan inflows, net of payments on deposits (Färe et al. 2004; Yoon and Smith 2002). The variable χ or k denotes outlays to gain access to an option (such as the acquisition of fixed assets). Asset accounts that reflect such outlays are loans and receivables (net of General Loan Loss Provisions), unquoted debt securities classified as loans, and other resources. These asset accounts are already outstanding loans that serve as generators of interest income (*Bangko Sentral ng Pilipinas* Financial Reporting Package for Banks, 2013; Yoon and Smith 2002). In the event of default, any collateral or receivables factored, receive treatment as salvage values, χ .

From Dixit (1989a), lognormal revenues function as the basis from which to determine variance. Our study also utilizes the lognormal values of particular accounts as those for Income Inflow, ϖ , as well as NPLs, ζ . This treatment is in consonance with views on measuring uncertainty by Dixit (1989a), as well as Yoon and Smith (2002). Following the treatment of volatility in the BSOPM by Brigham and Houston (2009), uncertainty is the standard deviation of the lognormal value from the return on the loan portfolio.

The annual percentage change in the lognormal Operating Profits (net inflation), measures the growth rate. Netting inflation from the growth rate allows the discernment of the real rate of growth. Operating Profit from the loan portfolio results from the difference between Income Inflows, and the total of interest expenses from deposit liabilities, compensation and fringe benefits, and allowances for impairment. Reasoning for the use of the Operating Profit Growth Rate is that service costs have the effect of slowing the growth of inflows from the loan portfolio. Färe et al. (2004) consider profits as a standard when ascertaining the productivity of inputs. Mandelman (2011) views benefits from the loan portfolio as a result of interest income net of interest expense.

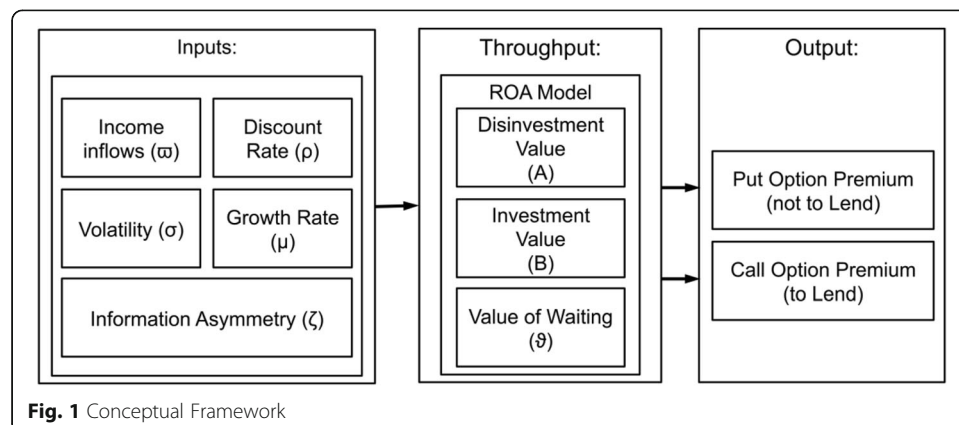
The discount rate for Retirement Plans of each cohort in the study serves as a proxy value for the hurdle rate of the firm. The impetus for using this proxy value is that banks in the sample must contribute to a retirement plan, which receives funding from firm operations. As such, in order to fund these retirement payments banks must, in the very least, seek this level of return on all projects to cover the costs of payments to retirees.

To capture information asymmetry, the model uses the standard deviation of log-normal NPLs values. According to Graham and Humphrey (1978) loan losses net recoveries, are synchronic with new loans. As banks cannot predict which loans will default in any given period, NPLs serve as a measure of information asymmetry, since the decision to pay a loan ultimately lay in the hands of the borrower. Inputs to the model allow for determination of cumulative distribution values for disinvestment, A , and investment, B , along with the Value of Waiting, ϑ . This Real Options Valuation Model determines option values for the strategy not to lend, as well as the strategy of lending. Essentially, these option premiums are the conceptual framework output (Fig. 1).

Methods

To qualify the behavior of the model, we assume banks do not have complete information about the activities, or even intent of their borrowers. Furthermore, a hedging portfolio is sought to offset any downside risks from either lending or idling. In order to establish a hedging portfolio, strong, positive correlation between the loan portfolio asset value and deposits should exist (Yoon and Smith 2002). This study assumes that the loan portfolio and deposit values are very strongly, and positively related, allowing for the construction of a hedging portfolio. Banks provide credit to consumers and firms that need to purchase goods and services in order to operate, and take advantage of opportunities. The credit banks extend manifest in loan agreements with individuals or firms (Villar 2006). In this study, we assume banks will continually lend to gain access to future payments from the projects these loans fund. While banks accept loan applications, and underwrite loans, they do not have complete information as to the actual value of the portfolio in the subsequent period. As such, banks only have an expectation of the future loan portfolio value at the time they lend. Loans may continue to perform as expected, fall into delinquency, or enter a state of impairment. Realization of the expected loan portfolio value does not manifest in states of loan delinquency or impairment.

From the concept of the investment trigger as Dixit (1992) and Grenadier and Malenko (2010) discuss, the returns on the loan portfolio in the presence of information asymmetry result from the interest rate and other factors affecting the value of a



strategic asset. In Eq. (1), Operating Income, π_P , measures the inflows from the existing loan portfolio. The equation finds a loan portfolio value in the presence of asymmetry.

$$v = \rho \zeta \pi_P \quad (1)$$

To find the return on an option, we set the value of the contingent claim equal to that for the loan portfolio in the presence of information asymmetry. Here, the contingency is in terms of the unexpanded loan portfolio. Doing this, we equate benefits from an incremental loan to the return on the existing loan portfolio. To isolate factors relating to growth in the existing portfolio we rearrange terms. Making time infinitely long, eliminates the Weiner process. Note that the elements for the normal return remain, as these arrive from the Geometric Brownian Motion terms that factor for the randomness of subsequent values. Through this technique, value in the presence of uncertainty may now be found. This brings the resulting expression into a state of equilibrium. Note that, π_L , denotes loan value in terms of interest income, fees, and commissions from the loan. [Appendix 1](#), describes the derivation to Eq. (2).

$$\frac{1}{2} \sigma^2 \varpi^2 \frac{\partial^2 \pi_L}{\partial^2 \varpi} + \mu \varpi \frac{\partial \pi_L}{\partial \varpi} - \rho \zeta \pi_P = 0 \quad (2)$$

It is at this point we must assume that the portfolio is active. Furthermore, we must also make the same assumption regarding the revenue process as Dixit (1992) and Belalalah (2001), where discounting Income Inflows, ϖ , follows a natural log function. This causes the system to continuously discount future inflows. We find the instantaneous rate of return for the revenue process as the first derivative of this system (Equation 4), and the upper and lower return values as the second derivative (Equation 5). Additionally, a correlating factor, a , that adjusts inflows for uncertainty influences the process.

$$\pi_P = a \varpi^\vartheta \quad (3)$$

$$\frac{\partial \pi_P}{\partial \varpi} = a \vartheta \varpi^{\vartheta-1} \quad (4)$$

$$\frac{\partial^2 \pi_P}{\partial^2 \varpi} = a \vartheta (\vartheta-1) \varpi^{\vartheta-2} \quad (5)$$

Now, we substitute the value for the revenue process into our expression for the returns on the option. This will produce a Quadratic Equation by which to determine the Value of Waiting, ϑ , on an option (an opportunity). Essentially, Eq. (6) provides the equilibrium condition for the return on a prospective loan considering volatility and the contingent claim, the return on the existing portfolio in the presence of imperfect information. [Appendix 2](#) describes the derivation of this expression.

$$\frac{1}{2} \sigma^2 \vartheta^2 - \left(\frac{1}{2} \sigma^2 - \mu \right) \vartheta - \rho \zeta = 0 \quad (6)$$

To further clarify the variance value, in the BSOPM the rate of return on the stock determines variance (Brigham and Houston 2009). Here, we base the variance from the rate of return on the loan portfolio value between consecutive years. In the numerical results from Dixit (1989a: 631), the article presents a central case whose annual

variance depends on the lognormal value from revenues. As such, the return on the loan portfolio value functions as a measure to determine volatility.

The Value of Waiting results from finding the positive and negative roots of the Quadratic Equation. The Value of Waiting serves as the continuous discounting factor that brings both the investment and disinvestment values to equality. [Appendix 3](#) describes the arrival to Eq. (7).

$$\beta_{P,N} = \vartheta_{P,N} = v \pm \frac{1}{\sigma} \sqrt{\left(\frac{\gamma^2}{\sigma^2} + 2\rho\zeta\right)} \quad (7)$$

To determine the correlating factor, a , we set the rate of return from the revenue process equal to the maximum rate of return for the system (from the second order derivative), which we assume behaves in a condition of unity. This vector magnitude factor correlates loan portfolio returns to those for the prospective loan (Bellalah 2001). The presence of this vector magnitude factor serves to produce the value of downside risks for each strategy. [Appendix 4](#) derives this relationship.

$$a = \vartheta^{-1} \varpi^{1-\vartheta} \quad (8)$$

Arrival to the risk adjusted values for the call and put options requires we group terms. The result is an equilibrium model that equates the values of the put and call options. The A and B factors in the generalized equilibrium condition function similar to the cumulative distribution expressions in Black and Scholes (1973). Arguably, these factors (A and B) function to determine the hedging portfolio value (Black and Scholes 1973). These terms essentially adjust the present value of inflows and outlays for the presence of risk, and information asymmetry. The first term, $\varpi^{\vartheta_N} A$, is the value of the hedging portfolio in a condition of disinvesting from the loan portfolio, the lending strategy. We may view this first factor as the downside risks from lending, accounting for loans that may default. The second term, $\varpi^{\vartheta_P} B$, is the value of the hedging portfolio in a condition of investment in the loan portfolio, the strategy not to lend. This second term describes the downside risks for choosing not to lend. Dixit (1989b) refers to the call option condition as a level of indifference between entering a project and that of waiting. At this level of indifference the paper implies that an investor accepts the project (Dixit 1989b). Given this relationship between the put and call options, a Universal Bank may identify arbitrage conditions between the strategies to increase or contract loan exposure. [Appendix 5](#) describes the derivation to this general condition.

$$\varpi^{\vartheta_N} A + \varpi^{\vartheta_P} B = 0 \quad (9)$$

As an extension of this view of loan portfolios, Real Options Theory allows for valuing strategies to either extend or idle the portfolio through the information that an option premium provides. A put option premium (the strategy to idle or even contract the portfolio) results from the difference between the salvage value of the loan, and the expected value of any inflows from the loan. The premium of a call option (the strategy to lend) results from the difference between the risk-adjusted underlying asset (the

inflows resulting from the loan portfolio), and that of any outflows (essentially sunk costs), to gain rights to the underlying asset (Yoon and Smith 2002).

To determine the option values on the loan portfolio, the output of our conceptual framework, we must ascertain the expressions for the put and call options. According to Dixit (1989a) the equilibrium condition equates the indifference and disinvestment values of Income Inflows. From this expression, the put option premium transpires from the salvage value of the loan, less lost operating inflows. For ease of reference, ϖ , denotes future interest income, service charges, along with fees and commissions. Discounting occurs from the real rate of return, the hurdle rate, ρ , net inflation, μ . The salvage value (any collateral or factored receivables) associated with the loan portfolio is denoted, χ .

$$P = (\varpi^{\theta_P} B - \chi) - \left[\varpi^{\theta_N} A + \left(\frac{\varpi}{\rho - \mu} \right) \right] \quad (10)$$

With regard to call options, the equilibrium condition fundamentally equates the future amortizations from a loan to the value of the outlays, k , made by the bank to provide the loan. The call option premium provides the level by which a bank may expand or contract lending policy.

$$C = \left[\varpi^{\theta_N} A + \left(\frac{\varpi}{\rho - \mu} \right) \right] - (\varpi^{\theta_P} B + k) \quad (11)$$

Results

Information for the study comes from publicly available, secondary data as reports by the BSP, and Universal Bank financial statements. The period from 2008 to 2015 facilitates an eight-year window of observation. The reasoning for this span of time is that the Central Bank installed Basel III requirements to protect against any further financial system collapse in 2007. Prior to this time, reporting standards varied widely between Universal Banks in the country. The frequency by which their stocks trade in the Philippine Stock Exchange, as well as the size of their loan portfolios in Philippine Pesos function as the criteria of cohort selection.

Eighteen banks ranging from Thrift, to Universal Banks compose the banking sector of the Philippine Stock Exchange. Three types of banks trade on the exchange Thrift, Commercial, and Universal Banks. From the 2015 annual reports of actively traded, Philippine Universal Banks in this study, the largest loan portfolio value was Php1.4 trillion, and the smallest was Php23.1 billion. Average loan portfolio size in the sample was Php272.6 billion. The median loan portfolio value was Php150.9 billion (Tables 1 and 2).

In effort to highlight the practicality of a Real Options Model for actively traded, Philippine Universal Bank loan portfolios, let us consider the output from our conceptual framework. From publicly available annual reports for the sample, the option values for lending (call option) show that the value of the loan inflows (the underlying asset) after 2012 is much greater than that of the unexpanded loan portfolio, or outlays to access a project (the exercise price). From 2008 to 2011, option values of both the underlying

Table 1 Sample Loan Portfolio Values

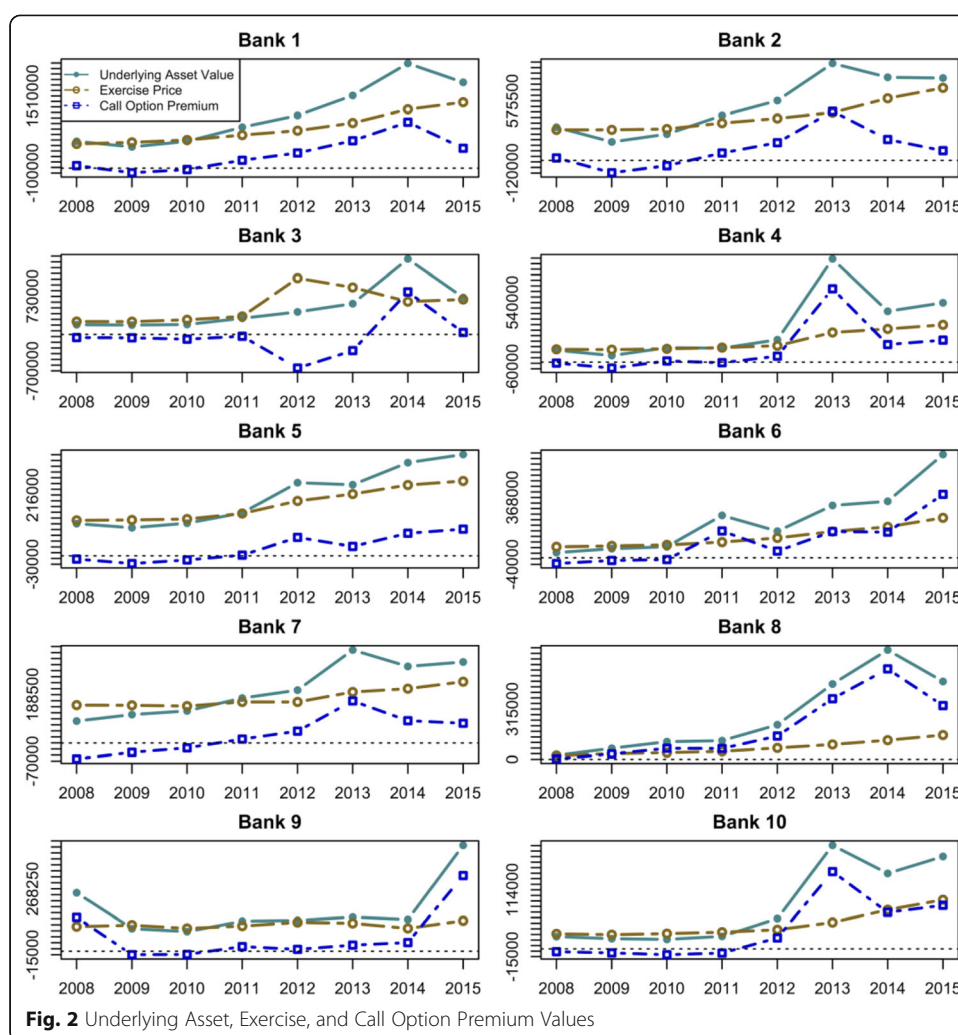
Cohort	2015 Loan Portfolio Value (in Php Millions)
Bank 1	1,378,378
Bank 2	700,710
Bank 3	671,005
Bank 4	337,963
Bank 5	265,964
Bank 6	243,535
Bank 7	239,119
Bank 8	151,634
Bank 9	130,645
Bank 10	94,748

asset and exercise price were very close, a reflection of the low interest rate and high inflationary environment in the country during the Global Recession. It is of note that the exercise price very closely reflected the loan portfolio book value from the annual reports. Differences between the exercise price and book value were relatively small, ranging from negative 0.6252% of the book value to no difference at all. In 2012, the underlying asset value began to rise above that of the exercise price for eight of the ten cohorts in this study. Only Banks 3 and 9 exhibited exercise prices higher or equal to their underlying asset values, respectively. In subsequent years the underlying asset value continues to rise for all banks in the sample. Yet, as exercise values very closely represent book values from public documents, it is concerning that the loan portfolio book values do not show as aggressive an increase as that of the call option premium. Figure 2, describes this phenomenon in the option values. Hence, a Real Options Model for actively traded Philippine Universal Banks allows these institutions to value lending policies considering the business environment they operate in. Estimates from the model may provide an expectation to the level of expansion or contraction of the loan portfolio asset value.

In terms of the call option premium, from empirical data, the premium follows movements in the underlying asset value. Since the call option premium nets the value of outlays for access to a borrower, positive premium movements suggest the level a loan portfolio may expand. Negative movements in the call option indicate the value of outlays in a given period is greater than the level of expected inflows. Hence, negative call option premiums suggest curtailing or contracting lending activities. For cohort banks, the period from 2008 to 2011 exhibited premiums very close to zero, or negative in value. At this time, the country was experiencing an environment of low interest

Table 2 Descriptive Statistics of the Sample

(in Php Millions)	Sample
Minimum	23,100
1st Quartile	104,004
Median	150,866
Average	272,649
3rd Quartile	301,836
Maximum	1,378,378



rates, and even more rapid inflation. In 2012, premiums indicated an expansion in lending for six of the ten subject banks. This general trend in premium growth extends into 2015. Yet, as the premiums suggest banks may lend more, movement in the existing loan portfolio values for many cohorts do not reflect a matching level of growth. It appears, despite indications that more lending may occur, banks in the sample are not offering access to funding commensurate with the call option premium.

Table 3 describes the ranges for the variables in the model. For variance, σ , the lognormal annual percentage change in loan portfolio value for each of the banks in the sample range from 1.15% to 12.91% in any given year of the window of observation. The percentage change in the Operating Profit (net inflation) for all cohorts in any given year ranges from negative 8.94% to positive 1.40%. It is of note, that all banks in the sample from 2008 to 2012 experienced negative values in the real growth rate. Thus, during the Global Recession and several years after, inflation was so rapid Operating Profit growth could not match the decline in purchasing power. The discount rate (net inflation) for banks in the sample ranges between negative 1.78% and positive 12.03%. The level of information asymmetry, the standard deviation in lognormal values from NPLs, for the window of observation spans from 0.8468 to 0.9986. This

Table 3 Variables and Value Ranges

Variable	Values
Variance (σ)	0.0115 to 0.1291
Growth Rate (μ)	−0.0894 to 0.0140
Discount Rate (ρ)	−0.0178 to 0.1203
Information Asymmetry (ζ)	0.8468 to 0.9986
Income Inflows (ϖ)	0.0332 ^a and 0.0748 ^a
Loan Portfolio (Book Value) (χ)	0.671 ^a and 1.4 ^a
Large Bank Vector Magnitude Factor (a)	−133.5
Smaller Bank Vector Magnitude Factor (a)	−27.5
Vector Magnitude Factor (b)	0

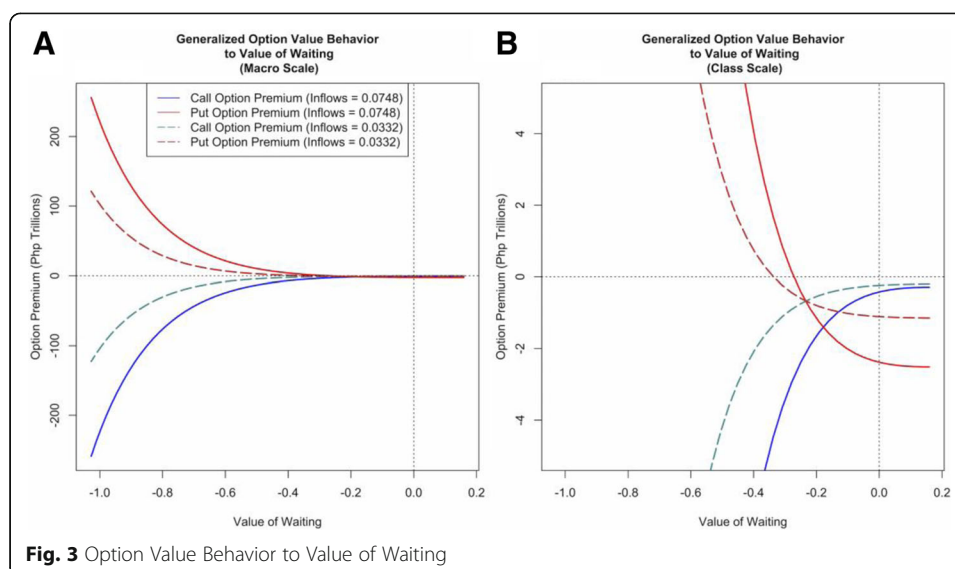
^aIn trillions of Philippine Pesos

indicates that banks have limited the level of delinquent loan accounts to within one standard deviation of the mean.

In this simulation, we take the loan portfolio Income Inflows from the largest and third largest bank in the sample, namely Banks 1 and 3, respectively. The three largest banks constitute 65.27% of total loan portfolio value in the sample. Set in perspective of the entire Philippine Financial System, the largest three actively traded, Universal Banks in the country account for 52.22% of total outstanding loans as of 2015 (*Bangko Sentral ng Pilipinas* 2015, Table 23). As such, 2015 Income Inflows, ϖ , for the third largest bank in the sample was Php33.2 billion, and that of the largest bank was Php74.8 billion. Amounts for the loan portfolio book value, χ , range from Php671 billion (Bank 3) to Php1.4 trillion (Bank 1). In the simulation we hold the correlating factor, a , as a constant reflecting its values for Banks 1 and 3 in 2015. This is done to observe the macro-scale behavior of the model over variance and information asymmetry ranges. The Large Bank Vector Magnitude Factor for the largest bank is negative 133.5. For Bank 3, the Smaller Bank Vector Magnitude Factor is negative 27.5. These are values for the strategy of continuing to lend. From empirical data, the vector magnitude factor for the strategy of not to lend, b , is very close to zero, as such, its value is zero in this simulation.

In Fig. 3, the option values (either call or put) of the loan portfolios exhibit convergence to the amount of the loan or salvage value as the Value of Waiting increases. The pecking order theory states firms ought to allocate as many low cost securities as they possibly could, and only when this volume is spent could they allocate higher cost securities (Barclay and Smith Jr. 1999). At very negative Value of Waiting levels, banks with larger incomes from loans will value the option to lend lower than those with smaller inflows. From the put option premiums, larger banks will value the strategy to idle (not to lend) more than that of smaller banks. Panel A describes these behaviors. This may indicate that larger banks enjoy the benefits from a pecking order, as these institutions attract more loan proposals than smaller competitors. Furthermore, these larger universal banks, by virtue of their size, may not experience declining Operating Profit growth rates to the same severity as smaller cohorts.

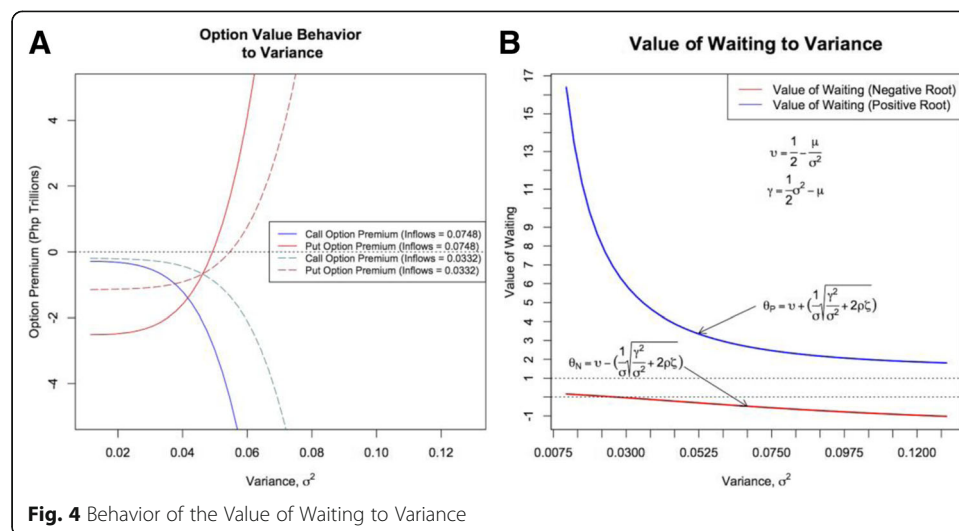
Behavior of the model is consistent at both macro and class scales. The macro scale (Panel A) looks at the general behavior of the model at very large values. This is necessary to gain a common understanding of Philippine Universal Bank behavior according



to the model. The class scale (Panel B) looks at the behavior of option values for the lending portfolio within a conceivable range of loan portfolios in the sample. It is of note that in December 2015, Universal Banks held a total of Php4.3 trillion in loans (*Bangko Sentral ng Pilipinas* 2016, Table 25). From the macro scale observation, the model indicates that banks with larger Income Inflows will value put options more than their smaller competitors. Examining the call option value, the model indicates that small banks will value the option to lend more than larger cohorts. At the class scale, which is more representative of the scale of loans in the financial system, the model shows that for the same option value, smaller banks will price the same loan at a Value of Waiting less than that of larger competitors. This indicates that larger competitors will choose borrowers that offer a lower variance in returns, and industries with the least volatility in loan non-performance (the measure of asymmetric information in this study). Thus, smaller banks are more apt to lend at higher levels of risk as described by the Value of Waiting. This finding indicates that competition for profitable borrowers is especially high in the Philippines, since smaller Universal Banks may lend in the presence of higher levels of uncertainty in both returns, and information asymmetry. These observations lead to the first proposition of this study.

Proposition 1: *From the model, banks with lower loan portfolio incomes will value inflows from new loans higher than larger banks. Bigger banks will exercise options on loan portfolios closer to a Value of Waiting of zero (0) than that of smaller cohorts in the sample.*

Fig. 4 describes the nature of the relationship between the Value of Waiting and Option Premium to variance. It is important to describe this relationship as variance in Real Options Theory expresses the effects of managerial flexibility on inflows from creating, or initiating commercial opportunities in the future (McGrath et al. 2004). Panel A, describes how variance in returns for Philippine Universal Banks diminishes the call option value of the loan portfolio. Essentially, the strategy to lend becomes less valuable in the Philippine environment when returns from loan portfolios become volatile. This behavior accords with findings from Daves and Ehrhardt (2007), where an increase in volatility in the value of an underlying asset decreases the return on its



derivative asset. The cumulative distribution factor A , reflects the downside risks to inflows for lending. As such, this value considers the possibility that certain loans do not payoff. Generally, as variance in returns from the loan portfolio value increase, the Value of Waiting for investment will approach one. In the case of the negative root, this value becomes more negative, further away from zero (Dixit 1992). Figure 4, Panel B describes this behavior that the model expresses.

From the model, we find that the Value of Waiting is sensitive to managerial flexibility in the Philippine Universal Banking environment. The Value of Waiting from the negative root descends from zero (0) as volatility in returns increase. Again, this indicates that competition for profitable loans is such that banks have to maintain very small variances in the returns from the loan portfolio value. Thus, managerial flexibility with regard to ventures that receive loans is very limited in the Philippine environment. Relating the option value to variance, the model shows that as variance in returns increase the value of the put option also increases. The effect of increasing variance on the call option renders the strategy to continue lending less valuable. Table 4, describes the Secondary Market, real one-year Philippine Treasury Bill, and inflation rates from 2007 to 2015. It is of note that from empirical data, Operating Profit real growth rates exhibited negative values for many of the banks, as the growth in in these inflows was

Table 4 Secondary Market 1-year Philippine T-Bill and Inflation Rates from 2007 to 2015

Year	1-year T-Bill Rate (Real)	Inflation
2007	0.022915 ^a	0.035985
2008	-0.034319	0.096461
2009	0.018357	0.029747
2010	0.004328	0.020864
2011	-0.022285	0.042000
2012	-0.020115	0.030000
2013	-0.031667	0.041000
2014	-0.000045	0.027000
2015	0.008710	0.015000

^a364-day T-Bill

less than inflation from 2008 to 2015 (Bangko Sentral ng Pilipinas, 2015, Table 4). Thus, the economic environment by the BSP, was such that banks had to lend, or incur losses the to loan portfolio value. To counter the behavior of banks to target loans at only the most profitable clients, and industries with long standing histories (as manufacturing, and trade), the concept of portfolio diversification according to Markowitz (1952) may offer a solution to developing a more inclusive banking system. According to the seminal paper, as the proportion of a security in a portfolio decreases, the risk of returns in the portfolio also declines (Markowitz 1952). Hence, it is to the advantage of banks to lend to more borrowers in each economic sector, and emergent industries, through smaller packaged loans. A basis for the second proposition of this paper results from the empirical evidence of Universal Bank investment behavior, and solutions that Portfolio Theory offers.

Proposition 2: *In the pressure to maintain small variances in the returns of a Philippine Universal Bank loan portfolio, diversifying investments over more borrowers in each economic sector, and emerging industry through smaller financing packages will mitigate return volatility for the entire loan portfolio.*

From Fig. 5, as information asymmetry increases, the option value of lending decreases. This finding is concurrent with statements from Bellalah (2001), as well as Grenadier and Malenko (2010), that information asymmetry has diminishing effects on asset values. Support for these positions are evident in the increase of the put option premium as the value of NPLs increase. This manifests in the modeling of call options. In turn, the option value of idling or contracting the portfolio increases. Figure 5, Panels A and B, describe the behavior of call and put options in the presence of information asymmetry, the standard deviation of lognormal NPL values. The simulation describes the behavior of the put options and provides explanation for loan portfolio contraction. In general, information asymmetry lowers the call option value of a loan portfolio, forcing Philippine Universal Banks to restrict access to lending. These observations support the third proposition of this study.

Proposition 3: *A narrow range of acceptable information exists such that lending in an environment of imperfect information becomes worthwhile for actively traded Philippine Universal Banks.*

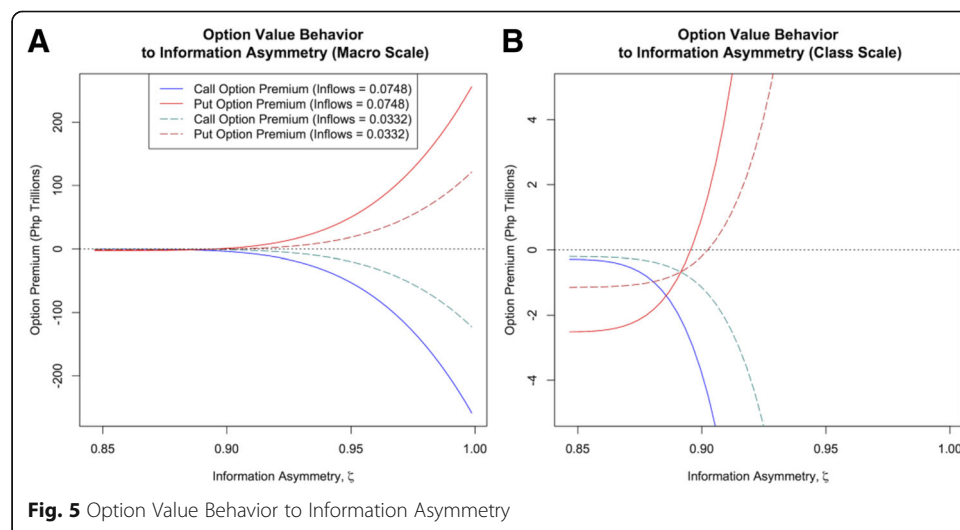


Fig. 5 Option Value Behavior to Information Asymmetry

Discussion

From Proposition 1, larger banks will value put options on their loan portfolios more than smaller banks. As the valuations of loan inflows differ between banks of varying Operating Income classes it is to the advantage of smaller banks to lend to more borrowers, while not going beyond lending limits set by the BSP. After a series of discussions with officers at various bank branches, and support from evidence of financial system wide outstanding loan values, actively traded Philippine Universal Banks tend to focus more efforts on making consumer loans (such as those for housing and cars). Distributing risk throughout more borrowers such that the amount in loans that do pay off, counter losses from defunct borrowers, proves as an impetus for more lending at an individual level. The practice of diversification, in this case diversifying among individual borrowers, echoes concepts from Markowitz (1952). This provides the argument for banks to engage in micro-lending activities to spur entrepreneurial ventures.

An implication of Proposition 1 is that actively traded, Philippine Universal Banks must provide more financing and insurance facilities for micro and small enterprises. In a Real Options perspective empirical evidence indicates that variances in the Operating Profit from the loan portfolio adversely affect the value of a lending strategy, while raising the value of idling the portfolio. Information Asymmetry, further impacts the Operating Profits. The influence of variance on the Value of Waiting thus, causes smaller banks in the sample to value the strategy to lend more than their larger counterparts. Furthermore, the current strategy of several banks in the sample to diversify the loan portfolio over a larger combination of borrowers overcomes any downside effects of default loans. As Chapter IV of Republic Act 8791 affords to a Universal Bank the powers of a commercial bank, and an investment house, these banks also have the exclusive power to invest in unrelated enterprises (An Act Providing for the Regulation of the Organization and Operations of Banks, Quasi-Banks, Trust Entities and for Other Purposes, 2000). Hence, it becomes the responsibility of these banks to create facilities or institutions that accord with Section 1, of Presidential Decree 72, more specifically, to promote conditions that encourage economic growth and stability (Amending Republic Act Numbered Two Hundred and Sixty-Five, Entitled "The Central Bank Act," 1972).

Proposition 2 highlights a serious limiting factor in the Philippine banking environment. From discussions with bank branch managers, due to the difficulty in assessing new firms (especially those in emergent industries of the country, as creative services, or ventures involved in technological development), focus remains on clients and industries with long running profitability. This behavior limits investment to already established firms, and industries. As such, new firms in emergent industries will receive less loan funding, if any. Such a limiting strategy overlooks clients and industries in conditions of impending obsolescence with regard to product and service offerings, or technologies. From Portfolio Theory, investment diversification involves the level of asset commitment, project returns, and its associated level of risk (Lintner 1965; Markowitz 1952; Sharpe, 1964). Being that the proportion an individual security holds in a portfolio bears on the level of risk for the entire portfolio, smaller financing packages to more micro and small scale enterprises may overcome operating income volatility that Philippine Universal Banks face. Given the behavior of option values in the model, where smaller institutions will value lending more than their larger

counterparts, and the legal affordance by Republic Act 8791, allowing Universal Banks to invest in unrelated ventures, it is to the advantage of this class of banks to establish more instruments, and institutions that mitigate project specific risk and provide more access to funding services. This entails smaller value risk mitigating and funding packages, which target micro and small scale ventures.

Proposition 3 forwards that actively traded Philippine Universal Banks can make more loans after hedging downside risks associated with information asymmetry. As the standard deviation of NPLs serves as a measure for information asymmetry, it is conceivable to hedge the amount of the downside risks of loans associated with asymmetric information to bring the put option premium closer to zero (0). The construction of a hedging portfolio is possible for assets and liabilities that are positively correlated, and in unison (Yoon and Smith 2002). As Philippine Universal Banks make loans from the deposits of savers, this study makes the same assumption as Yoon and Smith (2002). With hedging the value of the downside risks from each strategy (Eq. (9)), a bank may lower its associated exposure to NPLs. This strategy is conceivable in the current Philippine investment environment, as there exists a long standing money market industry, as well as a bond market, which may serve as sources for hedging instruments.

To further support the position of this paper that a narrow range of acceptable information will offset downside risks from lending in an environment of imperfect information, Tables 5 and 6, describe the hedging portfolio value as Eq. (9) finds. The proportion of loan portfolio book value that a hedging portfolio requires ranges from 0.03% to 0.89%. For all banks in this study the hedging portfolio to cover for imperfect information requires less than 1 % of the loan portfolio book value. For the largest bank in the sample a hedging portfolio that covers for imperfect information ranges from 0.21% to 0.83% of its loan portfolio book value. This translates to a hedging portfolio that ranges from Php2.54 billion to Php5.40 billion. Smaller banks in the sample require hedging portfolios far smaller than their largest counterpart. For the other nine cohorts in this study the minimum size of a hedging portfolio ranges from 0.03% to 0.15% of book value. For the smallest bank in the sample, a hedging portfolio in 2008 of 0.08% of book value equates to Php29.25 million. While a hedging portfolio in 2015 of 0.44% of book value is Php235.63 million, for the same bank.

The implications of Proposition 3 are significant to banks operating in other developing countries, as the model accounts for the level of information asymmetry, the level of NPLs in the banking system. A recent report by Reuters brings to light the

Table 5 Hedging Portfolio Values for Banks 1 to 5 from 2008 to 2015

Year	Bank 1	Bank 2	Bank 3	Bank 4	Bank 5
2008	0.0071	0.0011	0.0013	0.0011	0.0011
2009	0.0083	0.0033	0.0030	0.0037	0.0028
2010	0.0052	0.0012	0.0018	0.0017	0.0015
2011	0.0060	0.0009	0.0011	0.0011	0.0010
2012	0.0032	0.0005	0.0003	0.0006	0.0006
2013	0.0057	0.0034	0.0022	0.0046	0.0037
2014	0.0022	0.0011	0.0013	0.0015	0.0013
2015	0.0021	0.0016	0.0019	0.0021	0.0020

Table 6 Hedging Portfolio Values for Banks 6 to 10 from 2008 to 2015

Year	Bank 6	Bank 7	Bank 8	Bank 9	Bank 10
2008	0.0018	0.0010	0.0034	0.0006	0.0010
2009	0.0029	0.0023	0.0072	0.0025	0.0020
2010	0.0014	0.0014	0.0036	0.0016	0.0014
2011	0.0012	0.0010	0.0026	0.0014	0.0009
2012	0.0005	0.0006	0.0015	0.0007	0.0008
2013	0.0037	0.0043	0.0089	0.0047	0.0044
2014	0.0013	0.0016	0.0035	0.0016	0.0016
2015	0.0024	0.0023	0.0046	0.0029	0.0025

ramifications of information asymmetry in the Chinese banking industry. The lack of a collateral registry in the second largest economy (since 2010) serves as a barrier to information transparency that allows unscrupulous borrowers to pledge the same collateral for multiple loans. This practice resulted in the default of loans on the order of tens of millions in United States dollars that the International Finance Corporation (IFC) recently absorbed. Other multinational banks experienced losses in the billions of dollars from fictitious collateral in the country. One agency estimated NPLs in China at 15 % to 21 % of commercial bank loans (Tham et al. 2017). In light of business practices in developing Asian countries, the model in this paper serves as an alternative tool for valuation and risk assessment to determine the level of exposure a bank has in an environment of asymmetric information. The Real Options Valuation Model of this study expands the level for discernment in the current business landscape of developing Asia, by using available measures of imperfect information, and volatility. As such, individual banks, Central Banks, along with other banking and financial regulators may utilize the model to inform investment or regulatory policy.

Conclusion and directions for future research

Of the six Association of Southeast Asian Nations (ASEAN) members covered by the 2014 Global Entrepreneurship Monitor (GEM) report, the Philippines had the highest incidence of business discontinuation. The greatest reasons why start-up ventures in the country discontinue within three and a half years are: unprofitability, lack of access to credit, as well as personal matters (Velasco et al. 2016). According to the GEM report on the country, of the multitude of constraints entrepreneurs face, a scarcity of credit from formal institutions of finance impedes growth of venture performance (Velasco et al. 2016).

This study introduces a Real Options Model that describes option values of loan portfolios for actively traded Philippine Universal Banks. The model assumes that these banks may continually invest funds; the loan portfolio and deposit accounts are positively and strongly correlated; and banks operate in an environment of imperfect information. From simulation, the study finds that the Value of Waiting functions similar to a risk-adjusted discount factor to Operating Income from the Loan Portfolio. Resulting cumulative distribution factors (from the equilibrium condition) adjust asset values, and inflows for lending risks. A put option premium on the loan portfolio results from the difference between the salvage value of a loan, and its inflows. This put option values the strategy of not lending, or idling, the loan portfolio. The call option values

the strategy of lending, essentially expanding the loan portfolio. Call option premiums result from the difference between the risk-adjusted inflows, and the risk-adjusted value of the loan portfolio.

From the numerical analyses of the model, we find that in the Philippine banking environment, option premiums exhibit sensitivity to changes in the Value of Waiting, variance, and information asymmetry. As there exists very little value for banks not to lend as evident in the ranges of Operating Income growth (which tend to deteriorate by idling), coupled with the competition to lend to more profitable clients, larger banks will place more value on the put option than their smaller counterparts. Effectively, larger banks will lend to projects with a Value of Waiting closer to zero (implying less risky borrowers), than smaller competitors. Empirical data shows the Value of Waiting is far more sensitive to the decisions of managers, as they affect returns from the loan portfolio. More stable returns from the loan portfolio will direct lending toward profitable clients in a particular industry. As information asymmetry increases, the value of the put option also grows. In turn, the value of the call option (the strategy of lending) diminishes.

These analyses serve as the bases of three propositions in this study. The first proposition reflects that smaller banks will value loans higher than their larger competitors. For the supply side, this implies that smaller banks should lend to more borrowers. At the demand side, borrowers may target smaller banks for their borrowing needs. The second proposition reflects that managers will limit lending to established clients and industries. This underscores the current situation of lending in the country that does not spur more inclusive entrepreneurial activity. As such, the introduction of Universal Bank instruments and alternative funding subsidiaries that target micro and small scale ventures may allow for more entrepreneurial activity as the financial system supports their development. The third proposition of the paper that a narrow range of acceptable information exists such that lending in an environment of imperfect information is worthwhile, points to the possibility of creating a hedging portfolio (Yoon and Smith 2002). Basing the hedging portfolio on the value of the downside risks ($\varpi^N A$, and $\varpi^P B$), counters adverse risks from NPLs.

The propositions that this paper forwards partly reflect the lending environment of the Philippines. Implications from these propositions point to a conclusion that smaller scale funding for micro and small enterprises allows for a more inclusive banking and economic system. As risks can be spread over more borrowers, along with evidence that smaller lending institutions will value lending more than their larger counterparts, and discussions that indicate these banks engage in consumer lending activities (involving many borrowers), micro-scale funding, with smaller financing packages, may provide a possible growth market for actively traded Philippine Universal Banks. Furthermore, the behavior of the call option value serves as evidence from the Real Options Model that suggests banks do not offer enough funding and risk mitigating facilities to stoke entrepreneurial activity in the country. This conclusion supports the findings from the GEM report.

As this study examines loan portfolios of actively traded Philippine Universal Banks, scholars may find areas for future studies that revolve about extending the model, or applications of the model to a variety of cases. An extension of the model, and arguably

a more realistic description of business practice, may consider the effects on option premiums where Non-Performing Loans resume amortization after becoming thirty-days past due. This is of interest as there exist practices on the part of firms that delay payment as a result of slow paying customers, effectively extending the cash cycle. Another extension of the model could examine the hedging portfolio value for super-normal growth firms in emerging and developing countries (such as start-ups in the technology or creative services industries).

This paper focuses on the entirety of a loan portfolio, which is composed of investments in varying economic sectors of the country. A limitation of this study was the restriction of access to actual sector allocation bank data. An application of the model to discern the optimal value of lending in a particular sector relative to its current level of loans may carry far more insight as to which areas of the economy to focus upon. In terms of managerial flexibility, future studies may investigate how choice in capital expenditure affects income volatility in various sectors. As the model of this paper examines volatility, and its influence on the Value of Waiting, it is of interest to identify which types of managerial decisions are most likely to significantly affect project option values. With regard to information asymmetry, the extant literature of Real Options Theory does not adequately address if there exists a causal or anticipatory relationship with managerial flexibility. It is of interest to examine the behavior of the Value of Waiting in other imperfect markets, or industry sectors.

Findings from this study advocate a change in investment policies to support government mandates for the economic welfare of the nation. A direction for future research with regard to these data may manifest in an analysis, from a Real Options perspective, of bank profitability and economic growth as a result of extending credit to micro and small scale ventures in emergent or developing countries.

Lastly, more Real Options Valuation Models that *explicitly* consider the revenue processes of firms in various industries and countries must be developed. New models are necessary for the further development and acceptance of Real Options Theory in academic and industry discourse. In forwarding more models, the associations between human experience and the quantitative measurement of these actions humanize the value of an option, allowing for people to better understand, if not, predict the ramifications of strategies and decisions.

Appendix 1

Here we find the return on a project in the presence of imperfect information.

$$\frac{1}{2}\sigma^2\varpi^2\frac{\partial^2\pi_L}{\partial^2\varpi}dt + \mu\varpi\frac{\partial\pi_L}{\partial\varpi}dt + \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz - \left[\varpi\alpha\frac{\partial\pi_L}{\partial\varpi}dt + \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz\right] = vdt \quad (\text{a.1})$$

$$\frac{1}{2}\sigma^2\varpi^2\frac{\partial^2\pi_L}{\partial^2\varpi}dt + \mu\varpi\frac{\partial\pi_L}{\partial\varpi}dt - vdt = \left[\varpi\alpha\frac{\partial\pi_L}{\partial\varpi}dt + \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz\right] - \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz \quad (\text{a.2})$$

$$\frac{\frac{1}{2}\sigma^2\varpi^2\frac{\partial^2\pi_L}{\partial^2\varpi}dt + \mu\varpi\frac{\partial\pi_L}{\partial\varpi}dt - vdt}{dt} = \frac{\varpi\alpha\frac{\partial\pi_L}{\partial\varpi}dt + \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz - \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz}{dt} \quad (\text{a.3})$$

$$\frac{1}{2}\sigma^2\varpi^2\frac{\partial^2\pi_L}{\partial^2\varpi} + \mu\varpi\frac{\partial\pi_L}{\partial\varpi} - v = \lim_{dt \rightarrow \infty} \frac{\varpi\alpha\frac{\partial\pi_L}{\partial\varpi}dt + \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz - \varpi\sigma\frac{\partial\pi_L}{\partial\varpi}dz}{dt} \quad (\text{a.4})$$

$$\frac{1}{2}\sigma^2\varpi^2\frac{\partial^2\pi_L}{\partial^2\varpi} + \mu\varpi\frac{\partial\pi_L}{\partial\varpi} - \rho\zeta\pi_P = 0 \quad (2)$$

Appendix 2

To find the first expression necessary in order to determine the Value of Waiting, substitute the first and second derivate of the income process into Eq. (2).

$$\frac{1}{2}\sigma^2\varpi^2(a\vartheta(\vartheta-1)\varpi^{\vartheta-2}) + \mu\varpi(a\vartheta\varpi^{\vartheta-1}) - \rho\zeta a\varpi^{\vartheta} = 0 \quad (a.5)$$

$$\frac{1}{2}\sigma^2\vartheta^2 - \left(\frac{1}{2}\sigma^2 - \mu\right)\vartheta - \rho\zeta = 0 \quad (6)$$

Appendix 3

The Value of Waiting provides a discounting factor to the income process that considers volatility. Use of the Quadratic Equation on Eq. (6), reducing terms, and some minor substitutions we arrive at Eq. (7).

$$\beta = \frac{-\left[-\left(\frac{1}{2}\sigma^2 - \mu\right)\right] \pm \sqrt{\left[-\left(\frac{1}{2}\sigma^2 - \mu\right)\right]^2 - 4\left(\frac{1}{2}\sigma^2\right)[- \rho(\zeta)]}}{\sigma^2} \quad (a.7)$$

$$\beta = \frac{\left(\frac{1}{2}\sigma^2 - \mu\right) \pm \sqrt{\left(\frac{1}{2}\sigma^2 - \mu\right)^2 + 2\sigma^2\rho\zeta}}{\sigma^2} \quad (a.8)$$

Let:

$$\gamma = \frac{1}{2}\sigma^2 - \mu \quad (a.9)$$

$$\beta = \frac{\gamma \pm \sqrt{\gamma^2 + 2\sigma^2\rho\zeta}}{\sigma^2} \quad (a.10)$$

$$\beta = \frac{\gamma}{\sigma^2} \pm \sqrt{\frac{\gamma^2 + 2\sigma^2\rho\zeta}{\sigma^4}} \quad (a.11)$$

$$\beta = \frac{\gamma}{\sigma^2} \pm \sqrt{\frac{\gamma^2}{\sigma^4} + \frac{2\rho\zeta}{\sigma^2}} \quad (a.12)$$

$$\beta = \frac{\gamma}{\sigma^2} \pm \sqrt{\frac{1}{\sigma^2}\left(\frac{\gamma^2}{\sigma^2} + 2\rho\zeta\right)} \quad (a.13)$$

$$\beta = \frac{\gamma}{\sigma^2} \pm \frac{1}{\sigma}\sqrt{\left(\frac{\gamma^2}{\sigma^2} + 2\rho\zeta\right)} \quad (a.14)$$

Let:

$$v = \frac{\gamma}{\sigma^2} = \frac{\frac{1}{2}\sigma^2 - \mu}{\sigma^2} = \frac{1}{2} - \frac{\mu}{\sigma^2} \quad (\text{a.15})$$

$$\beta_{+,-} = v \pm \frac{1}{\sigma} \sqrt{\left(\frac{\gamma^2}{\sigma^2} + 2\rho\zeta\right)} \quad (7)$$

Appendix 4

The vector magnitude factor adjusts the present value of inflows for inherent risks in each of the strategies. Here, we assume the return on Operating Profits have a strong relationship with Income Inflows. From transposition and simplification, we arrive at Eq. (8).

$$\pi_p = a\varpi^\vartheta \quad (\text{a.16})$$

$$\frac{\partial \pi_p}{\partial \varpi} = a\vartheta \varpi^{\vartheta-1} \quad (\text{a.17})$$

$$\frac{\partial \pi_p}{\partial \varpi^*} = 1 \quad (\text{a.18})$$

$$a\vartheta \varpi^{\vartheta-1} = 1 \quad (\text{a.19})$$

$$a = \frac{1}{\vartheta \varpi^{\vartheta-1}} \quad (\text{a.20})$$

$$a = \vartheta^{-1} \varpi^{1-\vartheta} \quad (8)$$

Appendix 5

The generalized form of Eq. (9) identifies factors A and B , and establishes the value of the hedging portfolio.

$$\frac{1}{2}\sigma^2 \varpi^2 \frac{\partial^2 \pi_L}{\partial^2 \varpi} + \mu \varpi \frac{\partial \pi_L}{\partial \varpi} - \rho \zeta \pi_p = 0 \quad (\text{a.21})$$

$$\frac{1}{2}\sigma^2 \varpi^2 [a\vartheta(\vartheta-1)\varpi^{\vartheta-2}] + \mu \varpi [a\vartheta \varpi^{\vartheta-1}] - \rho \zeta (a\varpi^\vartheta) = 0 \quad (\text{a.22})$$

$$\varpi^\vartheta \left[\frac{1}{2}\sigma^2 (a\vartheta^2 - a\vartheta) \right] + \varpi^\vartheta (\mu a\vartheta - \rho \zeta a) = 0 \quad (\text{a.23})$$

$$\text{Let : } A = \frac{1}{2}\sigma^2 a\vartheta(\vartheta-1); B = a(\mu\vartheta - \rho\zeta) \quad (\text{a.24})$$

$$\varpi^{\vartheta_N} A + \varpi^{\vartheta_P} B = 0 \quad (9)$$

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Authors' contributions

JJT conducted data collection, investigations into the stochastic proofs in the extant literature, the model development, as well as the numerical and graphic analyses of the model. FLT, Ph.D. provided insight as to the use of Real Options Theory in valuing projects on the part of banks, as well as expounding on finance concepts. Both authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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