IMPLEMENTING A QUANTITATIVE METHODOLOGY TO TRANSLATE STRATEGIC RISK INTO ECONOMIC CAPITAL FOR A CANADIAN BANK

by

Anjit Oberoi
BTech Electronics Engineering VIT University 2015

and

Diego Costa
BE Industrial Engineering, Federal University of Rio Grande do Norte 2016

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Name: **Oberoi, Anjit and Costa, Diego**

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Supervisory Committee:

____

Professor Christina Atanasova
Senior Supervisor
Associate Professor, Finance

____

Professor Victor Song
Second Reader
Lecturer, Finance

Date Approved: ____

Abstract

This research paper focusses on a model to quantify strategic risk and calculate adequate capital that can be used to absorb losses in times of distress. Strategic risk, used interchangeably as business risk is relatively a new risk type and not as researched as other types like credit, market, operational etc. We analyse this subject particularly in the context of the Canadian economic environment. Most big banks are holding capital due to minimum capital requirements enforced by regulatory supervisors. However, there are no concrete explanations pertaining to the accounting of this risk type and the allocated capital. We use net income data for the Royal Bank of Canada and calculate Value at Risk and Expected Shortfall for Strategic risk. Our research can be used by Canadian regulators to mandate an efficient model for strategic risk calculations. By setting a common ground, this can be used by banks to calculate their strategic risk and compare it with their competitors. This will greatly reduce the ambiguity regarding the quantification of strategic risk and the associated capital held by Canadian banks.

Keywords: Strategic risk management, Economic capital, Value at Risk, Expected shortfall, Regulatory capital requirements

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1: Introduction

Banks are crucial to the proper functioning of an economy because they help in transferring capital from those with excess funds (depositors) to those in need of them (borrowers). Thus, they facilitate monetary flow in the economy. For this reason, banks are subject to regulations which direct them to effectively manage risks by holding capital proportional to the risks they take. As we saw with the financial crisis of 2008, bank failures can quickly spread and ultimately result in the collapse of the whole financial system and huge monetary losses. Thus, efficient enforcement of regulations is really important.

As a risk management strategy mandated by regulators, banks must hold capital commensurate to the risks they are subject to, such as credit, market, operational risks etc. These are pretty straight forward, and regulators have clearly defined guidelines regarding their quantification. A relatively new risk type which has assumed great importance following the financial crisis of 2008 is strategic risk, also referred to as business risk. It can be defined as the risk that bank earnings decline due to a new business strategy, new market entrants or changing customer needs. These can significantly affect profitability of financial institutions and is a cause of concern for regulators.

As of now, a clear mandate regarding strategic risk assessment does not exist. Banks are holding capital because they are required to, but each one in different segments. Further, since its assessment is more of a qualitative exercise, there is no way of verifying if a bank is holding adequate or higher capital. Thus, banks are holding arbitrary amounts of capital for strategic risk but a detailed calculation cannot be produced. Through this thesis, we have developed a model to quantify business risk relevant to the Canadian business environment. We have also tested the model by using net income figures for Royal Bank of Canada.

The research on this topic is fairly limited. There have been attempts to define strategic risk but a clear model to quantify it does not exist. Our primary reference paper is 'Economic capital for strategic risk in financial institutions' by Soetekouw, R.C.M. The author talks to industry experts to come up with a standardized definition of strategic risk and then goes on to calculate economic capital for it. The research has been done in the Netherlands economic environment for the bank 'ABN AMRO'.

Thus, our contributions to this area are twofold. Firstly, we quantify strategic risk in a Canadian environment which is different from the Netherland economy. Secondly, we have improved on the net income modelling and simulation process by using Brownian motion without a drift factor as it is producing better results for Canadian bank data.

The rest of the thesis is structured as follows. In Chapter 2, we study various literary sources on risk management for banks. We have explained the model in detail in Chapter 3. In this section, we have modelled net income and used it to quantify strategic risk. We test the model by inputting earnings data for Royal Bank of Canada and have explained the results in Chapter 4. In Chapter 5, we conclude by talking about how our research can lead to benefit regulators and banks. This is followed by possible future research which can be done on this topic.

Thus, our thesis aims at recommending the regulators a concrete calculation of strategic risk which can be used to enforce concise regulations on banks. It can also be used by the banks to compute the strategic risk that they are taking on and compare it with their competitors. This will help them calculate and set aside adequate economic capital so that they can withstand earnings volatilities that can be introduced by implementing new strategies.

2: Literature review

Banks are subject to several risks due to the nature of their business. Risks can arise due to counterparties defaulting on their obligations (credit risk), change in market conditions (market risk) and failures in internal processes (operational risk) and more. To effectively manage these risks, most big banks have sophisticated risk management systems in place.

2.1 Risk management for banks

According to (Schroeck, 2002), risk management can be defined as the prevention of the bankruptcy of a bank. This rationale is also reflected in the regulatory constraints for financial institutions. It ensures a bank's long-term survival by avoiding lower-tail outcomes (i.e. extreme losses). In addition, risk management strategies can lead to overall value maximization for a bank in the long run.

The various methods of managing risk in banks are: avoid, transfer and absorb/manage. Big banks implement a fraction of all these strategies to effectively manage their risks. We are more concerned with absorption/management of risk which is mostly done through diversification and holding capital. This is the main reason why we need to employ proper measures of risk to produce accurate calculations of capital as a part of this strategy. These strategies need to be implemented for all the major risk types for a holistic risk management framework.

Following the 2008 financial crisis, regulators around the world have increased capital requirements for all types of risks that banks are subject to. Thus, banks are required to hold capital for uncertainty in their earnings cash flows that can be caused by changing business conditions.

2.2 Definition of Strategic Risk

(Drzik, 2005) defines strategic risk as the risk of external trends or events that can influence a company's growth or value. These external events can further be divided into industry margin squeeze, technology shift, brand erosion, one-of-a-kind competitor, new-project failure, and market stagnation. Another definition provided by (Doff, 2008) is the risk of financial loss due to changes in the competitive environment or the extent to which the organization could timely adapt to these changes.

(Doff, 2008) also goes on to address its suitability within an economic capital framework. He classifies the business risk according to two criteria 'Adoption to changes' and 'Competitive Environment'. The author concludes that mitigation through an economic capital buffer would only work for 'abrupt temporary changes' and 'abrupt permanent changes' conditions. His findings can be validated by applying logic that it is easier to adapt the organization when changes occur gradually.

It can be clearly seen from these definitions that strategic events have a notable impact on the bank income statement and a lack or delay of proper business risk management can adversely impact bank profitability.

2.3 Economic capital

(Sweeting, 2011) states that economic capital refers to a surplus of assets or cash flows to deal with an unforeseeable decrease in assets or rise in liabilities over a predefined period within specific risk limits. It equals the unexpected loss on a one-tailed confidence limit. For instance, the economic capital for credit risk is the difference between the confidence limit and the expected loss.

Thus, economic capital is an efficient risk measure to assess the various risks that a bank is facing. It is a widely used to estimate the capital that needs to be held to account for the risk stemming from unforeseeable severe losses. It does not, however, denote a physical amount of capital. It can be used to decide upon the total risk exposure a company is facing so that it can plan to perform business activities within those risk limits. It is also helpful for regulators around the world to evaluate banks on a common metric and set industry standards.

In practice, a single methodology for banks to calculate economic capital does not exist. Therefore, banks use different internal models and processes in their internal risk assessment frameworks (Sweeting, 2011). The concept of economic capital, however, is consistent across banks. Thus, one of the main objectives of our paper is to clearly define a method to calculate economic capital pertaining to strategic risk.

2.4 Risk Measures

Measurement and quantification of risks is the hardest part of the risk assessment process. We have chosen 'Value at Risk' and 'Expected shortfall' measures as we feel that they would best quantify strategic risk. Furthermore, these are relatively easy to understand and adopt. Risk measures should be used to calculate the amount of economic capital and to internally assess the effects or magnitude of risk types (Basel Committee on Banking Supervision, 2015). We have discussed the idea behind economic capital in the previous section and how it represents the difference between the upper limit of the distribution and expected losses.

There are a wide range of standard risk measures discussed in literature and used in practice. The first risk measure, standard deviation is frequently used in the mean-variance theory (Guégan, 2015) . Standard deviation, however, assumes a symmetrical return distribution, which is hardly true in practice (Guégan, 2015). Also, as a risk measure, it is not coherent because it violates the monotonicity constraint (Basel Committee on Banking Supervision, 2015).

The second risk measure, Value at Risk $VAR\alpha$, is highly used in industry and represents a confidence interval of the loss distribution. This measure puts significant weight on the α-quantile (Dowd, 2008). The value at risk can be represented by (Guégan, 2015):

$$VAR_{\alpha}(X) = \inf \{x |\, P\, [X > x] \leq 1 - \alpha\}$$

The third risk measure, Expected Shortfall (ES), complies with the coherency properties and goes beyond the value-at-risk measure. It is defined as the average of losses that are greater than the value at risk. It is, therefore, classified as a more conservative risk measure (Guégan, 2015).

Now that we have studied the definitions of economic capital and risk measures used in practice, we can proceed to explain the model. Thus, the following sections describe the quantitative model, our assumptions and findings in detail.

3: Modeling economic capital for strategic risk

This section explains the process of modeling economic capital for strategic risk. By outlining this approach, this section talks about the rationale behind choosing cost of equity as the profitability ceiling. It further explains the process of modelling net cash flows by employing a stochastic process. Decreases in earnings caused by strategic events is a core component of strategic risk. Implementing a sustainable strategy that produces a practical business model is essential to face the challenge of being or remaining profitable in a changing business environment.

“Being or remaining profitable” is a generalist statement and it can be interpreted in different ways. For example, an activity that incurs a loss can be rapidly recognized as non-profitable. However, profitability can refer to a certain level of acceptable returns. Consider a line of business that has generated 200M in revenues in the last 5 years and that is above the required expectation of shareholders, which is around 100M. By the end of the year, revenues have fallen to 80M and, despite the absolute amount of revenues still is positive, it can be argued that the business was not profitable according to shareholders expectations.

Thus, modeling economic capital for strategic risk will have two objectives:

1. Modelling net cash flows capturing future uncertainty of the business environment; and
2. Determining a profitability limit that provides an acceptable and non-acceptable threshold.

3.1 Profitability Ceiling

Economic capital is mostly defined as earnings falling below costs. Therefore, one major assumption when considering the literature on economic capital for strategic risk, it is to contemplate only loss as a constituent of strategic risk. In this case, any profit will not contribute to the level of economic capital.

However, in the guidelines of identifying and dealing with weak banks, (Basel Committee on Banking Supervision, 2015), which provides instructions to the supervisory community on diagnosing the symptoms and treating the causes of bank problems, asserts that supervisors should evaluate profitability on a forward-looking basis and should encompass early warnings in the assessment of the business model. These guidelines clearly indicate that the lack of profitability should be perceived as a symptom and the establishment of a limit for it as a value above zero. Setting an early warning limit on zero will lead to losses before action is taken.

Another possible argument favouring a profitability risk limit above zero relates to the fact that supervisors can take corrective actions when banks are not performing according to the budget or underperforming in comparison to peers. When a bank does not perform as expected, supervisors will raise red flags or early warnings that may increase the level of perceived risks by shareholders and other stakeholders. This increased risk perception may encourage shareholders to require higher returns and access to credit may also be costlier, in other words, the riskier a bank becomes the higher the capital costs. Hence, even if a bank's activities generate a profit, it can still induce a scenario in which the organization or certain activities are in a "danger zone", suggesting that the profitability threshold should be above zero.

Assuming a profitability ceiling above zero as the proper limit to capture early warnings, the question that remains is what this limit should be. (McKinsey & Company, 2015) compares the return on equity with cost of equity to evaluate the profitability of banks. The idea behind this comparison is that when return on equity falls below the cost of equity a company will be less attractive to shareholders. Return on equity (ROE) is a well-known ratio in financial management and can be calculated by dividing net income before taxes by total amount of shareholder's equity. Return on equity reflects a company's ability to generate revenue for its shareholders. From the shareholders' perspective, ROE can be used to assess the return on an investment. Cost of equity (COE) can be understood as the compensation that the market demands in exchange for holding the asset and assuming the risk of ownership. If ROE falls below COE, it will result in a scenario in which shareholders would not be willing to invest because the required ROE has not been reached.

Accordingly, cost of equity seems to be a suitable limit to define the acceptable and non-acceptable earnings space. In order to determine the cost of equity, the capital asset pricing model (CAPM) can be applied (Luenberger, 1998). The CAPM expresses the relationship between the risk of an asset or portfolio and the required or expected return. Equation (1) shows the CAPM formula, which yields the required rate of return r.

$$r = r_f + \beta(r_m - r_f) \tag{1}$$

r = cost of equity

r_f = risk-free rate

r_m = market return rate

β = risk factor (systematic risk)

The risk-free rate can be obtained using the return of a "risk-free" asset. This study utilized as a proxy of risk-free rate the return on a 3-month Canadian Treasury bill. The market rate of return was estimated using historical returns of the S&P TSX Composite Index. The beta was determined through a univariate regression. The excess stock return ($r_{stock} - r_{free}$) of the Canadian bank that served as a benchmark for this study was regressed against the excess return of the market index ($r_{market} - r_{free}$). The table below summarizes the results:

	Coefficient	**P-value**	R^2
β	0.9559	1.0E-12	
Model Statistic			0.881

Table 1 - Regression output for beta coefficient

Once beta is determined and through the CAPM, an estimation of the absolute value of the cost of equity can be calculated by multiplying *r* with the amount of equity. Economic capital for strategic risk should depict the value of earnings below this absolute figure of the cost of equity.

$$COE_t = r \times \hat{E}_t \tag{2}$$

Equation 2 shows how to obtain the absolute value of cost of equity and that there must be an estimation of the equity amount at a certain point in time. Additionally, it can be argued that the value of *r* varies over time when variables of the CAPM change. Although they will change in the future, this may not have a significant impact on the time horizon for strategic risk considered in this study. Unless a disruptive event takes place, the return on market and the risk-free rate will be assumed to be constant over a three years horizon. On the other hand, the beta in theory should be more volatile and exposed to strategic events and changes in the business environment. However, it should be noted that beta was determined through a regression employing historical data, therefore, it lags the “real” beta since it does not represent a real time scenario.

3.2 Stochastic process for net cash flows

A good strategy or the absence of one in a dynamic business environment immediately impacts the profitability of company. This should be incorporated into how economic capital is modelled and explains the reason of utilizing the profit and loss statement as a data source to the model. Thus, earnings will be used to derive economic capital for strategic risk. A strategy has a certain horizon, which is typically of three to five years, and its planning is one of the responsibilities attributed to the board of directors. Future performance of a strategy is uncertain since it is hard to predict how the business environment is changing and if the implemented strategy is feasible. As an attempt to address these uncertainties, the following characteristics of earnings should be assumed:

- **Level.** Cash flows will have an existing level or starting value, which is higher or lower than zero and can be based on historical realizations;
- **Volatility.** There will be a random component in the behavior of cash flows;
- **No trend.** Net cash flows are simulated through a stochastic process. (Bocker, 2008) argues that the use of Brownian motions to model future cash flows might be highly suitable. Brownian motions account for the inclusion of a trend and volatility and have continuous outcome and time space. Additionally, Brownian motions are heavily explored in the literature, easy to interpret, and employed in (Bocker, 2008) various fields. This study applies the model of to compute economic capital for strategic risk but removes the trend (no growth factor)

originally included in Bocker's model. The idea behind excluding the trend is to generate simulation paths that allow for different impacts on earnings, reflecting the uncertainties of the business environment and capturing the occurrence of extreme strategic risk events.

3.2.1 Brownian motion

Financial products such as assets and commodities are typically modelled using geometric Brownian motions. The Black-Scholes model is probably the most well-known application of geometric Brownian motions, which is particularly suitable to calculate stock prices since it can only have positive values. However, cash flows are not necessarily positive and can assume negative values when losses occur. Therefore, arithmetic Brownian motions will be used to simulate future cash flows since this model allows for negative values.

Given a stochastic process $X_t = \{X_t, t \geq 0\}$ with drift parameter μ and scale parameter σ, the following properties hold (Siegriest, 2018):

- $X_0 = 0$;
- $X_t = \{X_t, t \geq 0\}$ has stationary and independent increments;
- $X_t \sim (\mu t, \sqrt{\sigma^2 t})$;
- X is continuous with probability 1.

The stochastic process is represented by:

$$X_t = X_0 + \mu t + \sigma B_t \quad (3)$$

However, considering the assumptions explained previously, equation 3 reduces to the following:

$$X_t = X_0 + \sigma B_t \quad (4)$$

In which, X_0 is the starting value, $\sigma \in (0, \infty)$ is the random volatility, B_t ~ N (0, $\sqrt{t}$), and X_t is the value of a cash flow on time *t*.

3.2.2 The idea behind the simulation

Economic capital for strategic risk, as defined previously, is a measure of earnings falling below a limit. This limit or threshold has been assumed to be cost of equity. Figure 1 illustrates the idea behind the performed simulation. Future cash flows can take different future paths, according to the Brownian motion described in the previous section. The black dashed line represents the absolute value of the cost of equity. When a net cash flow falls below the back dashed cost of equity line, it is assumed to be an early warning or danger zone. Additionally, it is helpful to observe that the black dashed line is an increasing function of time. This will be detailed in the following chapter, which explains how the adopted threshold was derived.

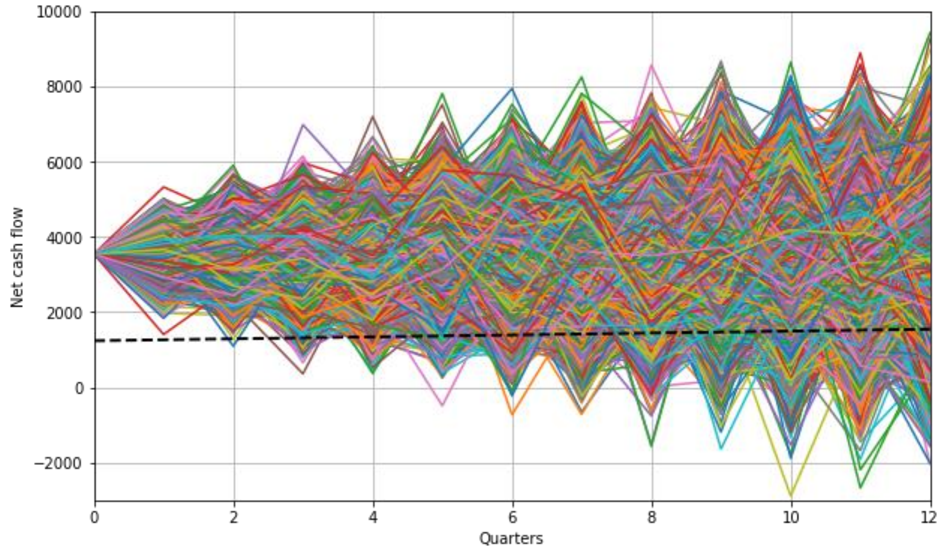

Figure 1 - Simulated future cash flows

Considering the simulated paths exhibited in the figure above, it is argued that economic capital should be the necessary amount of capital to raise net income above the black dashed line. Future realizations of net income will have a different amount of economic capital associated with. The paths that do come below the black dashed line will need economic capital of different size to raise the net cash flow above the acceptable limit. This means, in more technical words, that the amount of economic capital will be stochastic, since it will vary in each possible future scenario. There will be cases in which no capital is needed and other cases in which an amount of capital should be allocated to withstand the effects of a cash flow dropping below the established limit. Therefore, a risk measure is needed to express an acceptable level of economic capital with a single value.

3.2.3 Risk measures

Risk measures that are suitable to use are value-at-risk, expected shortfall, or spectral risk measures. This study focusses particularly on value-at-risk and expected shortfall since they are easy to interpret and well-known risk measures in practice.

Value-at-risk is the α-quantile upper bound of the loss distribution in which alpha is typically a value close to one (alpha is the confidence level). The loss distribution can be obtained by simulation, which will be explained in the next chapter. The equation below shows how to calculate for economic capital for a single simulation run:

$$EC_n = \sum_{t \in T} \max(limit - x_{t,n}; 0) \tag{5}$$

Equation 5 describes the summation during a certain horizon of all differences between the profitability limit and the net income. When net income drops below the limit, the difference equals the gap between the net income and the limit and when it above that limit, the difference equals to zero since no capital would be needed. The time space is presumed to be discrete since financial statements (one of the data sources utilized in this study) are released in discrete time intervals (yearly or quarterly reports). This explains the summation instead of an integral in equation 6.

When economic capital is calculated for multiple runs, the values can be used to build a distribution function of economic capital. Value-at-risk, specified in the formula below, can be determined using the distribution function of economic capital (Guegan & Hassini, 2015):

$$VaR_\alpha(EC) = sup\{x | F(EC < x) \leq \alpha\} \tag{6}$$

Equation 6 yields the value of economic capital that expresses the probability of economic capital being equal or less than this value equals α. Since α is usually a value close to one, the probability that economic capital will be higher than value-at-risk is low.

Apart of value-at-risk, another risk measure considered in this study was expected shortfall. Expected shortfall can be defined as the average of the tail values beyond the value-at-risk estimate. In the case of this study, it is the average of the economic capital values higher that value-at-risk. Equation 7 shows the formula for the expected shortfall (Righi & Ceretta, 2015).

$$EC^{\alpha}(EC) = E[EC|EC] > \ VaR_{\alpha}(EC) = \ \frac{1}{\alpha}\int_{\alpha}^{1} VaR_{S}(ES)ds \qquad (7)$$

Equation 7 clarifies that the expected shortfall is the expectation of all values higher than the value-at-risk.

Thus, this section explained important concepts regarding profitability ceiling and stochastic processes which form the base of modelling economic capital. After introducing the idea behind the simulation and risk measures employed, we proceed to talk in detail about the simulation and results produced.

4: Simulation and Results

This chapter elaborates on the simulation of the quantitative models presented in the previous chapter. The objective is to provide a clear understanding of the simulation developed in this study. First, the chapter elaborates on the data used to calibrate the model. Second, the simulation is explained. Finally, the achieved results are discussed.

4.1 Data

The required data that served as input for the simulations were obtained from the quarterly reports of Royal Bank of Canada, which also served as a benchmark for this study. The dataset consists of earnings before taxes excluding unusual items and total equity for each quarter from 2012 to 2017 and was obtained from the S&P Capital IQ database.

Economic capital for strategic risk is defined as earnings falling below a profitability limit, in the case of this study cost of equity. However, the adoption of earnings to reflect the strategy of an organization may have issues since it is an accounting figure and not a cash flow. Since the objective is to use a figure that reflects the strategy of business, using earnings seems to be a suitable figure since it expresses the profitability of a firm, but it needs to be adjusted excluding any abnormal costs or revenues.

For example, when an organization is fined or needs to respond to a legal claim, this will certainly impact its profitability. Nonetheless, these costs have nothing to do with the strategic risk faced by the organization and the data should be free from costs of such nature. The data collected for the development of this study consists, thus, of earning before taxes excluding the following unusual items:

- Restructuring charges;

- Total merger and related restructuring charges;
- Impairment of goodwill;
- Gain (or loss) on sale of assets;
- Asset writedown;
- Total legal settlements; and
- Other unusual items.

It is hard to clarify whether the data still polluted with other abnormal costs or revenues since they were obtained from quarterly profit and loss statements publicly available. This issue of pollution will not be addressed in this study except for the aforementioned items.

In conclusion, the data should be free from any expenses or revenues that are not related to strategic risk and earnings before taxes excluding unusual items are considered in the evaluation of strategic risk and as proxy to reflect the strategy of an organization.

4.2 Simulation

The objective of running a simulation is to define a distribution of economic capital. The economic capital per run was given by:

$$EC_n = \sum_{t \in T} \max(limit - \ x_{t,n}; 0)$$

The performed simulation involves the following steps:

1) A matrix is created containing the Brownian paths $\{x_0, \dots, x_t\}$ on the rows in which x_0 is assumed to be the last known value available in the earnings dataset,

and $\{x_1, \ldots, x_t\}$ are the results of the Brownian motion. Additionally, each column in the matrix represents one run.

2) Every value in the matrix is verified to be under or above the cost of equity threshold. If the cash flow value is above the limit, the value in the matrix is assigned zero. If the cash flow value falls below the cost of equity limit, then its value is subtracted from the cost of equity to obtain the difference between the realization and the limit. The result of subtraction is summed up per run for every time step. The table below shows a schematic overview of this procedure. Since economic capital for strategic risk is assessed over a specified time horizon that corresponds to a certain strategic plan horizon, all the rows per column are added up to construct a vector with length that equals the number of runs and each entry representing the necessary economic capital for the time horizon of that run.

	Run 1	*Run 2*	...	...	*Run n*
t = 1	0	$x_{1,2}$	…	…	$x_{1,n}$
...	…	…	…	…	…
t = T	$x_{3,1}$	0	…	…	$x_{T,n}$
	$\sum_{t \in T}$	$\sum_{t \in T}$	…	…	$\sum_{t \in T}$

Table 2 - Simulation procedure scheme

3) This vector is sorted in ascending order to obtain value-at-risk. This is done by multiplying the length of vector by the confidence level α. For example, when the

simulation is run 10000 times, a vector with length that equals 10000 is generated containing the calculated economic capital. The value-at-risk estimate for 95% confidence level would be the 9500th element in the vector.

4.3 Results

The simulation explained in the previous section was performed based on the following parameters presented in Table 3.

Parameter	*Value*
σ	447.7
x_0	3541
T	12
α	0.99

Table 3 - Simulation parameters

The first result that should be examined is the density of the simulated earnings. Figure 2 exhibits the histogram of simulated earnings that were generated with 100000 runs. These values include quarterly realizations over all time steps. In other words, it is the density of an earning value on random point in time.

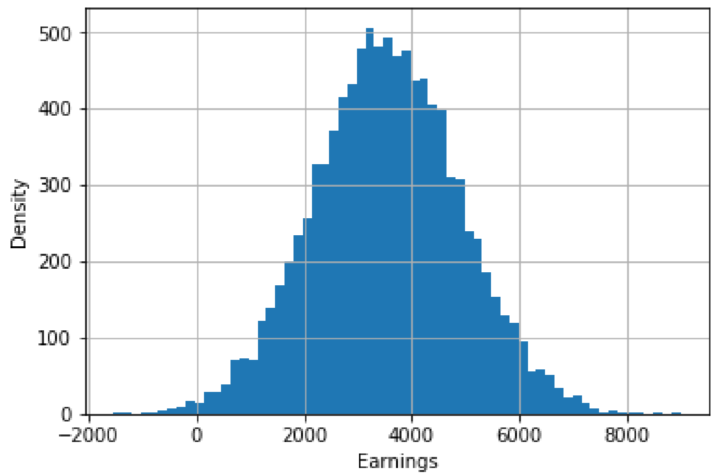

Figure 2 - Density of earnings

Although a constant threshold might be a reasonable assumption considering the short time range of the simulation, it is more probable that the amount of equity will change over time. In fact, the amount of equity in banking firms has increased due to legislative requirements. In addition, it is plausible to assume that banks have internal goals of increasing its equity amounts to have a more sustainable capital base. To test the effect of changing cost of equity over time, the simulation will incorporate a profitability limit that is evolving over time. Before adopting the simulation, it is first tested whether hypotheses of an increasing equity amount hold for Royal Bank of Canada. This was done through a simple linear regression represented in Equation 8 is applied to the total equity data.

$$y_t = \beta_0 + x_t\beta_t + \varepsilon \quad (8)$$

Equation 8 assesses whether there is a trend in the data. The variable y_t represents the quarterly equity amount on each time step (t = {1, 2, 3, …, T}) and x_t corresponds to the number of the quarter (first quarter, second quarter, etc). Also, β_0 is the intercept of the model and β_1 is the coefficient that represents the increase in equity per quarter. The results of the regression are stated below.

	Coefficient	**P-value**	$\boldsymbol{R^2}$
$\boldsymbol{\beta_0}$	3.891E04	< 1.0E-12	
$\boldsymbol{\beta_1}$	1536.89	< 1.0E-12	
Model Statistic			0.971

Table 4 - Regression outputs for the equity amount

As can be observed in Table 6, the hypotheses that the equity amount is evolving over time can be accepted. The model has a significant predictability with a R^2 equals 0.971. Furthermore, all the variables in the model are significant with p-values far below the 5% limit.

Once determined that the equity amount has trend, the next step is to incorporate the regression results into the simulation. Equation 1 shows that β equals to 0.9559 and from Equation 2, which yields the multiplication between cost of equity (*r)* and the last known amount of equity from the collected data, the absolute amount of cost of equity is calculated to be 1237.59 million. This will be the intercept of the linear function shown below and is represented as $limit_0$. Moreover, the quarterly increase is calculated as the increase in equity β_1, in Table 5, multiplied by cost of equity (*r)*, which is 25.55.

$$limit_t = limit_0 + t \times \beta_1 \times r \qquad (9)$$

Applying Equation 9 and running the simulation model 100000 times, the value-at-risk estimate equals to 2434.021 and is represented by the vertical red line in Figure 3. Apart from value-at-risk, the model also calculated expected shortfall and resulted in a value of 3108.115.

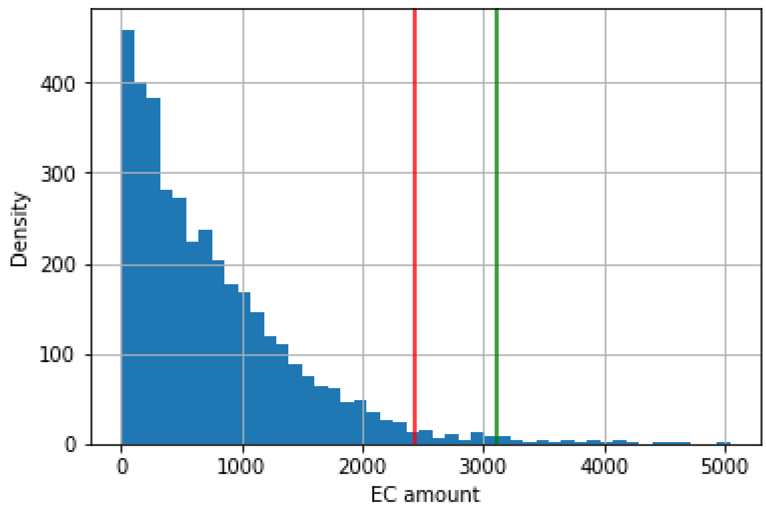

Figure 3 - Economic capital with increasing threshold

Concluding, this section focused on the outputs of the proposed simulation model to quantify economic capital for strategic risk. As previously discussed, this study employed two risk measures value-at-risk and expected shortfall and the achieved results were relatively aligned (no significant deviations) with the reported economic capital for strategic risk by Royal Bank of Canada in 2017, as illustrated in the figure below.

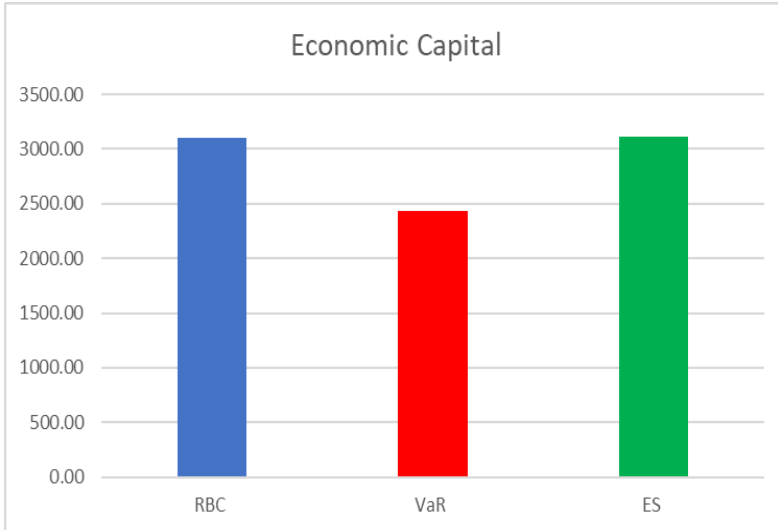

Figure 4 - Economic capital comparison

5: Conclusion

This study proposes to model earnings as a stochastic process and to use earnings as a performance measure of strategy, since a suitable strategy will lead to higher earnings. Utilizing the model of (Bocker, 2008) as a foundation, an arithmetic Brownian motion without drift was implemented as an adequate stochastic process to model future earnings. Moreover, CAPM was used to estimate a threshold for earnings by calculating the absolute cost of equity. All simulated paths below this threshold imply an underperformance and, consequently, capital is needed to raise earnings to acceptable levels.

Economic capital and risk measures (value-at-risk and expected shortfall) were defined based on theory and best practices from the Basel Accords. The data that served as input to the model was collected from the Royal Bank of Canada, which was also the benchmark to verify whether the achieved results are reasonable. It was observed that the results did not present significant deviations from the amount of economic capital for strategic risk disclosed by the banking firm in its annual report and, thus, making it arguable that the model generates useful output.

In conclusion, the model developed in this thesis can assist managers in calculating value-at-risk or expected shortfall for strategic risk. This could benefit small and large firms promoting discussions about the topic with management and other stakeholders. Additionally, Pillar II risks, such as strategic risk, are increasingly gaining importance among regulators. Therefore, the results in this thesis might be useful not only to practitioners but also regulators.

6: Future Research

Future research regarding strategic risk should focus on standardization. The research conducted for the development of this study shows that the content of strategic risk in terms of definitions or models highly varies. Regulation plays a major role in this standardization process and, thus, it should be further investigated and assessed to identify possible nebulous concepts so that the content of strategic risk can be more convergent.

Moreover, the proposed model should help managers in developing risk frameworks, so future research should contribute to that. There is a vast literature regarding to strategy, nevertheless, strategic risk measurement approaches based on a quantitative model is limited. This thesis contributes in this direction. Also, the proposed approach can be replicated to specific business units to identify weaknesses or prioritize strategic actions to those business units that need the most.

Finally, another relevant suggestion for future research is with regards to the model itself. It would be relevant to assess economic capital considering a growth in cash flows and, thus, incorporating into the model a drift, which was disregarded in this research. Additionally, the researcher may consider other stochastic processes to model cash flows and different assumptions about the defined profitability limit, such as a constant limit.

Appendices

Python code for the model:

```
import pandas as pd
import numpy as np
import statsmodels.api as sm
import matplotlib.pyplot as plt
from pandas_datareader import data as wb
from math import sqrt
from scipy import stats

def ec_sim(x0, sigma, limit_const, limit_coeff, T, nruns) :

    for n in range(0,nruns) :

        X.iloc[0,n] = x0
        EC.iloc[0,n] = 0

        for t in range(0,T) :
            X.iloc[t+1,n] = x0 + sigma * np.random.normal(0,sqrt(t+1))
            EC.iloc[t+1,n] = round(max((limit_const + limit_coeff*(t+1)) - X.iloc[t+1,n],0), 5)
    return EC

def es(v, var) :

    count = sum(total_EC >= var)
    dummy = total_EC * (total_EC >= var)
    es = dummy.sum() / count
    return es

# Loading RBC and S&P TSX prices
api_data = pd.DataFrame()

tickers = ['RY.TO', '^GSPTSE']

for t in tickers :
    api_data[t] = wb.DataReader(t, data_source = 'yahoo', start = '2012-1-1', end = '2017-12-31')['Adj
Close']

ry_ret = np.log(api_data['RY.TO']/api_data['RY.TO'].shift(1))
ry_ret = ry_ret.drop(ry_ret.index[0])
tsx_ret = np.log(api_data['^GSPTSE']/api_data['^GSPTSE'].shift(1))
tsx_ret = tsx_ret.drop(tsx_ret.index[0])

# Loading RBC accounting and financial data
exl_data = pd.read_csv('data.csv')

earn = exl_data['EBT']
eqty = exl_data['Total Equity']
```

```
# Define inputs
rf = 0.0166 # BoC 3-month Treasury Bill Average Yield

# Regress excess stock return against excess market return
x = tsx_ret - rf
y = ry_ret - rf

reg1 = sm.OLS(y, x).fit()
#print reg.summary()

# In-sample prediction of Cost of Equity
coe = reg1.predict(x.iloc[len(x)-1])

# Define inputs
t = exl_data['T']
t1 = sm.add_constant(t)

# Regress equity agaisnt the number correspondent to each quarter
reg2 = sm.OLS(eqty, t1).fit()
#print reg2.summary()

# Define inputs
#mu = earn.mean()
sigma = earn.std()
limit_const = abs(coe) * eqty.iloc[len(eqty)-1]
limit_coeff = abs(coe) * reg2.params['T']
x0 = earn.iloc[len(earn)-1]
CL = 0.99
T = 12
nruns = 10000

# Initialize outputs
X = pd.DataFrame(np.nan, index = range(0, T+1), columns = range(1,nruns+1), dtype = 'float')
EC = pd.DataFrame(np.nan, index = range(0, T+1), columns = range(1,nruns+1), dtype = 'float')

# Run Simulation
EC = ec_sim(x0, sigma, limit_const, limit_coeff, T, nruns)

# Calculate the necessary economic capital to support a 3-year strategic plan
total_EC = EC.sum()

# Calculate VaR
var = np.percentile(total_EC, CL * 100.0)
print('VaR = ' + str(round(var,3)) + ' CND')

# Calculate Expected Shortfall
es = es(total_EC, var)
print('ES = ' + str(round(es,3)) + ' CND')
```

```
# Plot the generated simulation runs
X.plot(figsize = (10, 6), legend = None)

# Plot the limit line
time = np.array([range(0, 13)])
time = np.squeeze(time)
limit = limit_const + limit_coeff * time
limit = np.squeeze(limit)
plt.plot(time, limit, 'k--', linewidth = 2.0)

plt.grid(True)
#plt.title('Net cash flow simulation')
plt.axis([0,12,-3000,10000])
plt.xlabel('Quarters')
plt.ylabel('Net cash flow')
plt.show()

# Randomly choosing a quarter of simulated cash flows
cf_sample = X.sample(n = 1, replace = True)

# Plot a histogram to observe the distribution
n, bins, patches = plt.hist(cf_sample, bins = 'auto')

plt.xlabel('Earnings')
plt.ylabel('Density')
plt.grid(True)
plt.show()

# Plot a histogram of EC to observe its distribution
ec_amounts = total_EC[total_EC != 0]
plt.hist(ec_amounts, bins = 'auto')

# Plot a line indicating the quantile that represents VaR
plt.axvline(var, color = 'r')

# Plot a line indicating the quantile that represents ES
plt.axvline(es, color = 'g')

#plt.title('Economic capital')

plt.xlabel('EC amount')
plt.ylabel('Density')
plt.grid(True)
plt.show()
```

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