A Proposed Data Analytics Framework to Predict Financial Stability: Case Study

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Abstract

The increasing interest of investment market in Egypt led to the necessity of studying the financial stability in it from three perspectives; credit risks, market risks and operational risks. The central focus of business intelligence is to transform data into a value-added information by gaining insight into large collections of data to enhance and deliver it as analytic insight to support business decision making. Business Analysts plays a supportive role in this process. There are many statistical techniques that is used to predict financial stability such as multiple linear regression (MLR). It is intended to apply prediction based on machine learning techniques to statistical techniques trying to enhance the analysis and prediction accuracy through studying the variables of each domain using Gaussian Process Regression (GPR) and decision tree (DT).

Keywords: *Business Intelligence, Financial Stability, Gaussian Process Regression, Decision tree, Multiple Linear Regression, Principle Component Analyses.*

1. Introduction

The real world uses big data. But despite what it seems, it can be hard to find in-depth information about many dimensions of financial market. We need Data mining, also known as "knowledge discovery in databases", which is a process for analyzing data from different perspectives and summarizing it into useful information can generate information that can be used to increase revenue, cut costs, or both[1] [2].The term financial stability becomes strained to the world in general. Egypt has observed various financial instability during the last few years as a result of region's Arab spring. It's time for Egypt to promote investments in various fields. This will not be achieved without technical analysis of financial market to reach financial stability.

There are three strategic forces affecting data management for financial supervisors. A very important area of financial risk management is credit risk modelling, which concerns the estimation of the relationship between credit risk and financial stability in Egypt. Credit risks are increasing as banks and insurance companies struggle to remain profitable in the low-growth, low-interest-rate environment [3].The other force is Market risk which relates to the volatility of the difference between the market values of assets and liabilities within a certain time frame due to future changes in asset prices, yields or returns [4].The last is Operational risk which is defined as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events, including legal risks, operational risks, unlike the key financial risks (credit risks and market risk), is not linked primarily with a financial institution's portfolios (credit, trading, investment), but instead relates to its processes and operations and the main elements thereof people, systems and technology [5].

The data analysis and prediction presented in this paper is relevant for macroeconomic and financial statistics covering "credit risk", "market risk ", and "operational risk" in Egypt. Several algorithms have been developed in the financial domains, such as machine learning, statistics and visualization to identify the pattern of data. Statistical techniques are the oldest, but it can't be ignored. The analysis of financial time series is involved with the theory and the practice of financial market valuation over time [6]. Unlike other time series analysis, uncertainty in financial time series plays an essential role in statistical theory and methods [6]. One of the most noteworthy problems is forecasting. The predictability of financial time series must be explicit before prediction. Indeed, the effectiveness of forecasting financial time series in various markets leads to a heated debate [7].

Analytics finds that executives are recognizing the opportunities associated with big data [8].Most early big data efforts are targeted at sourcing and analyzing internal data, and this is also true within financial markets. Big data itself does not create value unless it is used to address important business challenges. This requires access to more and different kinds of data as well as strong analytics capabilities that include not only the tools, but the skills to use them [9]. Gaussian Process Regression was employed as a type of non-parametric regression. Gaussian Process Regression A GPR model, a form of Bayesian non-linear regression, was trained using the Gaussian Processes for Machine Learning[10].It has been proven to be a powerful and effective method for non-linear regression problems due to many desirable properties. Such as ease of obtaining and expressing uncertainty in predictions and the ability to capture a wide variety of behavior through a simple parameterization and a natural Bayesian interpretation [11].

The non-parametric GPR approach is applied for several benefits with respect to cognitive monitoring; First, GPR makes few assumptions about the shape of the estimator function beyond the assumptions associated with the choice of covariance function. This is beneficial especially in high-dimensional input spaces. Second, a GPR model can be constructed to change the width of the local weighting functions separately for each known input dimension during training, providing an indirect measure of that input dimension's relevance. So GPR depends more directly on the data and is robust to such changes; it can even be applied to data containing many fewer features than the model received during training. Finally, its inherently probabilistic nature, returning both point predictions and confidence intervals around those predictions[12].

The Parametric regression method multiple linear regression (MLR) was trained as a comparative technique because it is the most common used technique for prediction in financial sector. MLR is a linear statistical technique that is very beneficial for predicting the best relationship between a dependent variable and several independent variables [13].

Then Gaussian processing regression was applied with Principle Component Analysis, Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. PCA is sensitive to the relative scaling of the original variables.

2. The Aim of The Research

Unlike other time series analysis, uncertainty in financial time series plays an essential role in statistical theory and methods [6]. One of the most noteworthy problems is forecasting. Indeed, the effectiveness of forecasting financial time series in various markets leads to a heated debate [7].Therefore, the overall aim of this research is to investigate the feasibility of using

machine learning techniques in addition to statistical techniques to enhance the prediction of the financial sector.

In addition to that, a few more specific questions were raised during the early stages of the research:

- Are the statistical techniques more accurate although the differences of financial data natures?
- What are the criteria the researcher should apply to choose the suitable technique?
- Does Egypt's financial market instability require combined prediction techniques?
- Is there an econometric technique that can be added to enhance the accuracy of prediction?

3. Research Workflow

There are two distinct understandings of the term business intelligence (BI)– a data-centric and a process-centric. The data-centric position uses BI systems to combine operational data with analytical tools to present complex and competitive information to planners and decision makers. The process-centric position notes a major shortcoming in this inherent data-centricity [13].

The term financial stability plays a vital role in any country's strength. This leads the researcher to search first the concept of financial stability and its main indicators. Based on findings from Basel1 and Basel 2, market risk, credit risk and operational risk are the major risks that can affect financial market [10].

The study used a model where Return On Investment ROA will be used as a measure of financial performance the dependent variable, the independent variable credit risk will be measured by Non-performing loan ratio, Capital Adequacy ratio, impaired loan reserve, and loan impairment charges, which were found to be suitable for the country of study and also data availability according to the reporting standards [14]The study applied the same variables used in Egyptian banksstudy which assumed that "equity return" as a market determinant [15].

The basic three approaches for operational risk are Basic Indicator Approach (BIA), The Standardized Approach (TSA), The Alternative Standard Approach (ASA),and Advanced Measurement Approach (AMA)[12]. The Basic Indicator Approach (BIA) and the Standardized Approach (TSA) or the Alternative Standardized Approach (ASA),are based on the assumption that the size of operational risk is directly proportional to the value of a particular indicator. The indicator is uniformly defined and based either on income (the BIA and TSA149) or on the volume of loans provided (the ASA)[16].

Historical time series data is collected for each of the previous risks from Central Bank of Egypt, International Monetary Fund, Central Agency for Mobilization and Statistics, World Bank and I-economics website. Based on a comparison of multiple researches, shown in table (1), Multiple linear Regression was the common statistical used technique in financial prediction domain. In order to develop the multiple linear regression equation, the parameters that obtained from training data sets are extracted using correlation. The quantity r, called the linear correlation coefficient measures the strength and direction of relationship between the two variables. The linear correlation coefficient is sometime called Pearson product moment correlation coefficient.

The researcher made a comparative study on the basic techniques used in financial prediction sector based on root mean square error to select the most suitable predictive

techniques to data nature. Decision tree added to these comparative techniques because Regression assumes continuous variable as it is and generates a prediction through fitting curves for each combination input variables, shown in table (2).Finally, the results of multiple linear regression prediction analysis were compared with Gaussian process regression and decision tree results. Then adding the statistical technique Principal component analysis (PCA) to Gaussian process regression trying to enhance prediction results.

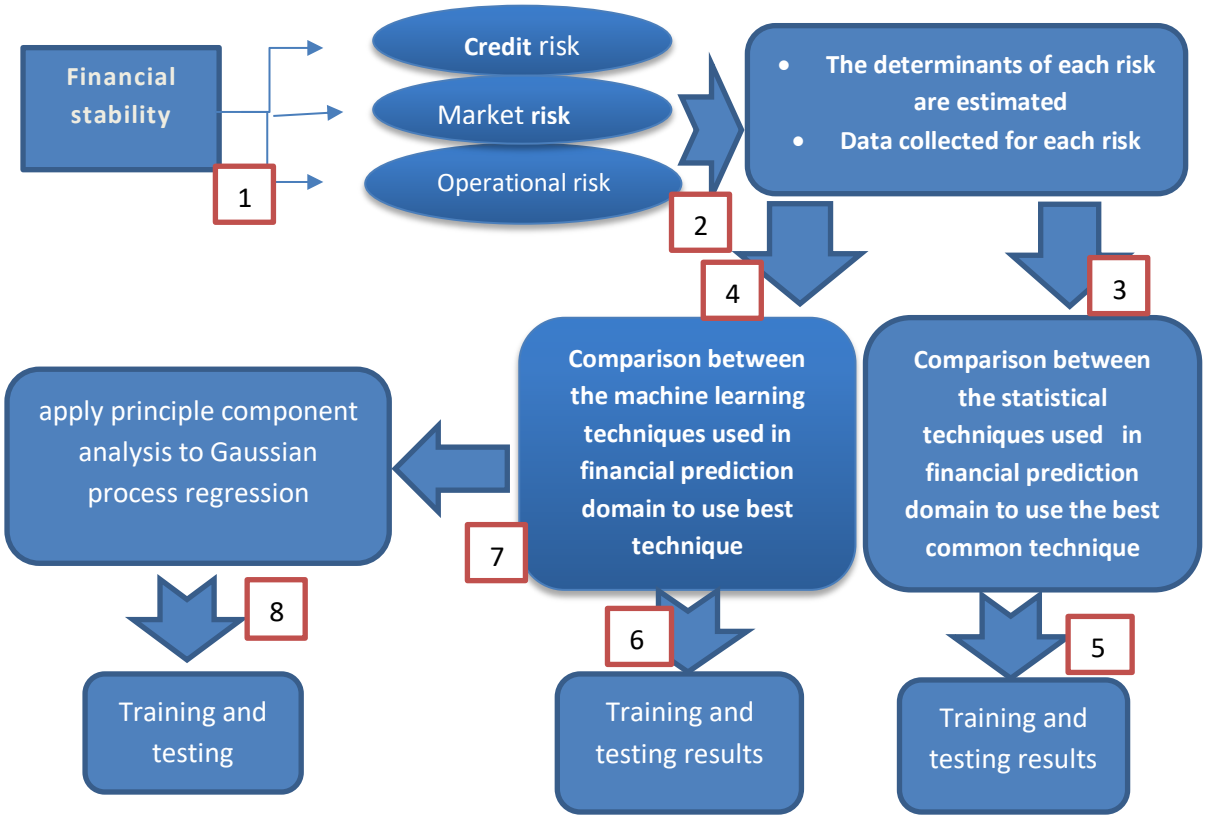

Figure 1: Research Workflow Diagram

4. Data and Methods

The economic and financial indicators were calculated for 1998 – 2017 to analyze the statistical correlation between the financial risk stability and its predictors. The three main domains of the predictors are credit risks, market risks and operational risks. The significance of each risk was analyzed to evaluate the prediction model based on Basel 2 the measurement of risk weighted assets is:

$$\boldsymbol{Measureofriskexposure} = \boldsymbol{creditrisk} + \boldsymbol{marketrisk} + \boldsymbol{operationalrisk}$$[10]

First the study aimed to find the impact of credit risk on financial performance of Egypt for 15 years.The study adapted a similar model as used by Gizaw etal 2015 [14]where Return on Investment (ROA) will be used as a measure of financial performance as the dependent variable, the independent variable credit risk will be measured by: [14]

$$\boldsymbol{ROA} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 NPL} + \boldsymbol{\beta_2 CAR} + \boldsymbol{B_3 IMPLR} + \boldsymbol{\beta_4 LIMPC} + \boldsymbol{e}$$

ROA is the measure of efficiency, Non-Performing Loan(NPL) is the measure of the percentage of gross loans that are non-performing loan portfolio , Capital Adequacy Ratio(CAR) is the measure of asset quality and prudent credit risk management due to BASEL, Impaired Loan Reserve Ratio(IMPLR) this ratio measures the percentage of gross loan which has been side but not yet charged off and Loan Impairment Charges (LIMPC) shows the percentage of loans which have been charging off as impaired loans thus has an impact on financial performance.

Second the Market risk is the risk of loss resulting from changes in the value of assets and liabilities due to fluctuations in risk factors. There are three material market risks as follows: cost of funds, equity price and interest expenses where cost of funds is the total annualized interest expense divided by the sum of average interest-bearing deposits, interest bearing borrowing and noninterest bearing deposit. [17]

$$costoffunds = \frac{total\text{annualized interest expense}}{(\text{average interest-bearing deposits + interest bearing borrowing + non- interest-bearing deposit})}$$

Third the Operational risk which is defined as the risk of loss resulting from inadequate or failed internal process, people and system or from external events. [9] There are three measurement methodologies due to Basel 2 to measure the capital requirement to face operational risk: [12] Basic Indicator Approach (BIA), The Standardized Approach (TSA), The Alternative Standard Approach(ASA), Advanced Measurement Approach(AMA). In this paper we used the Basic Indicator Approach (BIA):

$$\mathbf{KBIA} = (\sum(\ [\![G1]\!]\ \_(1 \dots \dots n) \times \propto))/n$$

KBIA is the capital requirement to face operational risk, GI1….n is the gross income in n years , α = %15 , n is no. of years .

5. The Measures of Various Techniques

There are recent searches in financial sector domain prediction that usedvarious techniques in prediction. The techniques used in financial prediction based on comparative performance measurement based on root mean square error in addition to the recommendation of these recent researches[3,10,14,17,18,19,20,21,22,23]. These researches in financial prediction sector used multiple techniques such as (regression, vector auto regression, gaussian process regression, artificial neural network, logistic regression)shown in Table (1).

Table 1: Recent researches in Financial Prediction Sector

Latest Papers in Financial Prediction sector		
Research Title	**Technique**	**Research goal**
Global Financial Stability Report (2018). [3]	Regression Analysis	Financial Stability Prediction
The Impact of Credit Risk on The Financial Performance of Chinese Banks (2017). [14]	Multiple Linear Regression	The Impact of Credit Risk on Financial Performance
Financial Stability in Europe. Banking and Sovereign Risk (2017). [17]	Regression Models	The Link Between the Quality of Banking Sector and Sovereign Risks.
A New Financial Stability Risk Index to Predict Near Term Risk (2018). **[18]**	Linear Regression, Principle Component Analysis	Near Term Risk of Recession Prediction

Follow Table 1: Recent researches in Financial Prediction Sector

Latest Papers in Financial Prediction sector		
Research Title	**Technique**	**Research goal**
Analysis of Stock Market Predictor Variables Using Linear Regression (2018). **[19]**	Linear Regression, Vector Autoregression	Stock Market Prediction
Gaussian Process Regression for Predictive But Interpretable Machine Learning Models (2017). **[10]**	Gaussian Process Regression	Mental Workload Prediction
Gaussian Process Regression Methods and Extensions for Stock Market Prediction, (2017). **[20]**	Gaussian Process Regression	Stock Market Prediction
Stock Market Prediction Using Regression (2018). **[21]**	Regression, Fuzzy Clustering	Stock Market Prediction
Predicting Banking Crises with Artificial Neural Networks: The Role of Nonlinearity and Heterogeneity (2018). [22]	A**rtificial Neural Network (ANN), Logistic Regression**	Predicting Banking Crisis
A SURVEY ON STOCK MARKET PREDICTION (2018). [23]	Comparison Between Support Vector Machine, Neural Network and Decision Tree.	Comparison Between SVM, ANN, Decision Tree in Stock Market Prediction

The researcher made a comparative study on the basic techniques used in financial prediction sector based on root mean square error. Decision tree added to these comparative techniques because Regression assumes continuous variable as it is and generates a prediction through fitting curves for each combination input variables. Decision tree on the other hand, converts these continuous variables into buckets which may enhance the prediction.

Table 2: Comparative Study between Prediction Techniques

Technique	**RMSE**	
Multiple Linear Regression	Credit Risk Market Risk Operation Risk	1.881 1.898 3.018
Linear Support Vector Machine	Credit Risk Market Risk Operation Risk	1.546 1.856 2.222
Guassian Process Regression	Credit Risk Market Risk Operation Risk	1.362 1.759 1.8
Decision Tree	Credit Risk Market Risk Operation Risk	2.1284 1.717 1.475
Neural Time Series	Credit Risk Market Risk Operation Risk	2.86 2.30 0.107

The previous comparative study shows that multiple linear regression and Gaussian Process Regression and decision tree are the suitable techniques for prediction. The researcher omitted neural network as ANN does not impose any restrictions on the input variables [24] and this conflicts with the evaluation analysis goal.

6. Data Analysis

The correlation is trained and tested between variables then Gaussian process regression and decision tree models.

There are four indicator variables used to predict credit risk (CAR, IMPLR, LIMPC, NPL), three indicator variables to predict market risk (cost of fund, equity price, interest expenses to liabilities), one indicator variable to predict operational risk(capital requirement to face operational risk).

The following table presents the correlation between financial stability and its predictor.

Table 3: List of Dependent Variables Correlation with Financial Stability

	Dependent variables	Correlation with financial stability
CREDIT RISK	CAR	0.29
	IMPLR	-0.502
	LIMPC	0.878
	NPL	-0.878
MARKET RISK	Cost of Funds	-0.809
	Equity Price	-0.267
	Interest Expenses to liabilities	-0.665
OPERATIONAL RISK	Capital Requirement to Face Operational Risk	1

As shown in Table (3) selected attributes are LIMPC in credit risk, cost of funds in market risk, and capital requirement to face operational risk. Those attributes represent the best correlation with financial stability.

6.1 Econometric Technique as A Comparative Model

An econometric technique applied as a comparative model, Multiple Linear Regression (MLR)which is a statistical technique that uses several explanatory variables to predict the outcome of a response variable.

$$y_i = B_0 + B_1 X_{i1} + B_2 X_{i2} + \cdots + B_p X_{ip} + E$$

The data scored for credit risk, market risk and operational risk as independent variables for the dependent variable financial stability.

As shown in Table (4) the performance of the MLR model trained on variables of credit risk, market risk and operational risk according to the null hypothesis. Null hypothesis is rejected when $p < .05$ and not rejected when $p > .05$. So, the variables which accepted were CAR in credit risk and EQUITY in market risk. so according to p-value MLR they were the best predictors of financial stability.

Table 4: Multiple Linear Regression Parameters

Parameter	Value	Standard error	t-statistic	p-value
Beta(CAR)	0.0314	0.1666	0.1887	0.8537
Beta (IMPLR)	-2.5141	1.0506	-2.3931	0.0357
Beta (LIMPC)	22.8413	2.7562	8.2871	4.6641e-06
Beta (NPL)	-0.1353	0.0459	-2.9460	0.0133
Beta (COST OF FUNDS)	-0.2724	0.0673	-4.0483	0.0011
Beta (EQUITY PRICE)	-0.0076	0.0066	-1.1418	0.2714
Beta (INTEREST EXPENSES)	-1.0367e+11	5.2390e+10	-1.9789	0.0665

According to results shown in Table (5) Akaike's Information Criterion (AIC) is a variable selection method intends to select the "best" subset of predictor variables for a specific purpose such as prediction. Roughly equals the number of parameters minus the likelihood of the overall model, therefore the lower the AIC value is the better model. So, according to the high AIC value the MLR model in the three domains don't represent a good prediction model.

Table 5: Multiple Linear Regression Goodness of Fit

AIC (credit risk)	56.6160
BIC (credit risk)	60.4789
AIC (market risk)	76.0149
BIC (market risk)	79.7927
AIC (operational risk)	98.2872
BIC (operational risk)	100.1761

6.2 Machine Learning Predictive Technique: Gaussian Process Regression

A GPR model, a form of Bayesian non-linear regression, was trained using the Gaussian Processes for Machine Learning (GPML). A GPR model is defined primarily by the selection of a covariance function. which defines how the expected value of the target variable changes as values change across the input space.

The model was evaluated by a combination of Metrics Mean Absolute Error (MAE), Root Mean Square Error (RMSE).Because RMSE is more appropriate to represent model performance than the MAE when the error distribution is expected to be Gaussian.R square is a statistical metric that is used to measure how much the variation in outcome can be explained by the variation in the independent variable. The higher R square is, the closer the estimated regression equation fits the data as shown in table (6).

Table 6: Results of Applying GPR and Decision Tree

	RMSE	R-SQUARE	MSE	MAE
GPR (credit risk)	1.3618	0.79	1.8545	1.0482
GPR (market risk)	1.7587	0.51	2.3107	1.616
GPR (operational risk)	3.0411	0.22	6.25	2.0449
Decision tree (credit risk)	2.1284	0.43	4.5	1.5
Decision tree (market risk)	1.7173	0.63	3.1202	1.4539
Decision tree (operational risk)	1.4755	0.76	2.1775	1.2655

Results in table (6) declared that the best prediction model for credit risk was GPR. As(root mean square error RMSE = 1.3618. R^2= 0.79), compared to market and operational risk.

It is to be noted that variables of credit risk are non-linearas shown in figure (2,3,4,5). So GPR is seemed to be a more powerful predictive technique for data that is highly non-linear or not easily modeled using linear modeling.

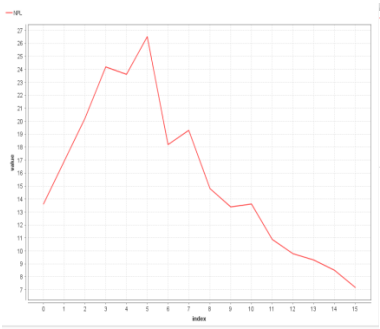

Figure 2: NPL Series Chart

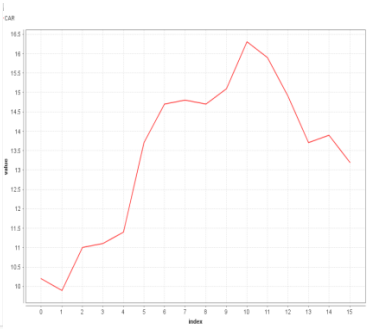

Figure 3: CAR Series Chart

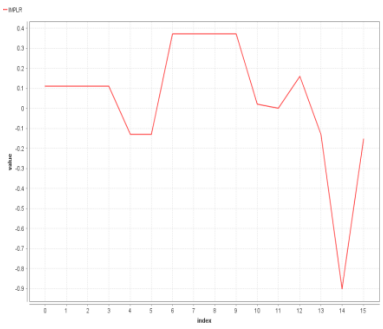

Figure 4: IMPLR Series Chart

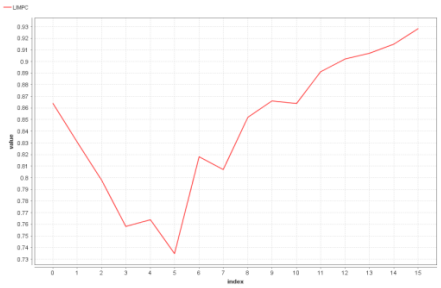

Figure 5: LIMPC Series Chart

The results of GPR model were not the best prediction model for market and operational risk. The best prediction model for market risk and operational risk was Decision tree model, (RMSE = 1.7173, RMSE = 1.4755,R^2 = 0.63,R^2 = 0.76), compared by gaussian process regression and multiple linear regression models. Because regression models predict a continuous variable and this model gives a jagged response, so it can work when the true regression surface is not smooth (discontinuous) with many leaves as shown in figure (6,7).

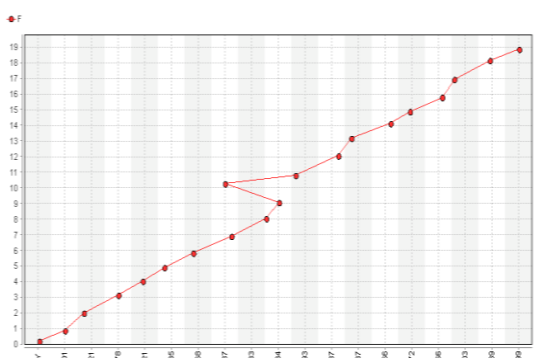

Figure 6: Market Risk

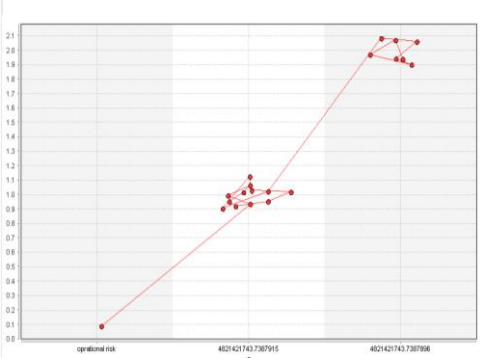

Figure 7: Operational Risk

7. Applying PCA (Principle Component Analysis) to Guassian Process Regression

PCA is often used when there are various explanatory variables in analysis that may be correlated with one another. the method allows you to identify the component of the dataset that maximizes variance, making standard linear models potentially more powerful.

Table 7: GPR with PCA Applied

	RMSE	R-SQUARE	MSE	MAE	Explained Variance in Order
GPR with PCA	0.96825	0.88	0.93762	0.72778	90.3%, 9.0%, 0.2%, 0.0%

Principal component has large positive associations with CAR and IMPLR as shown in table (7).So, these parameters primarily measure long-term financial stability. The results also declared that the mean square error of GPR with PCA is the best financial stability prediction model for credit risk.

8. The Proposed Framework for Prediction

The framework represents how the variables connect with each other. Thus, it identifies the variables required to analyze the financial stability. Then variables of each domain trained separately on several prediction techniques to choose the best one based on performance.

PREPARATION PHASE

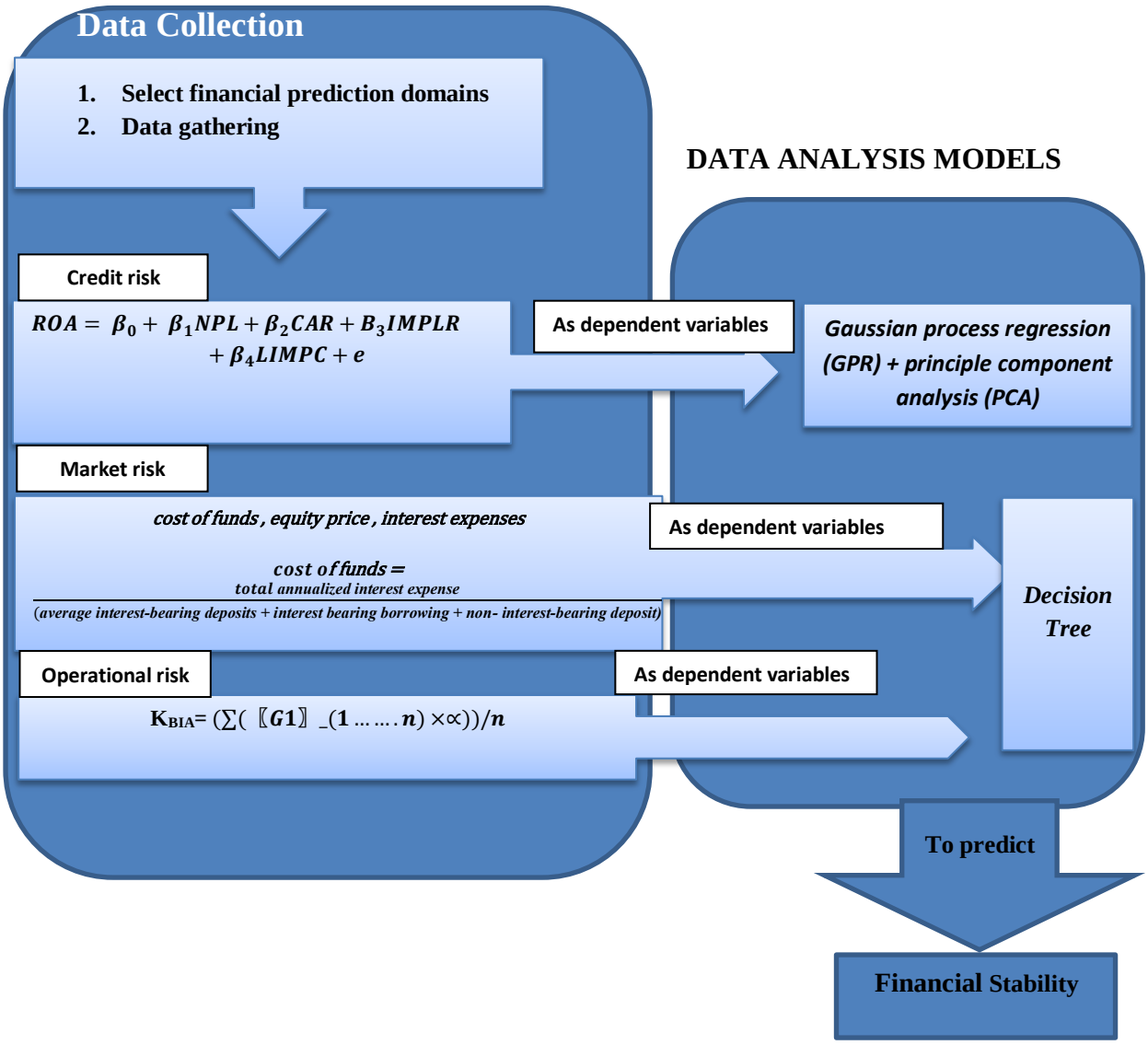

Figure 8:The Proposed Framework for Predicting Financial Stability

This proposed framework was introduced of the most suitable combined modelling techniques, based on statistical results, that suits financial data of Egypt to enhance the prediction accuracy of financial stability.

Financial market risk is considered a universal challenge. This proposed framework could be a universal scheme of risk analysis in financial markets, if we considered the economic and market derivativesthat differ between countries.

9. Conclusion

Egypt has observed various financial instability during the last few years as a result of region's Arab spring which led to the necessity of studying the financial stability in it. The overall aim was to investigate the feasibility of using some of machine learning techniques in addition to statistical techniques to enhance the prediction accuracy in financial sector in Egypt.

Dependent variables in credit risk domain was effective using Gaussian Process Regression (GPR), compared by the basic econometric model Multiple Linear Regression(MLR) and decision tree; because variables of credit risk are non-linear and GPR is popular kernel based for non-linear regression problems. in contrast to more traditional statistical methods such as MLR, the GPR approach provides confidence intervals around each prediction.

Principle component analysis (PCA) used to enhance the performance of GPR model to identify the component of the dataset that maximizes variance, making standard linear models potentially more powerful by declaring the most important variable for long term prediction.

On the other hand, the results of GPR technique in market risk and operational risk domains weren't efficient compared to decision tree because data is not smooth (discontinuous) with many leaves.

The researcher passes through many steps to obtain the previous results. First, the financial stability in Egypt was analyzed of three domains credit risk, market risk and, operational risk. Second, multiple linear regression (MLR) was trained as a comparative econometric technique because it is the most common used technique for prediction in financial sector. Then gaussian process regression (GPR) and decision tree applied. Finally, principle component analysis (PCA) was applied to (GPR).

10. Future Work

Following the previous results, the researcher recommends the following as future work:

1. Applying data quality management to the proposed framework.
2. Using fuzzy rough machine learning approaches.

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