PROBABILITY AND STATISTIC SOFTWARE FOR ENGINEERING APPLICATION: MODELING AND FORECASTING COPPER PRICES FOR INDUSTRIES

By

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FINAL REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Faizal Mazani

ABSTRACT

The objective of this final year project is to develop a probability and statistics software for engineering application. The chosen engineering application is modeling and forecasting copper prices for industries. The software may be used by managers, market researchers, and survey companies, in making decisions in copper-related business. The price of copper has been volatile over the years due to competing materials, remaining stocks available, and economic uncertainties. Therefore, the software modeling tool will be useful to forecast the future price of copper to enable the user in making some adjustments or preparation in their business.

The proposed framework of the system consists of three inter related components, the database that will provide input to the model, the forecasting modeling and user interface that provides a medium for the user to communicate with the system. Three stages have been identified in order to develop the system. They are variable identification, statistical model development and the development of the software. Several variables have been identified but only eight variables are finalized as the independent variables of the model.

The models that were identified are multiple regression analysis and time series. The best possible R^2 obtained in the modeling is 0.939 which is quite high. The accuracy of the forecasted price of copper is approximately higher than 87%.The model is incorporated in an interactive user-friendly interface.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADO:	ActiveX Data Objects
BASIC:	Beginner's All-purpose Symbolic Instruction Code
COMEX/NYMEX:	Commodity Exchange Division of the New York Mercantile Exchange
DAO:	Data Access Objects
DSL:	Digital Subscriber Line
GDP:	Gross Domestic Product
GUI:	Graphical User Interfaces
IP:	Industrial Product
LME:	London Metal Exchange
PPP:	Purchasing Power Parity
RDA:	Remote Data Objects
SHME:	Shanghai Metal Exchange
SPSS:	Statistical Package of Social Science

US:	United States of America
USD:	US Dollar
VB:	Visual Basic

CHAPTER 1
INTRODUCTION

1.1 Background of Study

The project mainly focuses on the development of a probability and statistics software that incorporates a statistical model. The model will assist the users in forecasting the future price of copper. A thorough study on the copper industry has been done to get the historical facts of the copper and its application in industries. From here, the supply and demand are identified as the factors that determine the price of copper in the market. Therefore, the supply and demand of copper is carefully studied to obtain the key variables which are utilized as an input to the statistical software. The output of the software is used to predict the future price of copper.

1.2 Problem Statement

The price of copper in the world market is increasing rapidly [1]. This is due to the higher world demand of copper compared to the world production of copper. The production of copper tends to decrease due to less mining stocks available at the copper mining countries such as Chile. Both prices of the copper and other commodities will affect one another. For example, construction industries use copper as the cores in the cables for the building wiring. The contractors need to know the copper price for several years ahead so that they do not underestimate the cost of the construction. Otherwise, they will not be able to afford the copper-core cables and this will affect the development of the project.

After careful consideration, it is found that it is feasible to develop a modeling software to forecast copper prices for industries using Visual Basic Programming 8.0. User-friendly interfaces which assist users to perform their modeling tasks efficiently have been developed. After performing probability & statistics calculations using SPSS software, the output is used as an input for the Visual Basic Programming in order to develop the final product.

1.3 Objectives & Scopes of Study

1.3.1 Objective of the study:

The main objective of the study is to develop software which incorporates a statistical model to assist users in forecasting aspect of planning. The model that is developed will be used to forecast the price of copper. In order to achieve this objective, the research has been focused on:

i. Understanding and identifying the key variable in the model
ii. Constructing the probability and statistics model
iii. Simulations of the results
iv. Development of a user friendly software using Visual Basic Programming Language

1.3.2 Scope of study

The scope of study is divided into three parts; understanding and identifying key variables, probability and statistical modeling and software development. The project is completed within two semesters.

CHAPTER 2
LITERATURE REVIEW AND/ OR THEORY

2.1 Commodities and Exchanges

Copper is one of the commodities in the world. Commodities are things of value, of uniform quality, that were produced in large quantities by many different producers; the items from each different producer are considered equivalent. Commodities can be classified into 5 categories:

- Precious Metals : gold, platinum, etc
- Base Metals : **copper**, aluminum, etc
- Energy : crude oil, natural gas, gasoline, etc
- Grains and Oil Seeds : wheat, canola,etc
- Softs : cocoa, coffee, white sugar, etc

Copper is traded between producers and consumers. Producers sell their present or future production to clients, who transform the metal into shapes or alloys, so that downstream fabricators can transform these into different end-use products. One of the most important factors in trading a commodity such as copper is the settling of the price for the present day (spot price) or for future days.

The role of a commodity exchange is to facilitate and controlling the process of settling prices. Three commodity exchanges provide the facilities to trade copper: The London Metal Exchange (LME), the Commodity Exchange Division of the New York Mercantile Exchange (COMEX/NYMEX), and the Shanghai Metal Exchange (SHME). In these exchanges, prices are settled by bid and offer, reflecting the market's perception of supply and demand of a commodity on a particular day. On the LME, copper is traded in 25 tonne lots and quoted in US dollars per tonne; on

COMEX, copper is traded in lots of 25,000 pounds and quoted in US cents per pound; and on the SHME, copper is traded in lots of 5 tonnes and quoted in Renminbi per tonne.

Exchanges also provide for the trading of futures and options contracts. Therefore, producers and consumers are allowed to fix a price in the future, thus minimizing the risks against price variations. In this process the participation of speculators, who are ready to buy the risk of price variation in exchange for monetary reward, gives liquidity to the market. Liquidity means the ease of exchanging asset into cash. A futures or options contract defines the quality of the product, the size of the lot, delivery dates, delivery warehouses, and other aspects related to the trading process. Contracts are unique for each exchange. The existence of futures contracts also allows producers and their clients to agree on different price settling schemes to accommodate different interests. Exchanges also provide for warehousing facilities that enable market participants to make or take physical delivery of copper, in accordance with each exchange's criteria. [2]

2.2 Properties and Uses of Copper

Copper is an excellent electrical conductor. It has exceptional strength, ductile, and provides good resistance against creeping and corrosion. Therefore, copper is widely used as electrical conductor in building wiring. Copper also is used as power cables, either insulated or uninsulated, for high, medium and low voltage applications.

The widely used optical fiber in telecommunication industry increases the demand of copper particularly in domenstic subscriber line, wide and local area network (WAN and LAN), as well as personal computers and other hardware.

xDSL (Digital Subscriber Line) technology allows the existing copper infrastructure of ordinary telephone wires to also carry high speed data. For internet users, xDSL technology means connecting at 1.5 million bits per second instead of 56 thousand bits per second.

Semiconductor manufacturers recently launched a revolutionary "copper chip". By using copper for circuitry in silicon chips, microprocessors are able to operate at higher speeds, using less energy.

Copper and brass are used in residential for plumbing, taps, valves and fittings. The advantage of using copper over PVC pipe is that copper does not burn, melt or release noxious or toxic fumes in the event of a fire. Copper tubes also help protect water systems from potentially lethal bacteria such as legionella. The use of copper doorknobs and plates prevents the transfer of disease and microbes.

Copper plays major part in transportation. Copper-nickel alloys are used on the hulls of boats and ships to reduce marine biofouling thereby reducing drag and improving fuel consumption. In vehicle, copper is used in the construction of motors, wiring, radiators, connectors, brakes and bearings. Today's average size automobile contains about 27.6 kilograms of copper and a Boeing 747-400 contains 4,000 kilograms. Copper's superior thermal conductivity, strength, corrosion resistance, and recyclability is very suitable for automotive and truck radiators.

Copper which is combined with other metal to form copper alloy is used as gears, bearings, and turbine blades due to their durability, machinability, and ability to be cast with high precision and tolerances. [3]

2.3 Theory of Supply and Demand

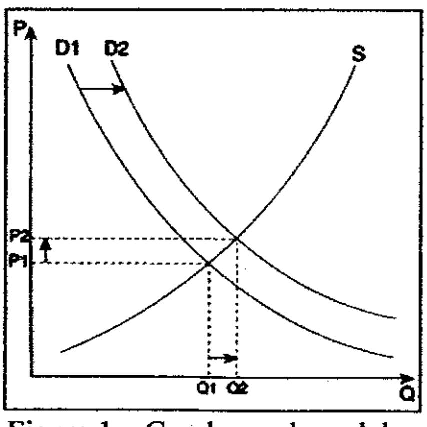


Figure 1 Graph supply and demand

The theory of supply and demand describes how prices vary as a result of a balance between product availability at each price (supply) and the desires of those with purchasing power at each price (demand). Figure 1 is a grah supply and demand. X-axis represent the quantity (Q), and y-axis represent the price (P). Supply is represented by S curve and demand is represented by both curve D1 and D2. The graph depicts an increase in demand from D_1 to D_2 results in an increase of price from P1 to P2 and also an increase of quantity from Q1 to Q2 to reach a new market-clearing equilibrium point on the supply curve (S).

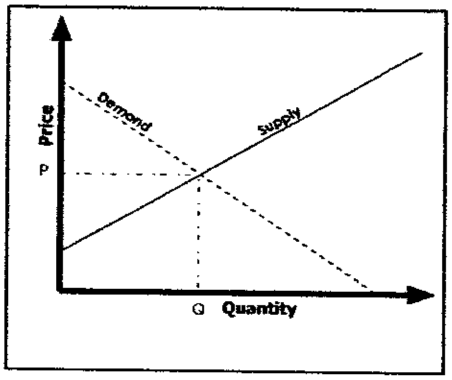


Figure 2 Graph price versus quantity

Figure 2 denotes graph price versus quantity. Both demand and supply curves are represented by straight line. The demand curve is inversely proportional to the supply curve. Therefore, a greater quantity will be demanded when the price is lower. On the other hand, as the price goes up, producers are willing to produce more goods. The point of intersection between the demand and supply curve is known as the equilibrium point with coordinate of (P,Q). At a price of P producers will be willing to supply Q units per period of time and buyers will demand the same quantity. P in this example, is the equilibrating price that equates supply with demand.

It should be noted that both of supply and demand curves are drawn as a function of price. Neither is represented as a function of the other. Rather the two functions interact in a manner that is representative of market outcomes. The curves also imply a somewhat neutral means of measuring price. In practice any currency or commodity used to measure price is also the subject of supply and demand. [4]

2.4 Lag Function

Lag creates new series by copying the values of the existing series and moving them forward the specified number of observations. This number is called the lag order.

First-order lag and lead of series X

X	Lag	Lead
198	.	220
220	198	305
305	220	470
470	305	.

Example:

CREATE LAGVAR TO LAGVAR5 = LAG (VARA, 2, 5).

Four new variables are created based on lags on VARA. LAGVAR2 is VARA lagged two steps, LAGVAR3 is VARA lagged three steps, LAGVAR4 is VARA lagged four steps, and LAGVAR5 is VARA lagged five steps. This command should be created in SPSS Syntax Editor.

2.5 Pearson's Correlation

Suppose

y: Dependent Variable

x: Independent Variable

To find the relationship between y and x, Pearson's Correlation is used. If the values of y and x are known, Table 1 can be constructed.

Table 1 The component needed to calculate Pearson's Correlation

	y	x	$y-\bar{y}$	$x-\bar{x}$	$(y-\bar{y})^2$	$(x-\bar{x})^2$	$(y-\bar{y})(x-\bar{x})$
	3	3	-5,42857	-1,4285714	29,46938776	2,040816	7,75510204
	7	4	-1,42857	-0,4285714	2,040816327	0,183673	0,6122449
	10	4	1,571429	-0,4285714	2,469387755	0,183673	-0,6734694
	-5	3	-13,4286	-1,4285714	180,3265306	2,040816	19,1836735
	20	5	11,57143	0,57142857	133,8979592	0,326531	6,6122449
	19	7	10,57143	2,57142857	111,755102	6,612245	27,1836735
	5	5	-3,42857	0,57142857	11,75510204	0,326531	-1,9591837
Σ	59	31	0	-1,776E-15	471,7142857	11,71429	58,7142857

N = 7 (Number of data)

$$\bar{y} = (\Sigma y) \div N$$
$$= 59 \div 7$$
$$= 8.428571429$$

$$\bar{x} = (\Sigma x) \div N$$
$$= 31 \div 7$$
$$= 4.428571429$$

$$r = \Sigma\,[(y-\bar{y})\,(x-\bar{x})] \div \sqrt{[\Sigma(y-\bar{y})^2\,\Sigma(x-\bar{x})^2]}$$
$$= 58.7142857142857 \div \sqrt{[(471.714285714286)\,(-11.7142857142857)]}$$
$$= 0.789853162$$

2.6 Modeling Seasonality and Trend

Seasonality is a pattern that repeats for each period. For example annual seasonal pattern has a cycle that is 12 periods long, if the periods are months, or 4 periods long if the periods are quarters. We need to get an estimate of the seasonal index for each month, or other periods, such as quarter, week, etc, depending on the data availability. [5]

2.6.1 Seasonal Index

Seasonal index represents the extent of seasonal influence for a particular segment of the year. The calculation involves a comparison of the expected values of that period to the grand mean. A seasonal index is how much the average for that particular period tends to be above (or below) the grand average. Therefore, to get an accurate estimate for the seasonal index, we compute the average of the first period of the cycle, and the second period, etc, and divide each by the overall average. The formula for computing seasonal factors is:

$$S_i = D_i/D,$$

where:

S_i = the seasonal index for i^{th} period,
D_i = the average values of i^{th} period,
D = grand average,
i = the i^{th} seasonal period of the cycle.

A seasonal index of 1.00 for a particular month indicates that the expected value of that month is 1/12 of the overall average. A seasonal index of 1.25 indicates that the expected value for that month is 25% greater than 1/12 of the overall average. A seasonal index of 80 indicates that the expected value for that month is 20% less than 1/12 of the overall average.

2.6.2 Deseasonalizing Process

Deseasonalizing the data, also called Seasonal Adjustment is the process of removing recurrent and periodic variations over a short time frame, e.g., weeks, quarters, months. Therefore, seasonal variations are regularly repeating movements in series values that can be tied to recurring events. The Deseasonalized data is obtained by simply dividing each time series observation by the corresponding seasonal index.

Almost all time series published by the US government are already deseasonalized using the seasonal index to unmasking the underlying trends in the data, which could have been caused by the seasonality factor.

2.6.3 Forecasting

Incorporating seasonality in a forecast is useful when the time series has both trend and seasonal components. The final step in the forecast is to use the seasonal index to adjust the trend projection. One simple way to forecast using a seasonal adjustment is to use a seasonal factor in combination with an appropriate underlying trend of total value of cycles.

2.7 Visual Basic

2.7.1 Introduction

Visual Basic (VB) is an event driven programming language developed by Microsoft. Event driven programming also known as object-oriented programming emphasis on the objects included in the interface and the events that occur on those objects. An event can be a user's mouse click, a menu selection, or a button press. VB was derived from BASIC and enables the rapid application development (RAD) of graphical user interface (GUI) applications, access to databases using DAO, RDO, or ADO, and creation of ActiveX controls and objects.

VB was designed to be easy to learn and use. It allows the creation of simple GUI applications as well as complex applications. Programming in VB is a combination of visually arranging components or controls on a form, specifying attributes and actions of those components, and writing additional lines of code for more functionality. Sections of code are executed only when an event triggers them [5].

2.7.2 Steps in Program Development [6]

- Analyse and define the problem
- Design the visual interface
- Define user-program interaction
- Design code structure
- Write code
- Test and edit the code
- Test the program in production

2.7.3 Procedures

A procedure is a block of program code that perfom a specific task [7]. Generally, there are three types of procedures:

i. Event Procedure - called by VB in response to an event
ii. Sub Procedure - user must called explicitly, user can define parameters
iii. Function Procedure – typically referred to as function, has return statement

Example of event procedure:

```
Private Sub btnExit_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles btnExit.Click
    Me.Close()
  End Sub
```

Example of sub procedure:

```
Const Pi As Double = 3.14159265359


Private Sub ComputeArea(Radius As Double)
```

```
' This Sub computes and displays the area of a circle
'given a radius, which is expected to be of the Double type
Dim Area As Double
            Area = Pi * Radius * Radius
   MsgBox "The area of a circle with a radius of " _
         & Radius & " is " & Area
End Sub
```

Example of function procedure:

```
Const Pi As Double = 3.14159

Private Function AreaOfCircle (Radius As Double) As Double
'This function computes and returns the area of a circle
'given a radius, which is expected to be of the Double type

                  AreaOfCircle = Pi * Radius*Radius

End Function
```

CHAPTER 3

METHODOLOGY/ PROJECT WORK

3.1 Methodology/ Project Work

The workflow of this project is as follows. First, the historical facts of copper and its application in industries are studied. The studies have been conducted by research via conference papers, journals, books, annual reports, and internet. All the gained information is carefully studied to get a clearer understanding of the copper industry. As the key variables that influence the price of the copper have been identified, quantifying process is done by using Statistical Package of Social Science (SPSS) software. The quantifying process is important to relate the proper variables to the copper prices. In the SPSS, a method known as Pearson's Correlation is used. Pearson Correlation which is also known as Pearson's r is a technique which is normally used for assessing the strength and direction of an association between two variables. Through Pearson's Correlation, the data that are supposed to be the key variables that influences the price of copper is correlated with the true value of copper prices to obtain the 'r'. r would ranges in value between -1 and +1 including 0. If r is negative, it shows that the selected key variables have negative correlation with the copper price. Negative correlation means the data is inversely associated with the copper price. If r is positive, the selected key variables are in positive relationship with the true value. However, if the value of r is zero, it means that the selected key variables have no relationship with the copper price at all. Thus, they can be eliminated from the project development. The data are further analyzed in SPSS through Regression analysis to obtain 'r^2'. The data are selected if the result of 'R^2' is very high provided that they significantly influencing the price of the copper. The Regression result is represented by 'R^2'. First, 'R^2' is determined by using 1 dependent variable with 1 independent variable. Then, the process continued by 1 dependent variable with 2 independent variables followed by 1 dependent variable with 3 independent variables and so on. This process is called Multiple Linear Regression because more than 1 independent variable is used with 1 dependent variable to determine the 'R^2'. However, the student need not to do 'all' the steps chronologically. The student needs to do the process wisely by using only the variables that result in a high value of 'R^2'. This is because, if all of the process is to be done, there are more than (${}^8C_2 + {}^8C_3 + {}^8C_4 + {}^8C_5 + {}^8C_6 + {}^8C_7$) = 246 combinations of independent variables to be calculated to obtain the 'R^2'.This is very redundant and impractical.

Throughout the quantifying process, there are several variables that are excluded and being changed by new variables. At the end, the finalized data that represent the key variables which influences the price of copper is obtained. The data is collected from January 2002 to December 2006 in monthly basis. Therefore, there are 60 data per independent variable (key variables which influence copper prices) and 60 data of dependent variable (original copper prices). The number of independent variables used is eight namely:

- Value of construction in United States (in millions USD)
- Exports of computer and electronic products (in thousands of USD)
- Exports of transportation equipment (in thousands of USD)
- Exports of primary smelting and refining of copper (in thousands of USD)
- Exports of copper rolling, drawing, and extruding (in thousands of USD)
- Exports of copper wire drawing (in thousands of USD)
- Exports of plumbing fixtures fittings and trim (in thousands of USD)
- Exports of metal valves and pipe fittings (in thousands of USD)

Note that all of the independent variables are based on the total world exports except for the value of construction in US. Meanwhile, the dependent variable is valued in US cent per pound.

Using the finalized eight independent variables, the SPSS will display the coefficients and 'R^2'. The desired mathematical model is made up of these coefficients. A model is created such that:

$$Y = a+bX_1+cX_2+dX_3+eX_4+fX_5+gX_6+hX_7+iX_8$$

Where, Y is the independent variable which depends on the dependent variables X_1, X_2, X_3, until X_8. Meanwhile, the constants a, b, c, d, up to i are automatically displayed by SPSS based on the Multiple Linear Regression result. The independent variables are representing the key variables that influenced the copper prices. They have been successfully quantified and have a strong association with the actual price of the copper. Meanwhile, Y is the dependent variable which represents the forecast price of copper. Next, Lag Function is used to obtain additional data of the independent variables. Lag creates new series by copying the values of the existing series and moving them forward the specified number of observations. The number is called the lag order. The advantage of using the Lag function is to create the new series of data. In the similar manner, mathematical models are created using these additional data to determine the 'R^2' and to make comparison between several models. Thus, 'R^2' between several models is compared to obtain the highest 'R^2'. Then, the model with the highest value of 'R^2' is selected to be used in the software development. Besides comparing the R^2, each of the models is substituted with the value of independent variables (X_1 to X_8) at any month of reference. A predicted price of copper is produced. This predicted value is compared with the true value of copper price to measure the percentage of error. Then, the model which produces the least percentage of error is chosen as the finalized model to be included in the software development process.

The model that has been finalized is not capable to forecast the future value of copper price yet because it only uses the existing data of independent variables. Therefore, a future data of independent variables need to be generated first. This is done by seasonal adjusted technique. For each variable, the total value per year is calculated. Then, mean for each month is determine. Index for each month is calculated by simply dividing mean for each month with grand mean. Next, a multiple linear regression is used between the total values per year versus year (The year 2002, 2003, 2004, 2005, and 2006 have been numbered with 1, 2, 3, 4, and 5 respectively). This creates a model such that: $Y = aT + b$; where T is the independent variable which represents the desired year and Y is the predicted total value of that variable corresponding to that year. a and b are just the coefficients of the model. For example, if $T = 6$ is substituted in that model, a value Y_6 is created. This value is divided by 12 to get the average estimated value per month during that year ($T = 6$). To get the estimated value per month during that year, that average estimated value is multiplied with index per month. In similar manner, all monthly values for other months for that year and any years are calculated. Note that; the whole processed described in this paragraph is meant for just one independent variable (for example X_1). Therefore, the whole process is repeated for the other seven independent variables (X_2 to X_8). Finally, the estimated future independent variables are generated. These variables can be substituted into the previous model:

$Y = a+bX_1+cX_2+dX_3+eX_4+fX_5+gX_6+hX_7+iX_8$; to forecast the future value of copper price at any future month and year.

There are several data that have been reserved earlier. The data are the actual copper price from January 2007 to April 2007. The word 'reserved' means that the data is not being taken into consideration during the modeling process. It is reserved to determine the forecasting accuracy of the model. All the independent variables (X_1 to X_8) for February 2007 for example are substituted into the model to obtain the forecast value of copper price for that month. The forecast value is then compared with the true value (actual) of copper price which has been reserved. Finally, the forecasting error is obtained and that error determines how accurate and reliable the model is.

At this stage, all the calculating parts are supposed to be done. The next stage is to put the model into software which is interactive and user-friendly where user can enter the input and get the output.

The software is developed using Visual Basic Programming Language. The student is using Microsoft Visual Basic (VB) to programme a software based on the model created from the SPSS. In the Visual Basic, there are three options available for the user. The first option allow the user to estimate the price of copper between the date of January 2002 to December 2006 by just selecting the desired month available in the combo box and click calculate button. Then, user shall get the estimated price of copper complete with its actual price and the corresponding percentage of error. The percentage of error is obtained by comparing the estimated price with the actual price of copper. Note that all the price of copper is in unit of US cent per pond. The second option enables the user to forecast the future price of copper between January 2007 to December 2020. All user have to do is just selecting the date of forecasting and click calculate button. By doing that, the forecasted price of copper shall be displayed. To check the accuracy or the reliability of the forecasted price, user may use the third option. This option allow the user to select any of the first four months of 2007. As a result, the software shall display the forecasted price of copper in any of that months complete with their actual price and percentage of error respectively. To ease the user in using any of the three options, user may varies the selected data by changing the selected date repeatedly and get the output instantaneously. The software can be terminated at any moment by just clicking the exit button. The software is tested to detect any errors and limitations. First, the output displayed in each selected month is compared with the valued computed earlier in the SPSS stage. If errors occurs, or if the output of the software does not lies within the acceptable interval, the coding of the software shall be checked and corrected. However, if some modification is needed in the modeling part, the process is restarted at the SPSS level in determining the Multiple Linear Regression and the data generated process.

Table 2 Gantt-Chart of Final Year Project I Development

No	Detail	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of project topic	■													
2	Preliminary research work		■	■											
3	Review on copper origin (from ores to end-products)				■										
4	Review on world production and consumption of copper				■	■									
5	Review on historical prices of copper					■									
6	Studies on copper supply and demand						■	■							
7	Research on copper supply						■	■	■						
8	Research on copper demand							■	■	■					
9	Identify the key variables from the supply and demand factors									■	■				
10	Research on probability and statistical modeling										■	■			

Table 3 Gantt-Chart of Final Year Project II Development

No	Detail	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Updating the data of key variables obtained from previous semester	■													
2	Quantifying process using Pearson's Correlation and Lag Function in SPSS software		■	■											
3	Discuss with Supervisor to finalize the independent variables				■										
4	Start creating forecasting model				■	■	■	■	■						
5	Build interfaces using Visual Basic Programming Language					■	■	■	■	■	■	■			
6	Testing and modification if necessary										■	■	■	■	

3.2 Resources Required

As the project conducted is a research-based project, the resources required are obtained from Internet Explorer, Visual Basic, library books, and some related sources.

3.3 Project Flow

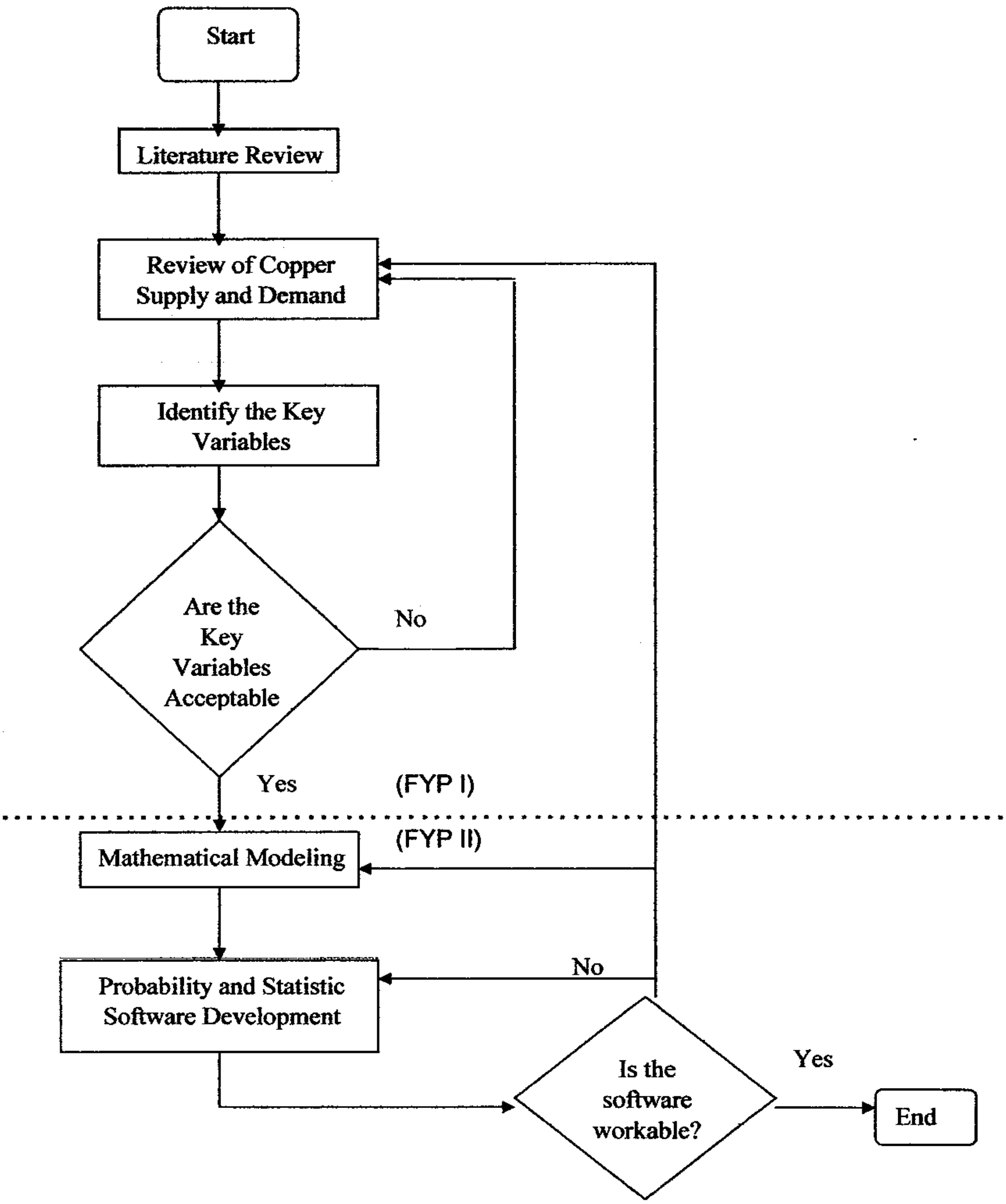


Figure 3 Flow-Chart of the Project

CHAPTER 4
RESULTS AND DISCUSSION

Copper prices in the world are affected by the demand and supply. Therefore, the demand supply variables have been identified.

4.1 Demand Variables

4.1.1 China Demand

A large population and strong market growth in China encourages the rapid development of infrastructure including the communication, manufacturing and construction industries. These industries consume copper and then make the China as the world largest consumer of copper. [9]

4.1.2 Construction Industries

Copper is widely used in construction line particularly in building wiring and plumbing system. As the construction industries all over the world is increasing, the demand of copper is increase as well. However, in building wiring system, copper faces the competency from aluminum because both of them are a good electrical conductor. Aluminum is cheaper than copper but it might cause more electrical hazard than copper does.

4.1.3 Automobile Manufacturing Industries

United States is the leading automobile manufacturer in the world followed by Japan. General Motors (US) produced 9,040,309 vehicles in 2005 such as Cadillac, Chevrolet, Pontiac, and Saturn. Meanwhile, Toyota Motor Company (Japan) produced 7,100,167 vehicles with Hino, Lexus, and Toyota as examples in the same year. Copper is used in the construction of automotive radiators as well as some contribution to the body of the vehicle itself. Furthermore, there is more than 50 pounds of copper in a typical U.S.-built automobile: about 40 pounds for electrical and about 10 pounds for nonelectrical components. [10]

4.1.4 Electronic Industries

Copper plays an important role in electronics as IBM and others are replacing aluminum with copper in the computer chips they manufacture. This resulting in much faster operating speeds and greater circuit integration- up to 200 million transistors can be packed onto a single chip. Thus, power requirement has been reduced less than 1.8V. Copper is an important element in many electronics devices from external cables and connectors to bus ways to printed circuit boards, sockets and lead frames. [11]

4.2 Supply Factors

Chile is the world largest copper mining producer [12]. They supply copper in the form of ores and concentrates. Copper-bearing ores are extracted from the ground, crushed, and then processed into powder to form concentrate. Alternatively, copper can be leached out of the rock or ore.

4.3 Other Factors

4.3.1 Gross National Product (GDP)

Gross national product is used to measure the size of economic in any country. The GDP of a country is defined as the market value of all final goods and services produced within a country in a given period of time. GDP can be defined as;

$$GDP = \text{private consumption} + \text{government} + \text{investment} + \text{net exports}$$

If GDP of any country is high, it shows the superiority of the economic power of that country. US remain the highest GDP above all countries enabling them to control the flow of world economic including the import and export of copper and thus influencing its prices in the market.

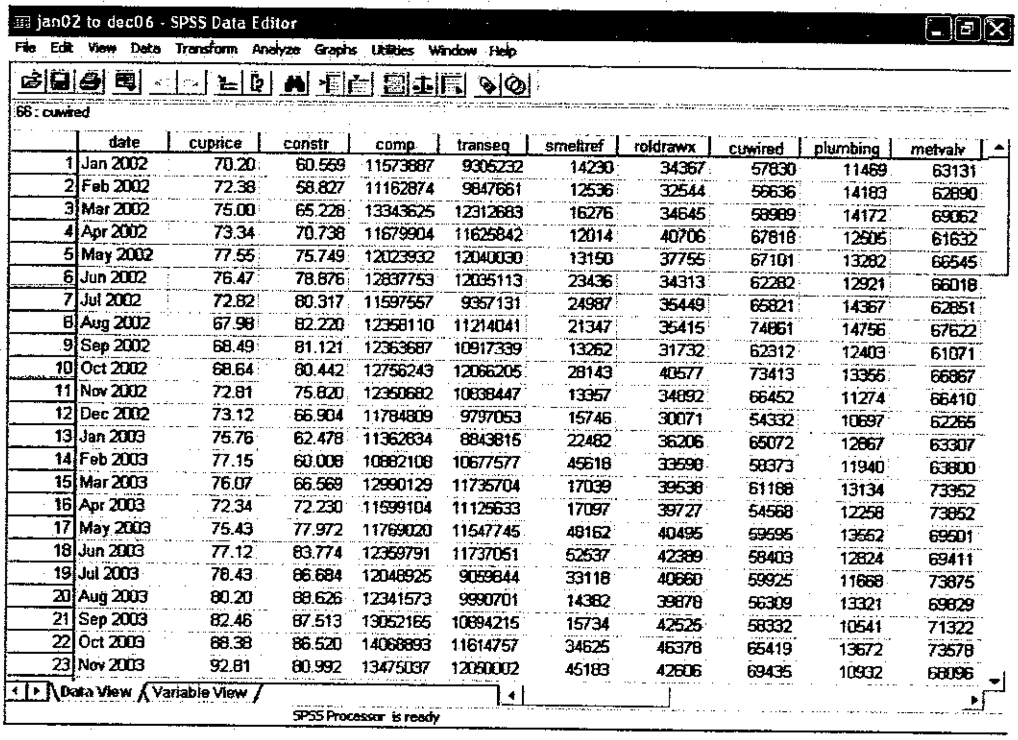
4.3.2 Industrial Product (IP)

IP is another indicator of the status of economic in any country. Industrial is well known as the fastest source of economic growth. Countries with higher IP tend to emerge as an advanced economic country which capable of controlling efficiently the import and export of goods in their respective country. Copper is one of the materials being imported and exported throughout the world. Therefore, IP of the country have a significant impact on the copper prices.

4.3.3 Other metals

The import and export of other metal in the world is also affecting the copper price. For example, trade of zinc, aluminum, nickel, and so on. Copper is one of many useful metals which are used in industry.

4.4 Finalized Independent Variables



	date	cuprice	constr	comp	transeq	smeltref	roldrawx	cuwired	plumbing	metvalv
1	Jan 2002	70.20	60.559	11573887	9305232	14230	34367	57830	11469	63131
2	Feb 2002	72.38	58.827	11162874	9847661	12536	32544	56636	14183	62890
3	Mar 2002	75.00	65.228	13343625	12312683	16276	34645	58989	14172	69062
4	Apr 2002	73.34	70.738	11679904	11625842	12014	40706	67818	12505	61632
5	May 2002	77.55	75.749	12023932	12040030	13150	37755	67101	13282	66545
6	Jun 2002	76.47	78.876	12837753	12035113	23436	34313	62282	12921	66018
7	Jul 2002	72.82	80.317	11597557	9357131	24987	35449	65821	14367	62851
8	Aug 2002	67.98	82.220	12358110	11214041	21347	35415	74861	14756	67622
9	Sep 2002	68.49	81.121	12363687	10917339	13262	31732	62312	12403	61071
10	Oct 2002	68.64	80.442	12756243	12066205	28143	40577	73413	13356	66867
11	Nov 2002	72.81	75.820	12350682	10838447	13357	34892	66452	11274	66410
12	Dec 2002	73.12	66.904	11784809	9797053	15746	30071	54332	10697	62265
13	Jan 2003	75.76	62.478	11362834	8843815	22482	36206	65072	12867	63307
14	Feb 2003	77.15	60.008	10882108	10677577	45618	33598	58373	11940	63800
15	Mar 2003	76.07	66.569	12990129	11735704	17039	39538	61188	13134	73352
16	Apr 2003	72.34	72.230	11599104	11125633	17097	39727	54568	12258	73852
17	May 2003	75.43	77.972	11769020	11547745	48162	40495	59595	13552	69501
18	Jun 2003	77.12	83.774	12359791	11737051	52537	42389	58403	12824	69411
19	Jul 2003	78.43	86.684	12048925	9059844	33118	40660	59925	11668	73875
20	Aug 2003	80.20	88.626	12341573	9990701	14382	39878	56309	13321	69829
21	Sep 2003	82.46	87.513	13052165	10894215	15734	42525	58332	10541	71322
22	Oct 2003	88.38	86.520	14068893	11614757	34625	46378	65419	13672	73578
23	Nov 2003	92.81	80.992	13475037	12050002	45183	42606	69435	10932	68096

Figure 4 Finalized independent variables (in SPSS Data View Window)

Data source of actual copper price: [13]

Data source of independent variables: [14]

Lag1 - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Window Help

69 : LAGcuwired1

	date	cuprice	LAGconstr1	LAGcomp1	LAGtranseq1	LAGsmeltref1	LAGroldrawx1	LAGcuwired1
1	Jan 2002	70.20	.	.	.	.	.	.
2	Feb 2002	72.38	60.559	11573887	9305232	14230	34367	57830
3	Mar 2002	75.00	58.827	11162874	9847661	12536	32544	56636
4	Apr 2002	73.34	65.228	13343625	12312683	16276	34645	58989
5	May 2002	77.55	70.738	11679904	11625842	12014	40706	67818
6	Jun 2002	76.47	75.749	12023932	12040030	13150	37755	67101
7	Jul 2002	72.82	78.876	12837753	12035113	23436	34313	62282
8	Aug 2002	67.98	80.317	11597557	9357131	24987	35449	65821
9	Sep 2002	68.49	82.220	12358110	11214041	21347	35415	74861
10	Oct 2002	68.64	81.121	12363687	10917339	13262	31732	62312
11	Nov 2002	72.81	80.442	12756243	12066205	28143	40577	73413
12	Dec 2002	73.12	75.820	12350682	10838447	13357	34892	66452
13	Jan 2003	75.76	66.904	11784809	9797053	15746	30071	54332
14	Feb 2003	77.15	62.478	11362834	8843815	22482	36206	65072
15	Mar 2003	76.07	60.008	10882108	10677577	45618	33598	58373
16	Apr 2003	72.34	66.569	12990129	11735704	17039	39538	61188
17	May 2003	75.43	72.230	11599104	11125633	17097	39727	54568
18	Jun 2003	77.12	77.972	11769020	11547745	48162	40495	59595
19	Jul 2003	78.43	83.774	12359791	11737051	52537	42389	58403
20	Aug 2003	80.20	86.684	12048925	9059844	33118	40660	59925
21	Sep 2003	82.46	88.626	12341573	9990701	14382	39878	56309
22	Oct 2003	88.38	87.513	13052165	10894215	15734	42525	58332
23	Nov 2003	92.81	86.520	14068893	11614757	34625	46378	65419

Data View / Variable View

SPSS Processor is ready

Figure 5 Finalized independent variables with lag 1

Lag2 - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Window Help

77 : LAGcomp2

	date	cuprice	LAGconstr2	LAGcomp2	LAGtranseq2	LAGsmeltref2	LAGroldrawx2	LAGcuwired2
1	Jan 2002	70.20	.	.	.	.	.	.
2	Feb 2002	72.38	.	.	.	.	.	.
3	Mar 2002	75.00	60.559	11573887	9305232	14230	34367	57830
4	Apr 2002	73.34	58.827	11162874	9847661	12536	32544	56636
5	May 2002	77.55	65.228	13343625	12312683	16276	34645	58989
6	Jun 2002	76.47	70.738	11679904	11625842	12014	40706	67818
7	Jul 2002	72.82	75.749	12023932	12040030	13150	37755	67101
8	Aug 2002	67.98	78.876	12837753	12035113	23436	34313	62282
9	Sep 2002	68.49	80.317	11597557	9357131	24987	35449	65821
10	Oct 2002	68.64	82.220	12358110	11214041	21347	35415	74861
11	Nov 2002	72.81	81.121	12363687	10917339	13262	31732	62312
12	Dec 2002	73.12	80.442	12756243	12066205	28143	40577	73413
13	Jan 2003	75.76	75.820	12350682	10838447	13357	34892	66452
14	Feb 2003	77.15	66.904	11784809	9797053	15746	30071	54332
15	Mar 2003	76.07	62.478	11362834	8843815	22482	36206	65072
16	Apr 2003	72.34	60.008	10882108	10677577	45618	33598	58373
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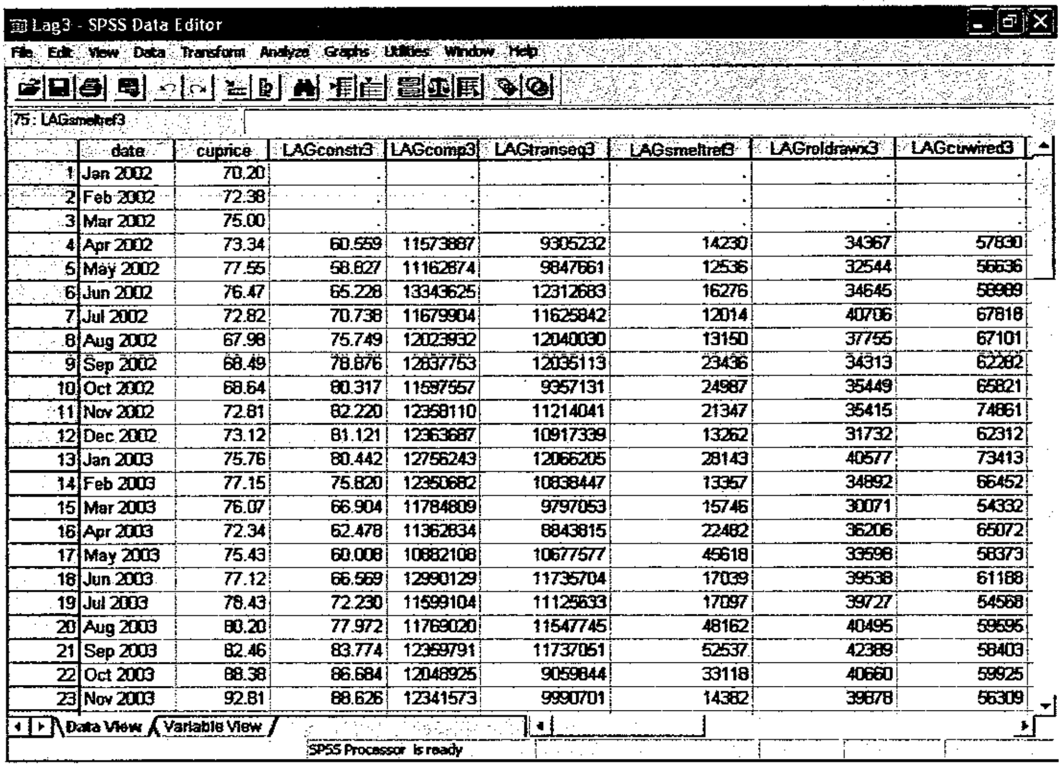
19	Jul 2003	78.43	77.972	11769020	11547745	48162	40495	59595
20	Aug 2003	80.20	83.774	12359791	11737051	52537	42389	58403
21	Sep 2003	82.46	86.684	12048925	9059844	33118	40660	59925
22	Oct 2003	88.38	88.626	12341573	9990701	14382	39878	56309
23	Nov 2003	92.81	87.513	13052165	10894215	15734	42525	58332

Data View / Variable View

SPSS Processor is ready

Figure 6 Finalized independent variables with lag 2



	date	cuprice	LAGconstr3	LAGcomp3	LAGtranseq3	LAGsmeltref3	LAGroldrawx3	LAGcuwired3
1	Jan 2002	70.20	.	.	.	.	.	.
2	Feb 2002	72.38	.	.	.	.	.	.
3	Mar 2002	75.00	.	.	.	.	.	.
4	Apr 2002	73.34	60.559	11573887	9305232	14230	34367	57830
5	May 2002	77.55	58.827	11162874	9847661	12536	32544	56636
6	Jun 2002	76.47	65.228	13343625	12312683	16276	34645	58989
7	Jul 2002	72.82	70.738	11679904	11625842	12014	40706	67818
8	Aug 2002	67.98	75.749	12023932	12040030	13150	37755	67101
9	Sep 2002	68.49	78.876	12837753	12035113	23436	34313	62282
10	Oct 2002	68.64	80.317	11597557	9357131	24987	35449	65821
11	Nov 2002	72.81	82.220	12358110	11214041	21347	35415	74861
12	Dec 2002	73.12	81.121	12363687	10917339	13262	31732	62312
13	Jan 2003	75.76	80.442	12756243	12066205	28143	40577	73413
14	Feb 2003	77.15	75.820	12350682	10838447	13357	34892	66452
15	Mar 2003	76.07	66.904	11784809	9797053	15746	30071	54332
16	Apr 2003	72.34	62.478	11362834	8843815	22482	36206	65072
17	May 2003	75.43	60.008	10882108	10677577	45618	33598	58373
18	Jun 2003	77.12	66.569	12990129	11735704	17039	39538	61188
19	Jul 2003	78.43	72.230	11599104	11125633	17097	39727	54568
20	Aug 2003	80.20	77.972	11769020	11547745	48162	40495	59595
21	Sep 2003	82.46	83.774	12369791	11737051	52537	42389	58403
22	Oct 2003	88.38	86.684	12048925	9059844	33118	40660	59925
23	Nov 2003	92.81	88.626	12341573	9990701	14382	39878	56309

Figure 7 Finalized independent variables with lag 3

4.5 Results of Pearson Correlation and Multiple Linear Regression (without lag)

Table 4 Dependent variable

Variable Name	Label
cuprice	• copper price average settlement (U.S. cent per pound)

Table 5 Independent variables

Variable Name	Label
1) constr	• value of construction in US (millions dollar)
2) comp	• exports of computer and electronic products (thousands of dollar)
3) transeq	• exports of transportation equipment (thousands of dollar)
4) smeltref	• exports of primary smelting and refining of copper (thousands dollar)
5) roldrawx	• exports of copper rolling, drawing, and extruding (thousands dollar)
6) cuwired	• exports of copper wire drawing (thousands dollar)
7) plumbing	• exports of plumbing fixtures fittings and trim (thousands dollar)
8) metvalv	• exports of metal valves and pipe fittings (thousands dollar)

Table 6 Pearson correlation and linear regression (single variable)

	Pearson Correlation (r)	Linear Regression (R^2)
constr	0,717	0,514
comp	0,818	0,669
transeq	0,809	0,655
smeltref	0,697	0,486
roldrawx	0,958	0,918
cuwired	0,955	0,913
plumbing	0,852	0,726
metvalv	0,931	0,866

Table 7 Multiple linear regression (2 independent variables)

	Multiple Linear Regression (R^2)
roldrawx cuwired	0,935
constr smeltref	0,677

Table 8 Multiple linear regression (3 independent variables)

	Multiple Linear Regression (R^2)
comp	
transeq	0,793
plumbing	
roldrawx	
cuwired	0,936
metvalv	

Table 9 Multiple linear regression (5 independent variables)

	Multiple Linear Regression (R^2)
constr	
smeltref	
comp	0,819
transeq	
plumbing	

Table 10 Multiple linear regression (excluded: constr, smeltref)

	Multiple Linear Regression (R^2)
transeq	
smeltref	
roldrawx	0,937
cuwired	
plumbing	
metvalv	

Table 11 Multiple linear regression (8 variables)

	Multiple Linear Regression (R^2)
constr	0.939
comp	
transeq	
smeltref	
roldrawx	
cuwired	
plumbing	
metvalv	

4.6 Models

Table 12 Coefficients of model 1 (without lag)

Model 1	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-84,863630394	44,115292214		-1,923678301	0,059985065
constr	-0,448087796	0,347343914	-0,074951032	-1,290040729	0,202855441
comp	0,000003329	0,000004914	0,057949717	0,677447745	0,501183664
transeq	-0,000001452	0,000003042	-0,037255111	-0,477347469	0,635154102
smeltref	0,000039268	0,000242723	0,008940648	0,161783094	0,872115915
roldrawx	0,001762717	0,000720185	0,423498709	2,447589860	0,017863975
cuwired	0,001012893	0,000288634	0,466938967	3,509260419	0,000948552
plumbing	0,000025162	0,002864659	0,000723204	0,008783721	0,993025964
metvalv	0,000510084	0,000624562	0,125393954	0,816706848	0,417894691

$$Y = a+bX_1+cX_2+dX_3+eX_4+fX_5+gX_6+hX_7+iX_8$$

$$= -84,863630394-(0,448087796)X_1+(0,000003329)X_2-(0,000001452)X_3+(0,000039268)X_4+(0,001762717)X_5+(0,001012893)X_6+(0,000025162)X_7+(0,000510084)X_8$$

Table 13 Accuracy of model 1

Model 1	January 2002	May 2004	October 2006
Estimated price of copper	65.22	148.54	305.89
Actual price of copper	70.20	120.95	340.61
% error	7.12	22.81	10.19

Table 14 Coefficients of model 2 (using lag 1)

Model 2	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-93,953549866	44,514779232		-2,110614755	0,039829126
LAGS(constr,1)	-0,561470227	0,347082326	-0,093899400	-1,617686022	0,112022437
LAGS(comp,1)	0,000006374	0,000004911	0,109094696	1,298046357	0,200227449
LAGS(transeq,1)	-0,000004166	0,000003087	-0,104275187	-1,349392793	0,183289552
LAGS(smeltref,1)	0,000008752	0,000242542	0,001980721	0,036082840	0,971359979
LAGS(roldrawx,1)	0,001115160	0,000722540	0,266746551	1,543387693	0,129042837
LAGS(cuwired,1)	0,001227208	0,000295859	0,568143478	4,147953343	0,000129907
LAGS(plumbing,1)	-0,000297430	0,002867167	-0,008549342	-0,103736552	0,917793403
LAGS(metvalv,1)	0,000913444	0,000625741	0,222284499	1,459779552	0,150605542

$$Y = a+bX_1+cX_2+dX_3+eX_4+fX_5+gX_6+hX_7+iX_8$$
$$=-93,953549866-(0,561470227)X_1+(0,000006347)X_2-(0,000004166)X_3+(0,000008752)X_4+(0,001115160)X_5+(0,001227208)X_6-(0,000297430)X_7+(0,000913444)X_8$$

Table 15 Accuracy of model 2

Model 2 (lag 1)	January 2002	May 2004	October 2006
Estimated price of copper	70.41	150.42	301.69
Actual price of copper	70.20	120.95	340.61
% error	0.29	24.37	11.43

Table 16 Coefficients of model 3 (using lag 2)

Model 3	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-93,413504021	46,054644633		-2,028318854	0,047981573
LAGS(constr,2)	-0,703171490	0,356353619	-0,117533199	-1,973240771	0,054122317
LAGS(comp,2)	0,000007311	0,000005022	0,123106230	1,455704528	0,151851842
LAGS(transeq,2)	-0,000001776	0,000003198	-0,042636394	-0,555330023	0,581195553
LAGS(smeltref,2)	-0,000020929	0,000250130	-0,004757586	-0,083672917	0,933657398
LAGS(roldrawx,2)	0,000531764	0,000740391	0,125489589	0,718220242	0,476032239
LAGS(cuwired,2)	0,001460258	0,000302527	0,665104960	4,826864314	0,000013971
LAGS(plumbing,2)	-0,003589107	0,002950241	-0,099457578	-1,216547213	0,229604168
LAGS(metvalv,2)	0,001282086	0,000641943	0,304846374	1,997196399	0,051372906

$Y = a+bX_1+cX_2+dX_3+eX_4+fX_5+gX_6+hX_7+iX_8$
$=-93{,}413504021-(0{,}703171490)X_1+(0{,}000007311)X_2-(0{,}000001776)X_3-$
$(0{,}000020929)X_4+(0{,}000531764)X_5+(0{,}001460258)X_6-$
$(0{,}003589107)X_7+(0{,}001282086)X_8$

Table 17 Accuracy of model 3

Model 3 (lag 2)	January 2002	May 2004	October 2006
Estimated price of copper	74.29	154.75	301.59
Actual price of copper	70.20	120.95	340,61
% error	5.83	27.95	11,46

Table 18 Coefficients of model 4 (using lag3)

Model 4	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-92,737740135	59,210570983		-1,566236207	0,123862940
LAGS(constr,3)	-0,788366561	0,454530057	-0,130568717	-1,734465189	0,089253953
LAGS(comp,3)	0,000004457	0,000006416	0,073073590	0,694690036	0,490598697
LAGS(transeq,3)	-0,000002270	0,000004081	-0,052731679	-0,556158960	0,580685722
LAGS(smeltref,3)	-0,000319764	0,000325688	-0,067905752	-0,981811713	0,331115623
LAGS(roldrawx,3)	0,000477552	0,000961341	0,108760494	0,496755980	0,621628711
LAGS(cuwired,3)	0,001270465	0,000404492	0,571194158	3,140891433	0,002882459
LAGS(plumbing,3)	-0,001740458	0,003829177	-0,046369551	-0,454525336	0,651499679
LAGS(metvalv,3)	0,001982883	0,000818797	0,453703480	2,421703053	0,019275580

$$Y = a+bX_1+cX_2+dX_3+eX_4+fX_5+gX_6+hX_7+iX_8$$
$$=-92{,}737740135-(0{,}788366561)X_1+(0{,}000004457)X_2-(0{,}000002270)X_3-(0{,}000319764)X_4+(0{,}000477552)X_5+(0{,}001270465)X_6-(0{,}001740458)X_7+(0{,}001982883)X_8$$

Table 19 Accuracy of model 4

Model 4 (lag 3)	January 2002	May 2004	October 2006
Estimated price of copper	80.53	157.03	305.66
Actual price of copper	70.20	120.95	340.61
% error	14.72	29.83	10.26

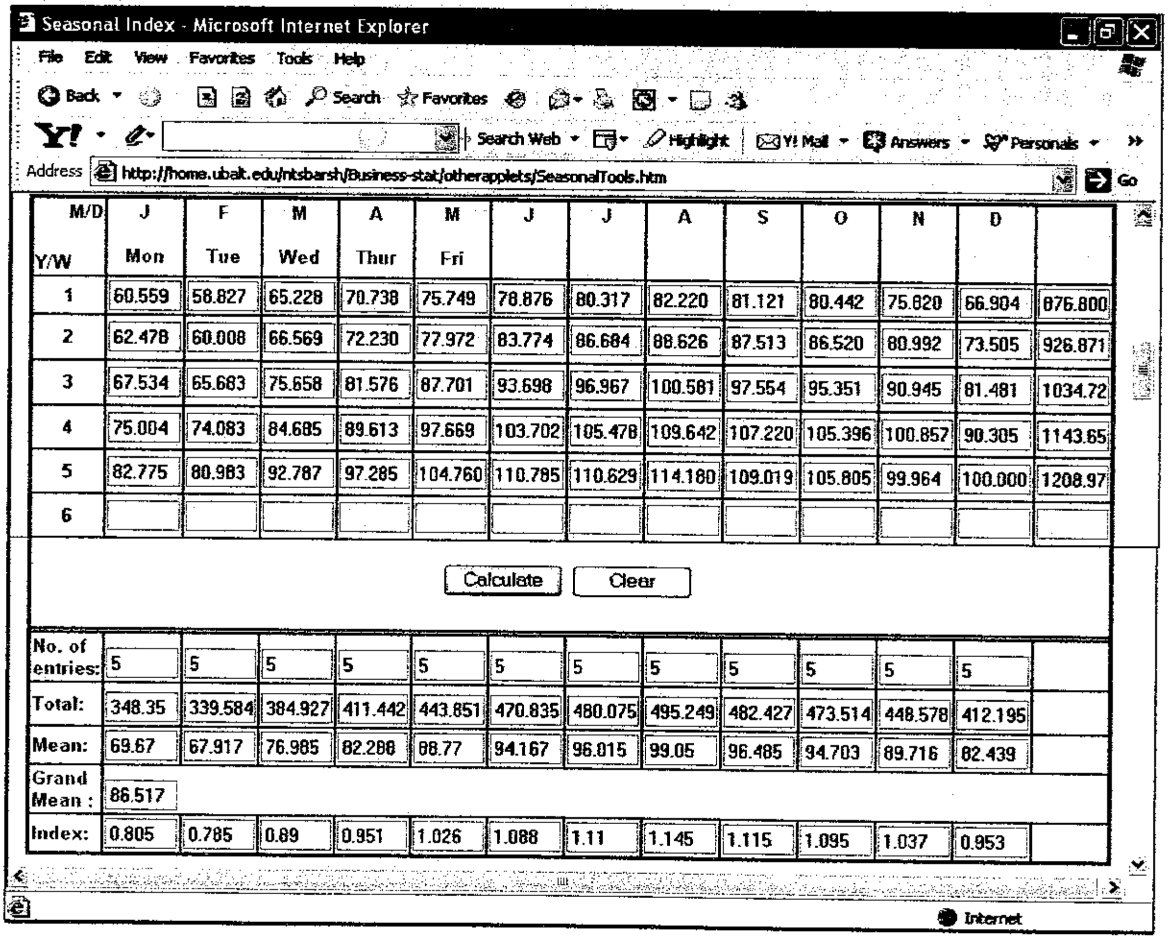
Table 20 Comparison of accuracy of all models

Model	% Error of Copper Price			R^2
	January 2002	May 2004	October 2006	
Model 1	7.12	22.81	10.19	0.939
Model 2 (lag 1)	0.29	24.37	11.43	0.939
Model 3 (lag 2)	5.83	27.95	11.46	0.937
Model 4 (lag 3)	14.72	29.83	10.26	0.898

The accuracy of the models is tested on randomly picked month where the actual copper price among the tested months is significantly different with each other. From Table 20, model 1 and model 2 are both having high value of R^2. If model 1 is compared with model 2 in term of percentage error, model 2 appeared as the better choice. However, model 1 is proven as a better model because that model becoming more accurate than other model as the month and year increases. This is in parallel with the objective of the model which is to forecast the 'future' price of copper. Therefore, model 1 has been selected as the finalized model.

4.7 Generated Independent Variables

The independent variables from January 2007 to December 2020 are not available. Therefore, they are generated using seasonal index method. Initially, the first independent variable which is construction variable from January 2002 to December 2006 are put in the form [15] as shown in Figure 8 to obtain the index for each month from January to December. Note that the year 2002 has been assigned with number 1, 2003 with number 2, and so on until 2006. Those indexes are the same for all years (2002 to 2020). After that, the similar process is repeated to get the indexes for each month for another seven independent variables.



M/D Y/W	J Mon	F Tue	M Wed	A Thur	M Fri	J	J	A	S	O	N	D	
1	60.559	58.827	65.228	70.738	75.749	78.876	80.317	82.220	81.121	80.442	75.820	66.904	876.800
2	62.478	60.008	66.569	72.230	77.972	83.774	86.684	88.626	87.513	86.520	80.992	73.505	926.871
3	67.534	65.683	75.658	81.576	87.701	93.698	96.967	100.581	97.554	95.351	90.945	81.481	1034.72
4	75.004	74.083	84.685	89.613	97.669	103.702	105.478	109.642	107.220	105.396	100.857	90.305	1143.65
5	82.775	80.983	92.787	97.285	104.760	110.785	110.629	114.180	109.019	105.805	99.964	100.000	1208.97
6													

No. of entries:	5	5	5	5	5	5	5	5	5	5	5	5	
Total:	348.35	339.584	384.927	411.442	443.851	470.835	480.075	495.249	482.427	473.514	448.578	412.195	
Mean:	69.67	67.917	76.985	82.288	88.77	94.167	96.015	99.05	96.485	94.703	89.716	82.439	
Grand Mean :	86.517												
Index:	0.805	0.785	0.89	0.951	1.026	1.088	1.11	1.145	1.115	1.095	1.037	0.953	

Figure 8 Value of the first independent variable (constr) from January 2002 to December 2006 are taken to calculate its index for each month

Next, using the same independent variable, the summation of values per year is taken into the form [16] as shown in Figure 9 to calculate slope and intercept using Linear Regression. Then, a linear equation is created such that:

$Y = mX+c$; where Y is the estimated value per year

m is the slope

X is the number represent the year (1, 2, 3...)

c is the intercept

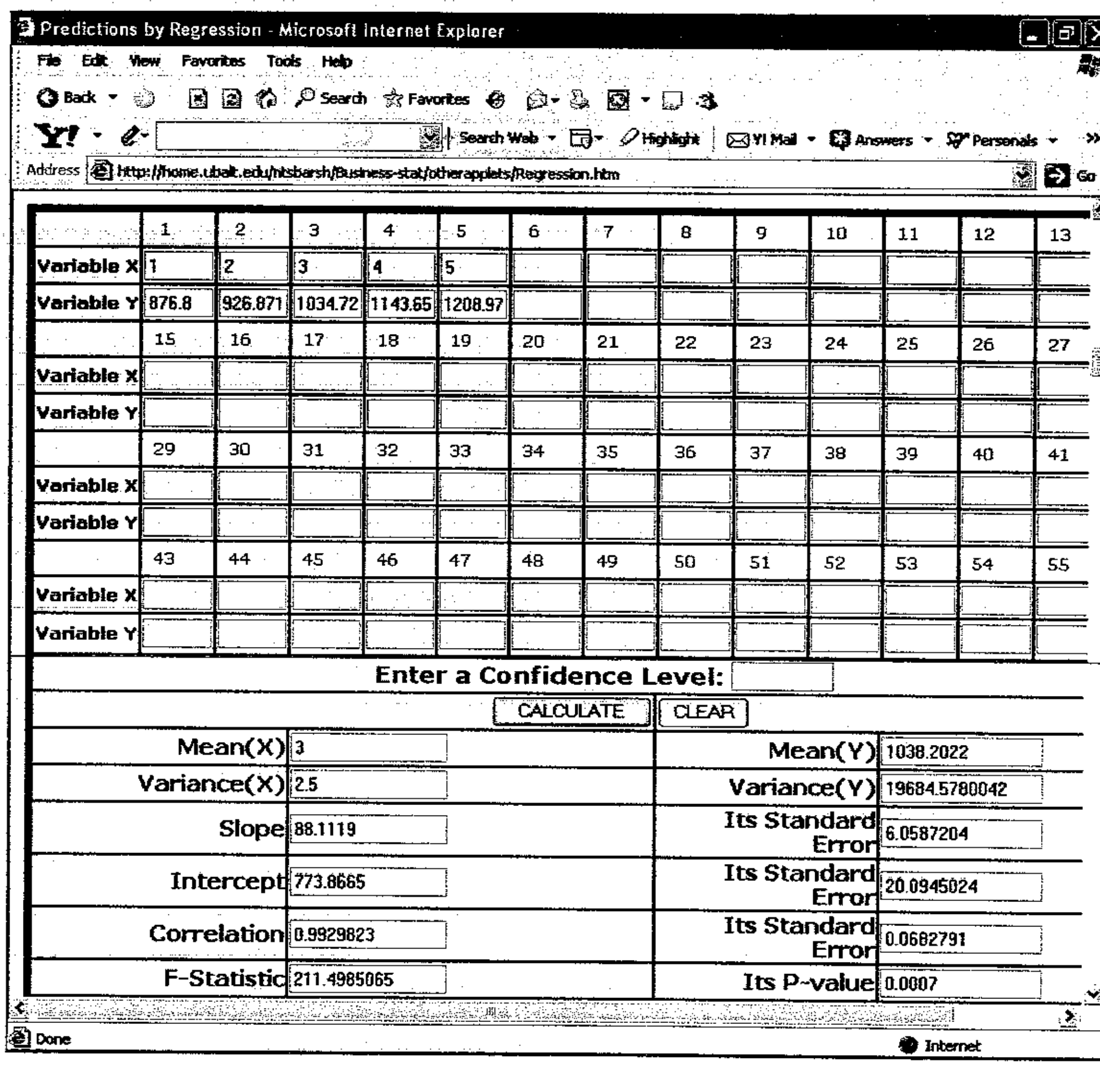


Figure 9 Summation of values per year is taken to calculate the slope and intercept to create linear regression equation

The equation obtained is used to estimate the value per year (Y). For example, the estimated value for 2007 can be calculated by substituting X = 6 into the previous equation (as 2006 has been assigned with X = 5). Next, the average value per month in that year can be obtained by dividing it with 12. Next, the monthly average is multiplied with the index obtained in Figure 8 to obtain the estimated value per month. Note that each independent variable corresponds to their respective index and linear equation only. After all the values from January 2007 to December 2020 for the first variable (constr) have been generated, the similar process is repeated for the rest of the independent variables.

The monthly average for all independent variables from 2007 to 2020 is shown in Figure 10.

Y(per year)	monthly avg									Corresponding Year
	cu price	var1	var2	var3	var4	var5	var6	var7	var8	
6	313.7353	108.5448	16195403	16140273	67398.14	97741.6	172423.3	18804.78	131984.6	2007
7	368.3830	115.8875	17052888	17349979	76877.93	111367	197360.4	20198.42	146419.5	2008
8	423.0307	123.2301	17910374	18559685	86357.73	124992.3	222297.5	21592.06	160854.4	2009
9	477.6783	130.5728	18767859	19769390	95837.52	138617.7	247234.6	22985.7	175289.3	2010
10	532.3260	137.9155	19625344	20979096	105317.3	152243	272171.6	24379.34	189724.2	2011
11	586.9737	145.2581	20482830	22188802	114797.1	165868.4	297108.7	25772.98	204159.1	2012
12	641.6213	152.6008	21340315	23398508	124276.9	179493.7	322045.8	27166.63	218594	2013
13	696.2690	159.9434	22197801	24608214	133756.7	193119.1	346982.9	28560.27	233028.9	2014
14	750.9167	167.2861	23055286	25817920	143236.5	206744.4	371920	29953.91	247463.8	2015
15	805.5643	174.6288	23912772	27027625	152716.3	220369.8	396857.1	31347.55	261898.7	2016
16	860.2120	181.9714	24770257	28237331	162196.1	233995.1	421794.1	32741.19	276333.6	2017
17	914.8597	189.3141	25627742	29447037	171675.9	247620.5	446731.2	34134.83	290768.5	2018
18	969.5073	196.6567	26485228	30656743	181155.6	261245.8	471668.3	35528.48	305203.4	2019
19	1024.1550	203.9994	27342713	31866449	190635.4	274871.2	496605.4	36922.12	319638.3	2020

Figure 10 The monthly average for all independent variables from 2007 to 2020

forecasted data (linear regression) - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Window Help

1 : constr 87.379

	date	constr	comp	transeq	smeltref	roldrawx	cuwired	plumbing	metvalv	var
1	Jan 2007	87.379	14851184	12992920	51357	85328	147767	16943	118258	
2	Feb 2007	85.208	14430104	15026594	67803	84253	153974	17827	121690	
3	Mar 2007	96.605	17507230	17802721	77575	98035	169320	20102	142411	
4	Apr 2007	103.226	15579977	16689042	63759	99696	162250	18485	131721	
5	May 2007	111.367	15693345	17237812	67061	104388	188114	19369	130137	
6	Jun 2007	118.097	16697460	17286232	69218	105659	181389	18447	133304	
7	Jul 2007	120.485	15515196	13283445	63287	97644	182769	18636	129477	
8	Aug 2007	124.284	16130621	16414658	74340	105952	190700	20629	138584	
9	Sep 2007	121.027	16778437	15962730	56075	101065	174148	18128	130137	
10	Oct 2007	118.857	17264299	17496056	82428	105170	181044	19971	140168	
11	Nov 2007	112.561	16616483	17334653	60658	96275	187769	19369	135680	
12	Dec 2007	103.443	17296690	16172554	75216	89531	149836	17733	132117	

Figure 11 Generated independent variables

Figure 11 shows the generated independent variables obtained by seasonal adjusted technique. These data can be used with model 1 to forecast the copper price for the desired month and year. Figure 8 only shows generated data from January 2007 to December 2007 for displaying purpose.

4.8 Forecast Accuracy

By comparing the forecasted price of copper to the actual price of copper from January 2007 to April 2007, the accuracy is computed. The result is shown in Table 21.

Table 21 Accuracy of the forecasted copper price

Model 1	2007			
	January	February	March	April
Forecasted copper price	269.40	272.83	324.79	306.75
Actual copper price	259.63	260.35	292.98	351.44
% error	-3.76	-4.79	-10.86	12.72

4.9 The Software

The software has been developed by using Visual Basic programming language. When the software is executed, the software will display the interfaces for the user to select the month as an input and then the software will display the copper price (in US cent per pound) as the output. There are three options available for the user to choose from:

i. Option 1: Estimated Price of Copper (Jan02-Dec06)

ii. Option 2: Forecasted Price of Copper (Jan07-Dec20)

iii. Option 3: Accuracy of the Forecasted Price (Jan07-Apr07)

The estimated price is not similar to forecasted price. The estimated price means the calculated price of copper obtained by substituting the existing independent variables into model 1. Note that the option for estimated price is within January 2002 to December 2006. Thus, there is no need to forecast the price of copper within these months as the actual price is already exists. That is why the actual price and percentage of error is included in Option 1.

Meanwhile, the forecasted price is the calculated price of copper obtained by substituting the generated independent variables into model 1. Note that the option for forecasted price is from January 2007 to December 2020. Thus, the actual price of copper is not available and that is why the calculated price is known as forecasted price (not estimated price).

Specifically, during the development of the software, the actual price of copper in January 2007 to April 2007 has been available. However, the independent variables for that period were not included during the development of model 1. Those independent variables have been reserved to check the accuracy of the forecasted price. Therefore, Option 3 is available for the user to check the accuracy of the forecasted price in Option 2 by looking at the accuracy of the forecasted price in January 2007 to April 2007.

Before a user enter any input, the software shall display the interfaces as shown in Figure 12.

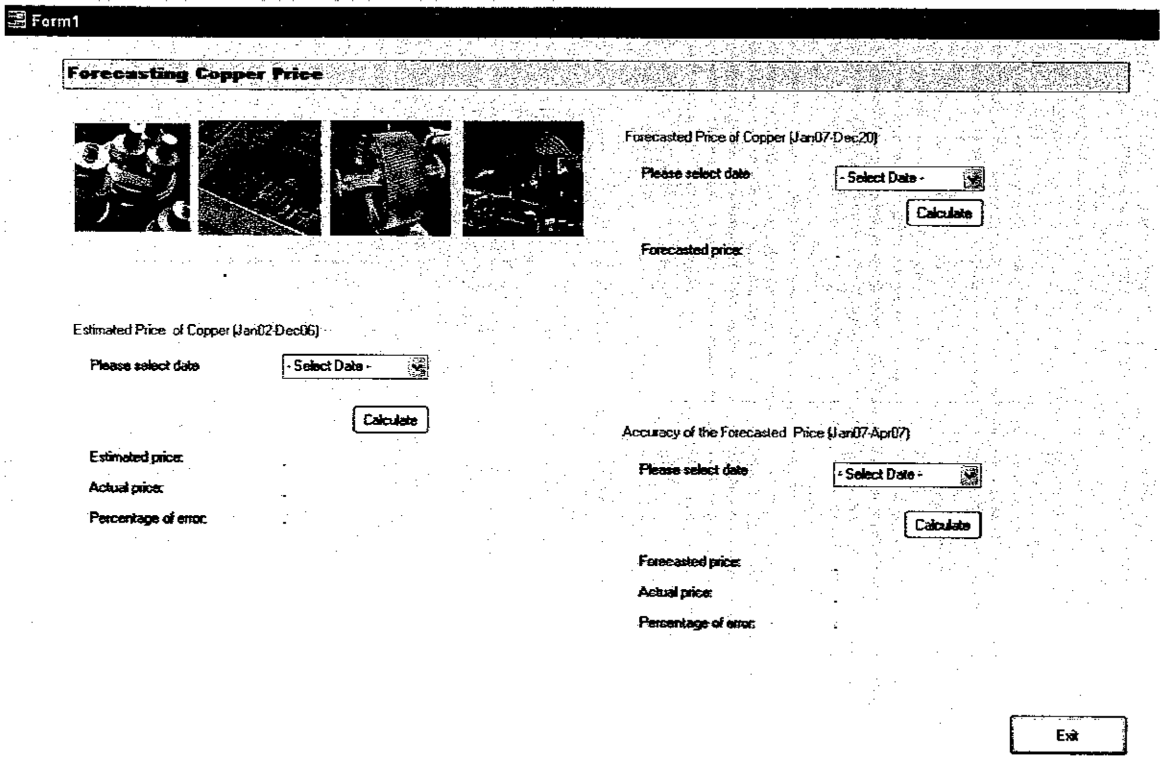


Figure 12 The display of the software

The first option allows user to estimate the price of copper in any months within January 2002 to December 2006. For example, if a user select Jan 2003 in the combo box, the software shall display the output as shown in Figure 13.

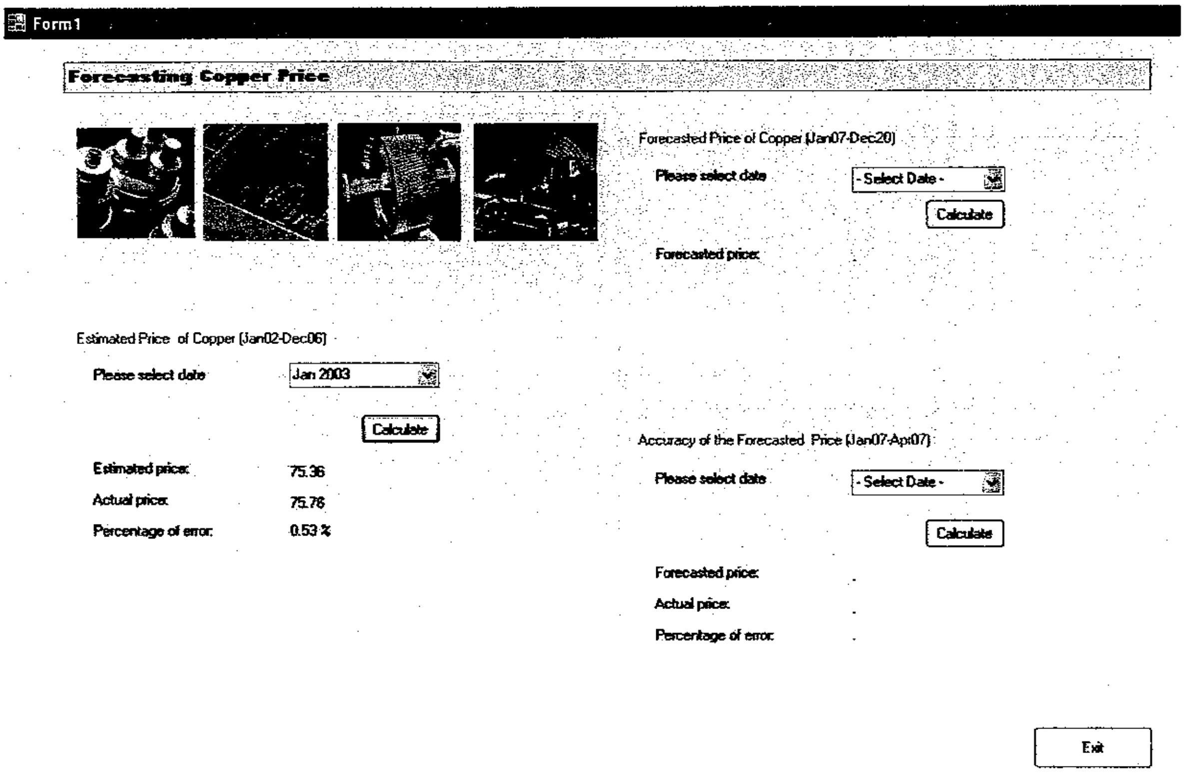


Figure 13 Option 1: Output displayed when a user selects Jan 2003 to estimate the price of copper in January 2003

Option 2 is the main function of the software which is to forecast the future price of copper within any months from January 2007 until December 2020. If a user wishes to forecast the price of copper in July 2010, the software shall display the output as shown in Figure 14.

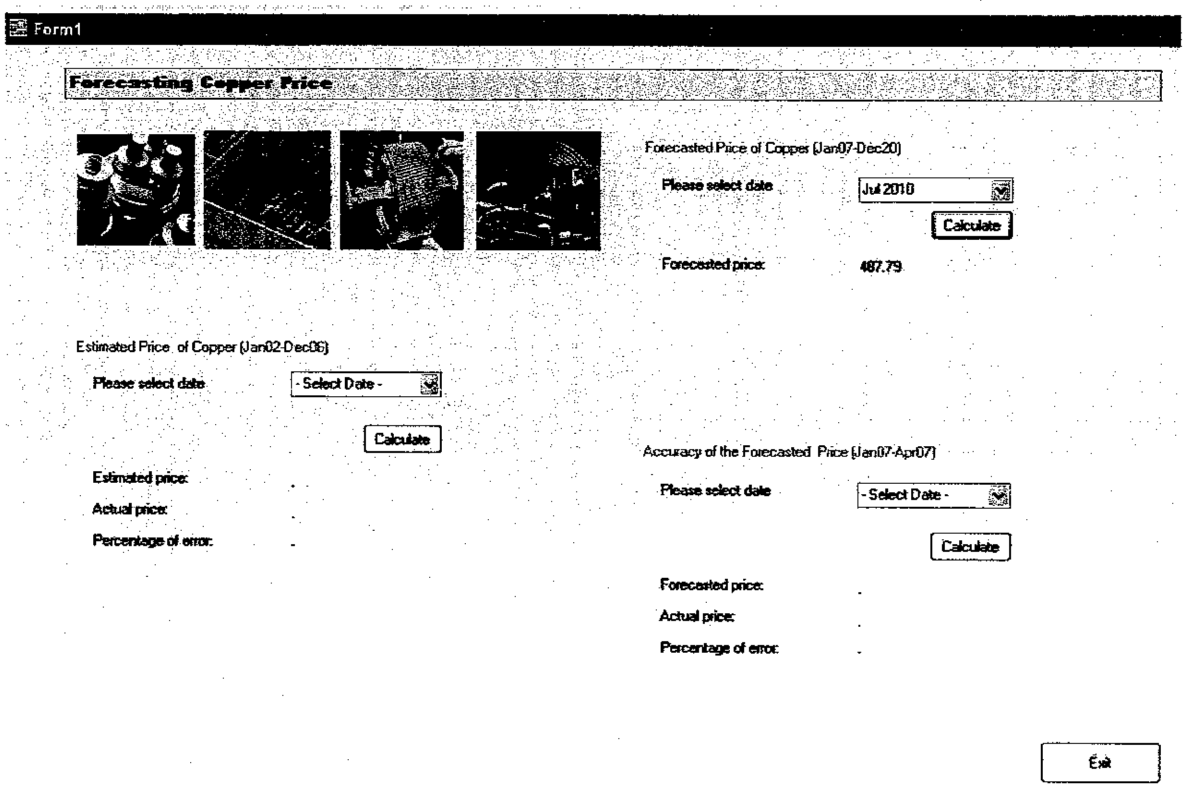


Figure 14 Option 2: Output displayed when a user selects Jul 2010 to forecast the price of copper in July 2010

If the user would like to check how reliable the forecasted price of copper is, option 3 may be chosen. For example, a user might select March 2007 to check the percentage of error and hence the accuracy of the forecasted price. The output displayed is shown in Figure 15.

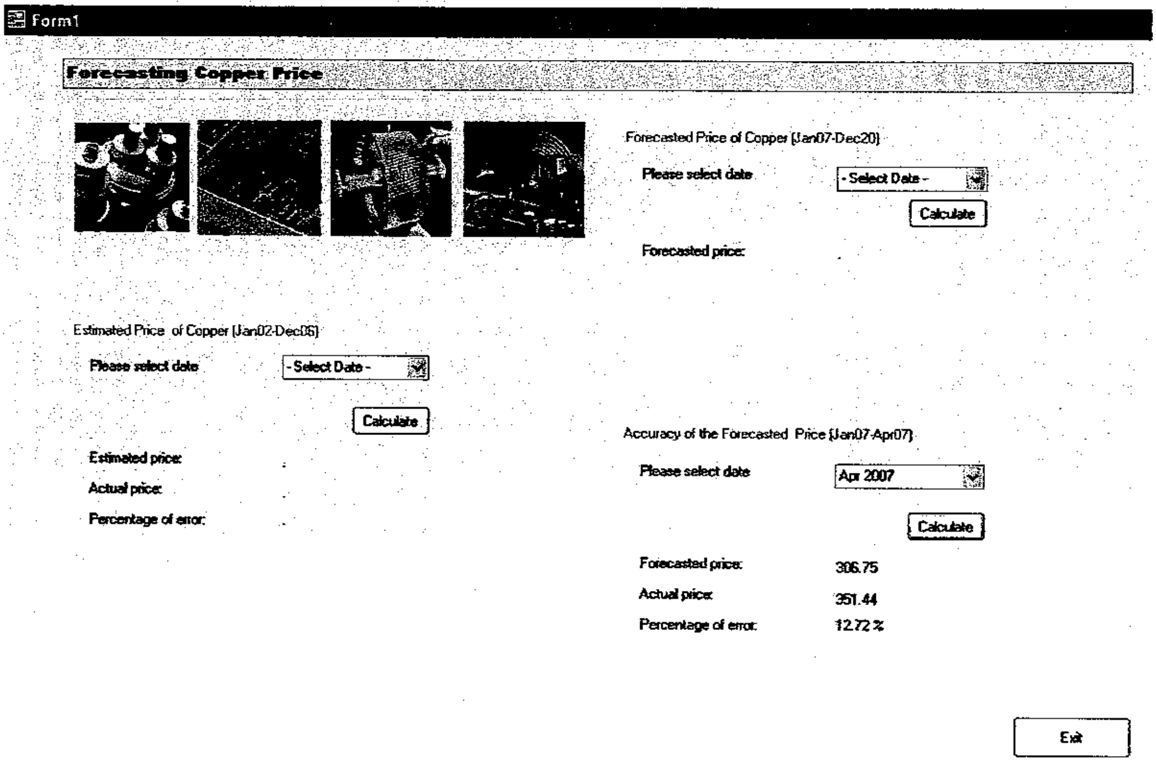


Figure 15 Option 3: Output displayed when a user select Apr 2007 to check the accuracy of the forecasted price of copper in April 2007

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As a conclusion, the forecasted price of copper is approximately deviates the unknown actual price of copper in the range of +13% and -13%. Therefore, the accuracy of the forecasting is approximately higher than 87%. The model that have been created and applied is:

$$Y = -84{,}863630394-(0{,}448087796)X_1+(0{,}000003329)X_2-(0{,}000001452)X_3+(0{,}000039268)X_4+(0{,}001762717)X_5+(0{,}001012893)X_6+(0{,}000025162)X_7+(0{,}000510084)X_8$$

Where; Y represents the estimated or the forecasted price of copper and X_1 to X_8 are the value of the independent variables. The selected with R^2 of 0.939 is utilized by programming it in Visual Basic Programming Language. Thus, a software which capable of guiding industries in making decisions regarding copper business is created.

5.2 Recommendations

The model can be further improved by incorporating more independent variables with higher value of R^2 . In addition, there are many techniques to forecast time series data. Each of the techniques have to be analyzed because each of them have their advantages over other techniques to suite certain pattern of time series data.

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APPENDICES

APPENDIX A

COPPER PRODUCTION FROM ORE TO FINISH PRODUCT

From its original home buried underground in a mine to its use in a finished product such as wire or pipe, copper passes through a number of stages. When it is recycled it can pass through some over and over again. Below is quick description of the path.

1. Mining, Crushing

The beginning for all copper is to mine sulfide and oxide ores through digging or blasting and then crushing it to walnut-sized pieces.

2. Grinding

Crushed ore is ball or rod-milled in large, rotating, cylindrical machines until it becomes a powder usually containing less than 1 percent copper. Sulfide ores are moved to a concentrating stage, while oxide ores are routed to leaching tanks.

3. Concentrating

Minerals are concentrated into a slurry that is about 15% copper. Waste slag is removed. Water is recycled. Tailings (left-over earth) containing copper oxide are routed to leaching tanks or are returned to the surrounding terrain. Once copper has been concentrated it can be turned into pure copper cathode in two different ways: Leaching & electrowinning or smelting and electrolytic refining.

4a. Leaching

Oxide ore and tailings are leached by a weak acid solution, producing a weak copper sulfate solution.

5a. Electrowinning (SX/EW)

The copper-laden solution is treated and transferred to an electrolytic process tank. When electrically charged, pure copper ions migrate directly from the solution to starter cathodes made form pure copper foil. Precious metals can be extracted from the solution.

OR

4b. Smelting

Several stages of melting and purifying the copper content result, successively, in matte, blister and, finally, 99% pure copper. Recycled copper begins its journey to finding another use by being resmelted.

5b. Electrolytic Refining

Anodes cast from the nearly pure copper are immersed in an acid bath. Pure copper ions migrate electrolytically from the anodes to "starter sheets" made from pure copper foil where they deposit and build up into a 300-pound cathode. Gold, silver and platinum may be recovered from the used bath.

6. Pure Copper Cathodes

Cathodes of 99.9% purity may be shipped as melting stock to mills or foundries. Cathodes may also be cast into wire rod, billets, cakes or ingots, generally, as pure copper or alloyed with other metals.

7. Cathode is converted into:

Wire Rod - Coiled rod about 1/2" in diameter is drawn down by wire mills to make pure copper wire of all gages.

Billet - 30' logs, about 8" diameter, of pure copper are sawed into these shorter lengths which are extruded and then drawn as tube, rod and bar stock of many varied sizes and shapes. Rod stock may be used for forging.

Cake - Slabs of pure copper, generally about 8" thick and up to 28' long, may be hot- and cold-rolled to produce plate, sheet, strip and foil.

Ingot - Bricks of pure copper may be used by mills for alloying with other metals or used by foundries for casting.

APPENDIX B

SPSS DATA EDITOR WINDOW

1) SPSS Variable View Window:

FYP II - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Window Help

	Name	Type	Width	Decimals	Label	
1	date	String	8	0	month and year	None
2	cuprice	Comma	8	2	copper price average settlement (U.S. cent per pound)	None
3	constr	Comma	8	3	value of construction in US (millions dollar)	None
4	comp	Numeric	8	0	exports of computer and electronic products (thousands of dollar)	None
5	transeq	Numeric	8	0	exports of transportation equipment (thousands of dollar)	None
6	smeltref	Numeric	8	0	exports of primary smelting and refining of copper (thousands dollar)	None
7	roldrawx	Numeric	8	0	exports of copper rolling, drawing, and extruding (thousands dollar)	None
8	cuwired	Numeric	8	0	exports of copper wire drawing (thousands dollar)	None
9	plumbing	Numeric	8	0	exports of plumbing fixtures fittings and trim (thousands dollar)	None
10	metvalv	Numeric	8	0	exports of metal valves and pipe fittings (thousands dollar)	None
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						

Data View / Variable View

SPSS Processor is ready

2) SPSS Data View Window:

FYP II - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Window Help

36 : smeltref 15746

	date	cuprice	constr	comp	transeq	smeltref	roldrawx	cuwired	plumbing	metvalv
25	Jan 2002	70.20	60.559	11573887	9305232	14230	34367	57830	11469	63131
26	Feb 2002	72.38	58.827	11162874	9847661	12536	32544	56636	14183	62890
27	Mar 2002	75.00	65.228	13343625	12312683	16276	34645	58989	14172	69062
28	Apr 2002	73.34	70.738	11679904	11625842	12014	40706	67818	12505	61632
29	May 2002	77.55	75.749	12023932	12040030	13150	37755	67101	13282	66545
30	Jun 2002	76.47	78.876	12837753	12035113	23436	34313	62282	12921	66018
31	Jul 2002	72.82	80.317	11597557	9357131	24987	35449	65821	14367	62851
32	Aug 2002	67.98	82.220	12358110	11214041	21347	35415	74861	14756	67622
33	Sep 2002	68.49	81.121	12363687	10917339	13262	31732	62312	12403	61071
34	Oct 2002	68.64	80.442	12756243	12066205	28143	40577	73413	13356	65867
35	Nov 2002	72.81	75.820	12350682	10838447	13357	34892	66452	11274	66410
36	Dec 2002	73.12	66.904	11784809	9797053	15746	30071	54332	10697	62265
37	Jan 2003	75.76	62.478	11362834	8843815	22482	36206	65072	12867	63307
38	Feb 2003	77.15	60.008	10882108	10677577	45618	33598	58373	11940	63800
39	Mar 2003	76.07	66.569	12990129	11735704	17039	39538	61188	13134	73352
40	Apr 2003	72.34	72.230	11599104	11125633	17097	39727	54568	12258	73852
41	May 2003	75.43	77.972	11769020	11547745	48162	40495	59595	13552	69501
42	Jun 2003	77.12	83.774	12359791	11737051	52537	42389	58403	12824	69411
43	Jul 2003	78.43	86.684	12048925	9059844	33118	40660	59925	11668	73875
44	Aug 2003	80.20	88.626	12341573	9990701	14382	39878	56309	13321	69829
45	Sep 2003	82.46	87.513	13052165	10894215	15734	42525	58332	10541	71322
46	Oct 2003	88.38	86.520	14068893	11614757	34625	46378	65419	13672	73578
47	Nov 2003	92.81	80.992	13475037	12050002	45183	42606	69435	10932	68096

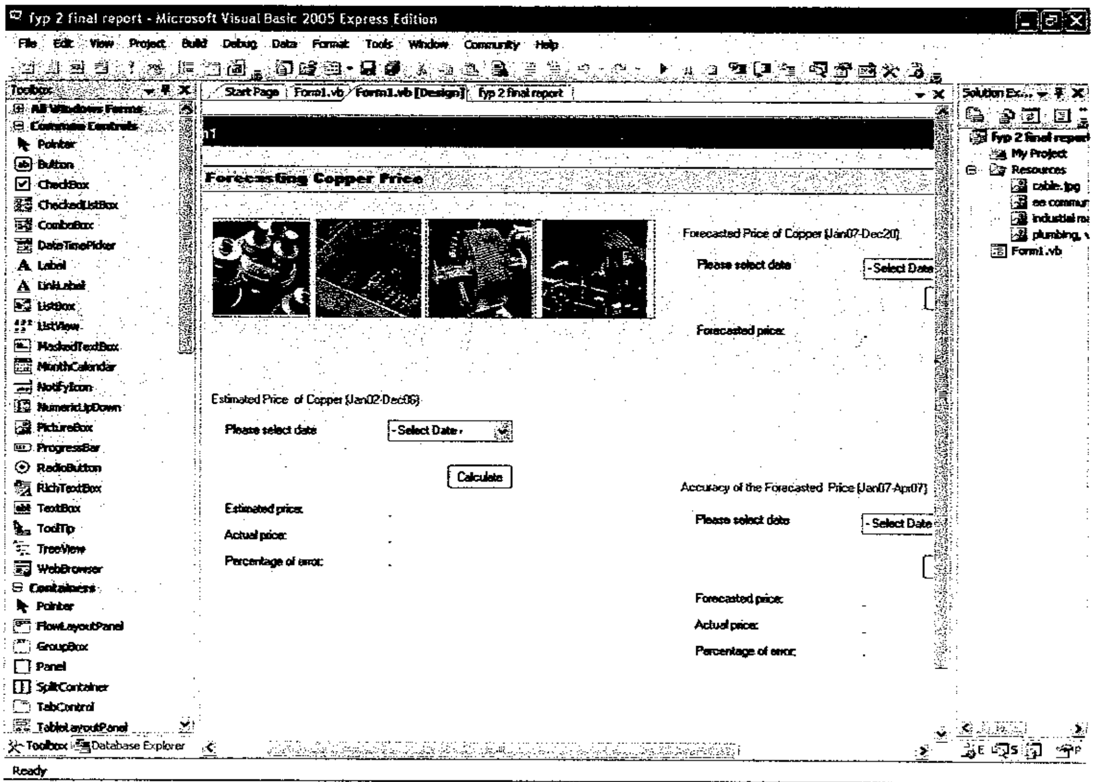
Data View / Variable View

SPSS Processor is ready

APPENDIX C

VISUAL BASIC

1) Visual Basic Windows



2) Codes:

```
Public Class frmCalc
    Dim udtIndiVar(240, 10) As String
    Dim intIndex, intIndex2, intRecord As Integer
    Dim dblEstPrc1, dblActPrc1, dblErr1 As Double
    Dim dblEstPrc3, dblActPrc3, dblErr3, dblForcast As Double

    Dim intdate, intRun As Integer

    Private Sub frmCalc_Load(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles MyBase.Load
        intIndex = 0
        FileOpen(1, "data.dat", OpenMode.Input)
        Do Until EOF(1)
            For intIndex2 = 0 To 9
```

```
                Input(1, udtIndiVar(intIndex, intIndex2))
            Next
            intIndex += 1
        Loop
        FileClose(1)
        intRecord = intIndex
    End Sub

    Private Sub btnCalc1_Click(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles btnCalc1.Click

        intdate = 0

        If cmbDate1.Text = "- Select Date -" Then
            lblEstPrc1.Text = "Please select a date."
            lblActPrc1.Text = "Please select a date."
            lblErr1.Text = "Please select a date."
        End If

        For intRun = 0 To 99
            If cmbDate1.Text = udtIndiVar(intRun, 0) Then '"Jan
2002" Then
                intdate = intRun

                dblEstPrc1 = (-84.863630394) + (-0.448087796209137)
* CDbl(udtIndiVar(intdate, 2)) + (0.0000332887584067351) *
CDbl(udtIndiVar(intdate, 3)) + (-0.0000145199973852066) *
CDbl(udtIndiVar(intdate, 4)) + (0.0000392684835791957) *
CDbl(udtIndiVar(intdate, 5)) + (0.00176271748278774) *
CDbl(udtIndiVar(intdate, 6)) + (0.00101289278773367) *
CDbl(udtIndiVar(intdate, 7)) + (0.0000251623644336083) *
CDbl(udtIndiVar(intdate, 8)) + (0.000510084248319017) *
CDbl(udtIndiVar(intdate, 9))
                lblEstPrc1.Text = FormatNumber(dblEstPrc1, 2, , ,
TriState.True)

                dblActPrc1 = udtIndiVar(intdate, 1)
                lblActPrc1.Text = FormatNumber(dblActPrc1, 2, , ,
TriState.True)

                dblErr1 = 100 * (dblActPrc1 - dblEstPrc1) /
dblActPrc1
                lblErr1.Text = FormatNumber(dblErr1, 2, , ,
TriState.True) + " %"
            End If
        Next

        dblEstPrc1 = (-84.863630394) + (-0.448087796209137) *
CDbl(udtIndiVar(intdate, 2)) + (0.0000332887584067351) *
CDbl(udtIndiVar(intdate, 3)) + (-0.0000145199973852066) *
CDbl(udtIndiVar(intdate, 4)) + (0.0000392684835791957) *
CDbl(udtIndiVar(intdate, 5)) + (0.00176271748278774) *
CDbl(udtIndiVar(intdate, 6)) + (0.00101289278773367) *
CDbl(udtIndiVar(intdate, 7)) + (0.0000251623644336083) *
CDbl(udtIndiVar(intdate, 8)) + (0.000510084248319017) *
CDbl(udtIndiVar(intdate, 9))

        'cmbDate1.Text(+"    " + Str(dblEstPrc1) + "\n" + "    " +
udtIndiVar(0, 1))
        'lblTest.Text = FormatNumber(dblErr1, 2, , , TriState.True)

    End Sub
```

```
    Private Sub btnExit_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles btnExit.Click
        Me.Close()
    End Sub



    Private Sub btnCalc3_Click(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles btnCalc3.Click
        intdate = 0

        If cmbDate3.Text = "- Select Date -" Then
            lblEstPrc3.Text = "Please select a date."
            lblActPrc3.Text = "Please select a date."
            lblErr3.Text = "Please select a date."
        End If

        For intRun = 0 To 99
            If cmbDate3.Text = udtIndiVar(intRun, 0) Then '"Jan
2002" Then
                intdate = intRun

                dblEstPrc3 = (-84.863630394) + (-0.448087796209137)
* CDbl(udtIndiVar(intdate, 2)) + (0.0000332887584067351) *
CDbl(udtIndiVar(intdate, 3)) + (-0.0000145199973852066) *
CDbl(udtIndiVar(intdate, 4)) + (0.0000392684835791957) *
CDbl(udtIndiVar(intdate, 5)) + (0.00176271748278774) *
CDbl(udtIndiVar(intdate, 6)) + (0.00101289278773367) *
CDbl(udtIndiVar(intdate, 7)) + (0.0000251623644336083) *
CDbl(udtIndiVar(intdate, 8)) + (0.000510084248319017) *
CDbl(udtIndiVar(intdate, 9))
                lblEstPrc3.Text = FormatNumber(dblEstPrc3, 2, , ,
TriState.True)

                dblActPrc3 = udtIndiVar(intdate, 1)
                lblActPrc3.Text = FormatNumber(dblActPrc3, 2, , ,
TriState.True)

                dblErr3 = 100 * (dblActPrc3 - dblEstPrc3) /
dblActPrc3
                lblErr3.Text = FormatNumber(dblErr3, 2, , ,
TriState.True) + " %"
            End If
        Next

        dblEstPrc3 = (-84.863630394) + (-0.448087796209137) *
CDbl(udtIndiVar(intdate, 2)) + (0.0000332887584067351) *
CDbl(udtIndiVar(intdate, 3)) + (-0.0000145199973852066) *
CDbl(udtIndiVar(intdate, 4)) + (0.0000392684835791957) *
CDbl(udtIndiVar(intdate, 5)) + (0.00176271748278774) *
CDbl(udtIndiVar(intdate, 6)) + (0.00101289278773367) *
CDbl(udtIndiVar(intdate, 7)) + (0.0000251623644336083) *
CDbl(udtIndiVar(intdate, 8)) + (0.000510084248319017) *
CDbl(udtIndiVar(intdate, 9))
```

```
        'cmbDate3.Text(+"    " + Str(dblEstPrc3) + "\n" + "    " +
udtIndiVar(0, 1))
        'lblTest.Text = FormatNumber(dblErr3, 2, , , TriState.True)
    End Sub



    Private Sub GroupBox3_Enter(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles GroupBox3.Enter

    End Sub

    Private Sub GroupBox1_Enter(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles GroupBox1.Enter

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button2.Click
        intdate = 0

        If cmbDate2.Text = "- Select Date -" Then
            lblForcast.Text = "Please select a date."
        End If

        For intRun = 0 To 240
            If cmbDate2.Text = udtIndiVar(intRun, 0) Then '"Jan
2002" Then
                intdate = intRun

                dblForcast = (-84.863630394) + (-0.448087796209137)
* CDbl(udtIndiVar(intdate, 2)) + (0.00000332887584067351) *
CDbl(udtIndiVar(intdate, 3)) + (-0.0000014519997385 2066) *
CDbl(udtIndiVar(intdate, 4)) + (0.0000392684835791957) *
CDbl(udtIndiVar(intdate, 5)) + (0.00176271748278774) *
CDbl(udtIndiVar(intdate, 6)) + (0.00101289278773367) *
CDbl(udtIndiVar(intdate, 7)) + (0.0000251623644336083) *
CDbl(udtIndiVar(intdate, 8)) + (0.000510084248319017) *
CDbl(udtIndiVar(intdate, 9))
                lblForcast.Text = FormatNumber(dblForcast, 2, , ,
TriState.True)

            End If
        Next

    End Sub
End Class
```