



## Modeling Bangladesh's Gross Domestic Product Using Regression Approach

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### ABSTRACT

This study finds the factors that affect Bangladesh's Gross Domestic Product (GDP) through regression approach. Stepwise and Ridge regression techniques have been applied to build the suitable regression model. Model adequacy also has been checked and multicollinearity problem is addressed for a plausible model using appropriate remedial measures for each of the model one after another that yields stepwise regression. The multicollinearity problem has also been tried to combat by ridge regression. Finally, the model which is adequate and free from multicollinearity problem after applying the ridge regression has been considered as the credible model for predicting the GDP of Bangladesh. The final model shows that the factors population, imports of goods and services, agriculture value added, manufacturing value added and labor force are positively affecting the GDP of Bangladesh.

**Keywords:** Model adequacy, Multicollinearity, Backward elimination, Ridge regression, Variance inflation factors, Ridge trace.

## 1. Introduction

Gross Domestic Product (GDP) is the financial value in the market of all finished goods and services that formed within the boundaries of a country. Functionally, it can be defined as the accumulation of Private and public spending (C), Government spending (G), Investments (I) and country's net exports ( $NX = Exports - Imports$ ) i.e.,  $GDP = C + G + I + NX$ .

During the liberation war of 1971 nearly fifth of the Bangladesh's economy had been damaged and there was a deep macro-economic crisis of the late 1980s and then this worse situation overcome introducing a series of stabilization measures in the Bangladesh's economy. Subsequently, the Bangladesh's average GDP growth rate has been raised to 4.8 percent in the 1990s, which was one full percentage point higher than that recorded in the previous decade (i.e. 3.8 percent). The economy started rising sharply from 1990 (Bhattacharaya, 2002). Despite such impressive growth throughout the decade, the per capita income of Bangladesh at the beginning of the new decade was not only the lowest among the South Asian countries but also below the average per capita income of the least-developed countries. Nevertheless, Bangladesh's GDP remarkably increased during the period 2006-2008, it has been raised at an average rate of 6.4% (Ministry Finance, Bangladesh, 2014).

There is a large number of theoretical and empirical research have found various reasons for GDP to change and economy to grow (Wu et al., 2010; Hassan, et al., 2011; Lee, 2011). Through the improved efficiency of investment, the well-functioning financial system promotes private saving and private investment and leads to higher economic growth. The efficient financial system is necessary; however this is not a sufficient condition to reach a stable economic growth (Ang, 2008; Hassan, 2011). Other might play an important role in explaining the development of GDP (Christiaans, 2008; Wu et al., 2010; Lee, 2011). Although scientific literature is well-off publications on factors influencing GDP development and economic growth, however, this study analyzes the only impact of a specific factor to predict the GDP of Bangladesh. For instance, using the stepwise regression technique Chin and Fitrianto (2013) found private consumption, exports of goods and services and interest rate have a significant contribution to Malaysia's GDP. Likewise, the same technique, Mehmood (2012) identified significant factors for Pakistan and Bangladesh's GDP and, Bobinaite et al. (2011) for Lithuania's GDP. Considering seventeen factors, Akter et al. (2012) applied factor analysis for finding the significant factors that contribute to Bangladesh's GDP.

In this study, we also aimed to find the appropriate significant factors to

estimate the Bangladesh's GDP. Correlation analysis, Stepwise regression, and Ridge regression techniques are applied to build a plausible regression model. Additionally, the model adequacy has been checked to get the valid estimated model.

## 2. Materials and Methods

### 2.1 Data

For modeling the GDP of Bangladesh, the data have collected from the World Bank website (The World bank, 2014). This annual time series data is taken over the year 1990 to 2011 which consider 14 variables to predict the GDP of Bangladesh. The independent variables,  $X_1$  = Life expectancy at birth total (years),  $X_2$  = Population,  $X_3$  = Population ages 15-64 (% of total population),  $X_4$  = Agricultural land (square kilometers),  $X_5$  = Cereal production (metric tons),  $X_6$  = Foreign direct investment, net inflows (BoP, current US\$),  $X_7$  = Electricity production (kwh),  $X_8$  = Exports of goods and services (current US\$),  $X_9$  = Imports of goods and services (current US\$),  $X_{10}$  = Agricultural value added (current US\$),  $X_{11}$  = Manufacturing value added (current US\$),  $X_{12}$  = Labor force, and  $X_{13}$  = Gross capital formation and the dependent variable  $Y$  = Gross Domestic Product (GDP) have considered.

### 2.2 Correlation Analysis

Correlation coefficient measures the linear association between the two variables (Draper and Smith, 2011). Thus, the best predictors for the GDP of Bangladesh are selected by calculating the significant correlation coefficient of each of the independent variable with GDP.

### 2.3 Stepwise Regression (Backward Elimination Method)

In this study, backward elimination method was used since it is an economic procedure to finds only the best set of regressors in the model. It is very well-known procedure among the statistician due to the optimal predictive ability of the model based on the best set of regressors (Draper and Smith, 2003). Thus, through the stepwise procedure in our model, we consider as many as predictors which satisfied the model adequacy.

## 2.4 Model Adequacy Checking

To build a regression model, model adequacy must be checked to make the model useful in real life for taking a decision regarding a particular problem. Because specifying the functional form of the model is not enough, we must also make some assumptions about the manner in which  $Y$  (dependent variable) are generated (Gujarati, 2003). Because of this, the normality, linearity, homoscedasticity, autocorrelation and multicollinearity assumptions are checked throughout the backward elimination method. The necessary remedial measures are applied for a worthwhile regression model of GDP. According to Neter et al. (1996) multicollinearity is the problem that arises due to very high correlation among the independent variables. For the perfect multicollinearity, the regression coefficients become indeterminate and their standard errors become infinite. Though the regression coefficients are determinate in the case of high multicollinearity, they possess large standard errors and even the sign of the regression coefficients might be changed (Gujarati, 2003). Draper and Smith (2003) suggested using Ridge Regression in the presence of multicollinearity which adds specific additional information to the problem to remove the multicollinearity. Recently numerous articles have discussed the solution of the multicollinearity problem. Irfan et al. (2013) and Ramzan et al. (2010) has compared three shrinkage regression models, Ridge Regression, Principal Component Regression (PCR) and Partial Least Squares Regression (PLSR) and find that these three shrinkage regression methods provide more informative results as compare to the Ordinary Least Square (OLS) method to meet the multicollinearity problem on real GDP data in Pakistan. However, in this study, ridge regression technique is used to resolve the multicollinearity problem.

### 2.4.1 Ridge Regression

The ridge regression technique can be used to remedy the multicollinearity problem for analyzing the multiple regression model. In the presence of multicollinearity, least squares estimates are unbiased, but their variances are large so they may be far from the true value. Ridge regression minimizes the standard errors by adding a degree of bias to the regression estimates and among all the biased regression technique ridge regression is the most popular method. The multiple linear regression in matrix form can be written in the form of usual notation

$$Y = X\beta + \epsilon \quad (1)$$

where  $Y$  is the dependent variable,  $X$  is the matrix of independent variables,  $\beta$  is the regression coefficients and  $\epsilon$  represents the random error term.

The ordinary least square estimate of the regression coefficients are:

$$\hat{\beta} = (X'X)^{-1}X'Y \quad (2)$$

If the variables are standardized (both dependent and independent) by subtracting their means and dividing by their standard deviations we can write  $X'X = R$ , where  $R$  is the correlation matrix of independent variables. These estimates are unbiased so that the expected value of the estimates is the population values. That is,

$$E(\hat{\beta}) = \beta \quad (3)$$

The variance-covariance matrix of the estimates is

$$V(\hat{\beta}) = \sigma^2 R^{-1} \quad (4)$$

and since we are assuming that the  $Y$ 's are standardized, then  $\sigma^2 = 1$ . Thus, from the equation (4) can be written as

$$V(\hat{b}_j) = r_{jj} = \frac{1}{1 - R_j^2} \quad (5)$$

Where  $R_j^2$  is the value of  $R^2$  (coefficient of determination) obtained from the regression of  $X_j$  on the other independent variables. In this case, this variance is the Variance Inflation Factors (VIF) on the other independent variables. We see that as  $R_j^2$  is closer to one, the variance (and thus VIF) will get larger. The VIF value greater than 10 indicates the presence of strong multicollinearity (Marquardt, 1980). On the other hand, Snee (1973) suggested that VIF value should below 5 and, the independent variables will be uncorrelated if the VIF equal to 1 (Levine et. al., 2003).

The ridge regression starts with adding a small value  $\lambda$  to the diagonal elements of the correlation matrix. That is

$$\tilde{\beta} = (R + \lambda I)^{-1}X'Y \quad (6)$$

Where  $\lambda$  is the positive quantity which ranges from 0 to 1 (Brown and Payne, 1975) and when  $\lambda = 0$ , we obtain the least square estimates.

$$E(\tilde{\beta} - \beta) = ((X'X - \lambda I)^{-1}X'X - I)\beta \quad (7)$$

is the amount of bias and the covariance matrix is given by

$$V(\tilde{\beta}) = (X'X - \lambda I)^{-1}X'X(X'X - \lambda I)^{-1} \quad (8)$$

The main problem of using ridge regression is to select the value of  $\lambda$ . Hoerl and Kennard(1970), the pioneer of ridge regression, suggested using a graphic

method which they called the ridge trace. By this plot ridge regression coefficients can be estimated as a function of  $\lambda$ . The value of  $\lambda$  usually chosen by viewing the ridge trace for which the regression coefficients have stabilized. Choose the smallest value of  $\lambda$  as small as possible (which introduces the smallest bias) after which the regression coefficients remain constant.

## 2.5 Steps to Build the Model

In this study, the R statistical software is used for analyzing the data. Different statistical analysis and graphical techniques are performed to get an optimal regression model for the GDP of Bangladesh.

To find the predictors of GDP, correlation analysis between the GDP ( $Y$ ) with the independent variables have been calculated. The independent variables which have the significant correlation with  $Y$  are considered as the possible candidate for predicting GDP. Then stepwise regression (backward elimination) is used to build up the model of GDP. To select the plausible model for the GDP the following steps are considered.

**Step 1:** Consider the multiple regression with a maximum number of independent variables in the models that yield backward elimination method for testing assumptions of multiple regression. The assumptions except multicollinearity problem which does not meet the model have mitigated by using appropriate remedial measures.

**Step 2:** VIF is calculated for detecting multicollinearity. If multicollinearity problem is serious in the data then ridge regression technique is applied for combating multicollinearity.

**Step 3:** If the model does not satisfy the assumptions of multiple regression after applying the remedial measures and ridge regression technique, consider the next model with a second maximum number of independent variables of the backward elimination method and follow the steps 1, 2 and 3.

**Step 4:** Continue these processes until obtaining a plausible regression model for GDP of Bangladesh.

## 3. Results and Discussions

### 3.1 Correlation Analysis between the Variables

In order to diagnosis, the linear relationship between the variables, correlation matrix between the dependent and independent variables is constructed which is shown in Table 1. The independent variables  $X_1, X_3$  and  $X_5$  are not

reported in Table 2 since they are not significantly correlated with  $Y$ . The table indicates that all the independent variables except  $X_4$  have a positive significant linear relationship with the dependent variable at 1% level. The only  $X_4$  has a significant negative linear relationship with the dependent variable at 5% level. The independent variables are significant, linearly and positively related among themselves except the variable  $X_4$ . The variable  $X_4$  is significant, linearly and negatively related with others independent variables. However, all the independent variables have a significant correlation with the dependent variable; therefore, all of them are the candidate for predicting the GDP of Bangladesh. The significant association between the independent variables is the signal of multicollinearity problem; we will combat this problem using ridge regression.

Table 1: Correlation coefficients between the variables with significance testing

	$Y$	$X_2$	$X_4$	$X_6$	$X_7$	$X_8$	$X_9$	$X_{10}$	$X_{11}$	$X_{12}$
$X_2$	0.884** (0.000)									
$X_4$	-0.552** (0.008)	-0.710** (0.000)								
$X_6$	0.928** (0.000)	0.872** (0.000)	-0.508* (0.016)							
$X_7$	0.979** (0.000)	0.930** (0.000)	-0.566** (0.006)	0.953** (0.000)						
$X_8$	0.992** (0.000)	0.886** (0.000)	-0.564** (0.006)	0.935** (0.000)	0.976** (0.000)					
$X_9$	0.990** (0.000)	0.866** (0.000)	-0.543** (0.009)	0.932** (0.000)	0.968** (0.000)	0.998** (0.000)				
$X_{10}$	0.983** (0.000)	0.826** (0.000)	-0.490* (0.021)	0.880** (0.000)	0.931** (0.000)	0.969** (0.000)	0.970** (0.000)			
$X_{11}$	0.998** (0.000)	0.885** (0.000)	-0.566** (0.006)	0.929** (0.000)	0.981** (0.000)	0.991** (0.000)	0.989** (0.000)	0.976** (0.000)		
$X_{12}$	0.927** (0.000)	0.993** (0.000)	-0.673** (0.001)	0.912** (0.000)	0.967** (0.000)	0.928** (0.000)	0.912** (0.000)	0.868** (0.000)	0.928** (0.000)	
$X_{13}$	0.785** (0.000)	0.975** (0.000)	-0.698** (0.000)	0.792** (0.000)	0.840** (0.000)	0.792** (0.000)	0.767** (0.000)	0.733** (0.000)	0.781** (0.000)	0.945** (0.000)
$n$	22	22	22	22	22	22	22	22	22	22

Note: \*\* Significant at the 0.01 level, \* Significant at the 0.05 level and the value within parenthesis is the  $p$ -value of the respective correlation coefficient.

### 3.2 Stepwise Regression Models

The backward elimination process that begins considering the entire set of variables and remove one independent variable at each iteration process. The backward elimination method selects six several regression models (a-f) as seen

in the below. For all the models the  $R^2$  and Adjusted  $R^2$  values were 0.99, i.e., same for all models (a-f).

- Model (a) Predictors: (Constant),  $X_{13}$ ,  $X_4$ ,  $X_{10}$ ,  $X_6$ ,  $X_7$ ,  $X_9$ ,  $X_{11}$ ,  $X_2$ ,  $X_8$ ,  $X_{12}$   
 Model (b) Predictors: (Constant),  $X_{13}$ ,  $X_4$ ,  $X_{10}$ ,  $X_6$ ,  $X_9$ ,  $X_{11}$ ,  $X_2$ ,  $X_8$ ,  $X_{12}$   
 Model (c) Predictors: (Constant),  $X_{13}$ ,  $X_4$ ,  $X_{10}$ ,  $X_9$ ,  $X_{11}$ ,  $X_2$ ,  $X_8$ ,  $X_{12}$   
 Model (d) Predictors: (Constant),  $X_4$ ,  $X_{10}$ ,  $X_9$ ,  $X_{11}$ ,  $X_2$ ,  $X_8$ ,  $X_{12}$   
 Model (e) Predictors: (Constant),  $X_{10}$ ,  $X_9$ ,  $X_{11}$ ,  $X_2$ ,  $X_8$ ,  $X_{12}$   
 Model (f) Predictors: (Constant),  $X_{10}$ ,  $X_9$ ,  $X_{11}$ ,  $X_2$ ,  $X_{12}$

### 3.3 Regression Model Diagnostics

According to the Figures 1-3 and the Table 2, we see that models (a) - (c) affected by the outliers. Also, these models have multicollinearity problems and the problems could not be solved even using the ridge regression. The model (d) is also not adequate due to the dependence of errors, outliers (Figure 4) and multicollinearity. The errors of the model (e) and the model (f) are independent at 1% level (from Table 2,  $p$ -value = 0.022 and 0.023 respectively) and they are not affected by the outliers as seen in Figures 5 -6. However, the only serious problem in this model is multicollinearity. Model (e) fails to overcome multicollinearity problem after applying the ridge regression technique but model (f) finally has successfully been overcome the multicollinearity problem with the help of ridge regression. Therefore, we arrive at the decision that the model (f) is plausible for estimating the GDP of Bangladesh.

### 3.4 Validation of the Desired Plausible Model

The Box-Cox power transformation curve in Figure 7 indicates that  $Y$  is not normal, but the suggested power transformation by  $\lambda = 0.7071$  in Figure 8 shows that the transformed  $Y$  becomes normal. The normal probability plot of Figure 9 also supports the normality behavior of the transformed  $Y$ . As per model diagnostic in Table 2, we can conclude that the model (f) has satisfied all the assumptions of multiple regression except multicollinearity problem. This problem has been solved using ridge regression. Now in order to use ridge regression for the model (f), the ridge trace in Figure 10 suggested the value of  $\lambda = 0.1$  for which the regression coefficients of the model (f) is stabilized. Therefore, after defeating all the complications to build a credible regression model for forecasting the GDP of Bangladesh, finally we have got the following

model:

$$Y = -11.4215 + 0.61802X_2 + 0.0178X_9 + 0.1039X_{10} + 0.1338X_{11} + 0.3093X_{12} \quad (9)$$

Table 2: Model Diagnostics

Model	Normality	Linearity	Outlier	Constant variance	Independence of errors	Multicollinearity
Model (a)	Y becomes normal after square root transformation on Y	Correlation table suggests that each of the independent variables is linearly related to Y	Fig: 1 suggests that observation 22 is an outlier	$\chi^2 = 0.22549$ $p$ -value = 0.63489 So variance is constant	D-W Statistic = 2.05674 $p$ -value = 0.082 So errors are independent at 1% level of significance	Each of the independent variables have more than 10 VIF value except $X_4$ but the problem could not solve by ridge regression
Model (b)	Y becomes normal after square root transformation on Y	Correlation table suggests that each of the independent variables is linearly related to Y	Fig: 2 suggests that observation 22 is an outlier	$\chi^2 = 0.21608$ $p$ -value = 0.64204 So variance is constant	D-W Statistic = 2.05200 $p$ -value = 0.162 So errors are independent at 1% level of significance	Each of the independent variables have more than 10 VIF value except $X_4$ but the problem could not solve by ridge regression
Model (c)	Y becomes normal after square root transformation on Y	Correlation table suggests that each of the independent variables are linearly related with Y	Fig: 3 suggests that observation 22 is an outlier	$\chi^2 = 0.3894204$ $p$ -value = 0.53260 So variance is constant	D-W Statistic = 2.05914 $p$ -value = 0.156 So errors are independent at 1% level of significance	Each of the independent variables have more than 10 VIF value except $X_4$ but the problem could not solve by ridge regression
Model (d)	Y becomes normal after square root transformation on Y	Correlation table suggests that each of the independent variables are linearly related with Y	Fig: 4 suggests that observation 22 is an outlier	$\chi^2 = 0.0003919$ $p$ -value = 0.98420 So variance is constant	D-W Statistic = 1.49796 $p$ -value = 0.006 So errors are dependent at 1% level of significance	Each of the independent variables have more than 10 VIF value except $X_4$ but the problem could not solve by ridge regression
Model (e)	Y becomes normal after square root transformation on Y	Correlation table suggests that each of the independent variables are linearly related with Y	Fig:5 suggests that there is no outlier	$\chi^2 = 0.12178$ $p$ -value = 0.72711 So variance is constant	D-W Statistic = 1.5006 $p$ -value = 0.022 So errors are independent at 1%level of significance	Each of the independent variables have more than 10 VIF value but the problem could not solve by ridge regression
Model (f)	Y becomes normal after power transformation on Y by 0.7071 (Fig: 8 and 9)	Correlation table suggests that each of the independent variables are linearly related with Y	Fig:6 suggests that there is no outlier	$\chi^2 = 0.79508$ $p$ -value = 0.37257 So variance is constant	D-W Statistic = 1.5206 $p$ -value = 0.023 So errors are independent at 1%level of significance	Each of the independent variables have more than 10 VIF value but the problem has been solved by ridge regression

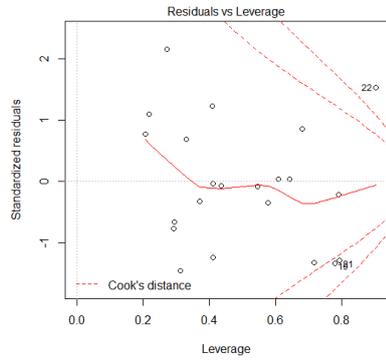


Figure 1: Leverage-residual plot (Model a)

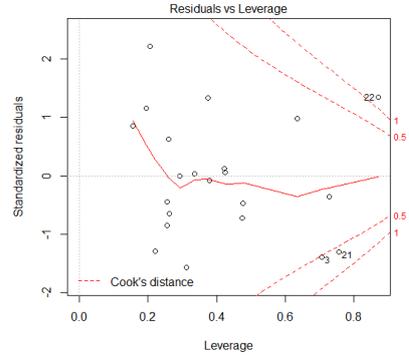


Figure 2: Leverage-residual plot (Model b)

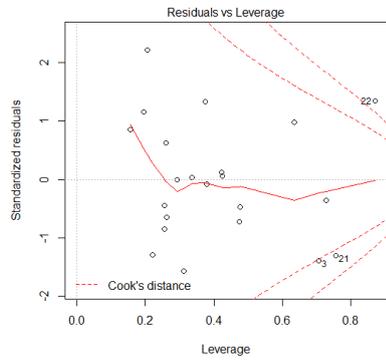


Figure 3: Leverage-residual plot (Model c)

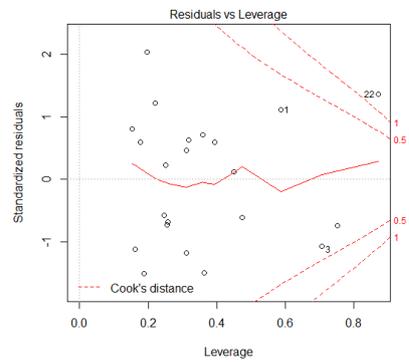


Figure 4: Leverage-residual plot (Model d)

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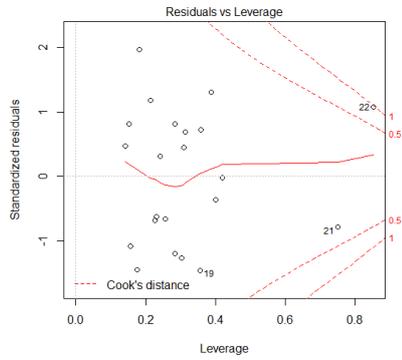


Figure 5: Leverage-residual plot (Model e)

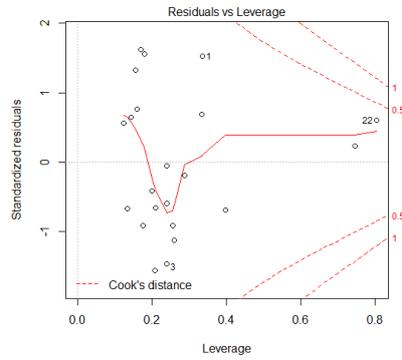


Figure 6: Leverage-residual plot (Model f)

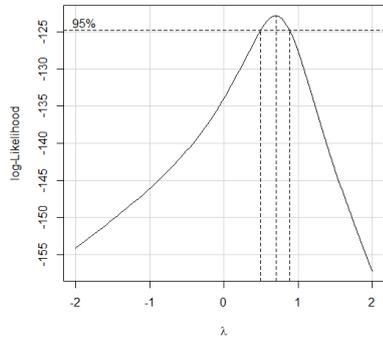


Figure 7: Box-cox power transformation curve

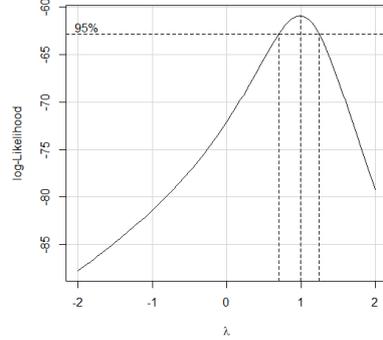


Figure 8: Box-cox power transformation curve

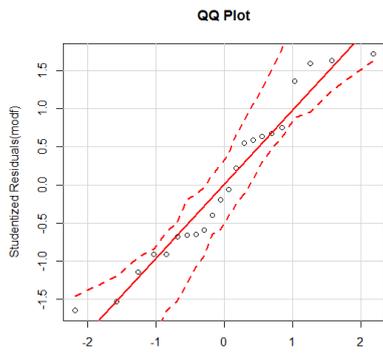


Figure 9: Normal probability plot

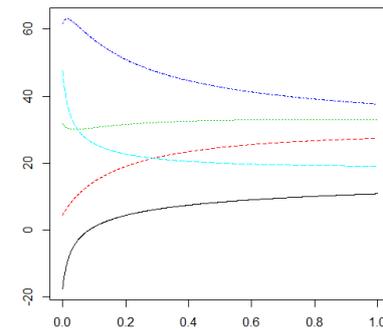


Figure 10: Ridge trace of the model (f)

## 4. Conclusion

Our objective was to fit a regression model for predicting the GDP of Bangladesh. We have analyzed a real life data set and before analyzing the data model adequacy were checked and remedial measures were applied if necessary. Multicollinearity is a big problem for modeling economic data and that has been successfully overcome using ridge regression. This study scrutinized 10 selected factors for explaining the Gross Domestic Product (GDP) of Bangladesh. Though all the selected factors significantly affecting the GDP of Bangladesh, we could not consider all of them in the final model as some of the factors have failed to pass the model assumptions. Moreover, there are also other factors which affect the GDP of Bangladesh were not allowed in this study due to the insufficiency of data. Among the 10 selected factors only 5 factors like  $X_2 =$  Population,  $X_9 =$  Imports of goods and services,  $X_{10} =$  Agricultural value added,  $X_{11} =$  Manufacturing value added and  $X_{12} =$  Labor force were found as the best candidate for explaining GDP after passing a series of testing processes. Finally, we found the regression model (9) as the desired plausible one. In this model, all the chosen factors (independent variables) positively affecting the GDP of Bangladesh.

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