Modeling Blood Pressure:Comparative Study Of Seemingly Unrelated Regression And Ordinary Least Squares Estimators

Onatunji, A. P And Alaba, O.O
University Of Ibadan, Nigeria. Waleonat@Gmail.Com

Abstract

Most authors have focused on Systolic Blood Pressure(SBP) and Diastolic Blood Pressure(DBP) separately. The effect of some identified risk factors on SBP and DBP can be estimated separately since they are affected by different factors.This study is aimed at developing a model that can appropriately capture the relationship between SBP and DBP rather than estimating the two separately. Also, to compare the efficiency of joint estimator; Seemingly Unrelated Regression(SUR) over the separate estimator; Ordinary Least Squares(OLS). The SUR model which is a special case of multivariate regression model was used to simultaneously capture the effect ofSBP and DBP. Data collected on age, sex, weight, waist, profession, history, Triglycerides(TRS) and Body Mass Index (BMI) from 100 patients of Olabisi Onabanjo University Teaching Hospital were used for the analysis. The results showed that there is a positive correlation between the SBP and DBP.The standard errors of SUR estimator were consistently lower than that of OLS estimator. The Correlation between SBP and DBP is $|\rho| = 0.4434$ *which confirmed the report of Zellner, 1962, Dieliman1989 Aebayo, 2003;and shows that SUR is an appropriate estimator for this study.The simultaneous estimation of SBP and DBP gave a higher precision in this study*

Key words: *systolic and diastolic blood pressures, joint and separate estimators*

Introduction

Blood Pressure (BP) is regarded as a major public health problem (Murray and Lopez, 1997) and a major threat to the health of adults in sub-Saharan Africa (Cappucio *et al.* 2004; 1997). This proves theEmerging evidence that identifies hypertension as a major cause of morbidity and mortality globally (Cooper *et al*. 1997; Olatunbuson *et al*. 2000; Rufus et.al. 2008). High BP is considered to be the result of environmental influences acting over time on the genetically predisposed individual (Pickering, 1967). High level of hypertension in the South Africa community with inadequate treatment status(Steyn k *et al*, 1998).It is higher in persons engaged in occupations involving little physical activity than those who are more active (Mial, 1959; Idahosa, 1987). In Nigeria, 30 million people suffer from hypertension which is the main risk factor for stroke and renal failure; 1.5 billion people worldwide suffer from high BP which claims about 7 million lives every year (Abubakar *et al*. 2009). Blood pressure (BP) is higher in the urban area African population than in their rural counterparts (Akinkugbe and Ojo, 1969; Pobee *et al.*1977)and this supports the indications that the burden of Non-Communicable Diseases (NCDs) such as hypertension is increasing in epidemic proportions in Africa; according to the World Health Report (2001), NCDs accounted for 22 percent of the total deaths in the region in the year 2000; cardiovascular diseases alone accounted for 9.2 Percent of the total deaths, killing even more than malaria (WHO, 2002). From 5,200 civil servants, factory and plantation workers living in an urban setting in the South Eastern part of Nigeria, the prevalence of hypertension, using the WHO criteria among the workers was 8.1 percent, and was lower in women than men, 3.5 and 8.9 percent respectively (Ekpo *et al*. 1992).

Approximately 25 percent of the adult population of the United States is hypertensive. In Framingham and Massachusetts, 37 percent of men and 51 percent of women who died of cardiovascular disease had been noted previously to have had BP over 140|90 mmHg Sleight *et al.* (1971). The prevalence of obesity is rising in developed and developing nations, which is the main risk factor for early mortality (WHO, 1998).Over nutrition is obesity which is the leading cause of hypertension in Framingham (Kannel, 2000). Body Mass Index (BMI) is the most useful epidemiological measure of obesity (WHO, 2000). About 50 million adults are hypertensive in China. A number of reports have shown intrauterine growth retardation and low birth weight as risk factors for high BP in adult. To support this argument, a study investigated BP in 1,183 Chinese nuclear families (mother, father and first two children), there was a strong familial aggregation of BP in this population and it shows that a familial influence can be detected from early childhood onward (Wang *et al*. 1999).

The prevalence of hypertension is 27.2 percent in the adult population aged between 35 to 74 years in China (Gu *et al*. 2002). Both nutrition and non nutrition factor should be paid attention to rather than single risk factor (WHO, 1983). In Malaysia, The National Health and Morbidity survey of 21,391 individuals over the age of 30 in 1996 showed a high prevalence of high BP with 33 percent of adults having hypertension (Lim *et al.* 2004). In a survey of rural Filipinos age 30 and above, the prevalence of hypertension is 23 percent (Reyes-Gibby and Aday 2000). In Spain, family history(53 percent), high cholesterol level(37 percent), smoking(35 percent), obesity (33percent), alcohol consumption (13 percent) and diabetes mellitus (11 percent) showed in hypertensive patients (Gavalda *et al*.1993). In a longitudinal study in Japan from 1997 to 1999, family history of hypertension, obesity, diabetes mellitus associated with the elevation of BP and that the number of risk factors positively associated with the increase in the level of both SBP and DBP (Tozawa *et al*. 2002).Kearney *et al.* (2005) projected that three quarters of World's hypertensive population will be in economically developing countries and also women will have a 0.5 percent higher prevalence of high BP compared to men by year 2025

Method of the study: Comparison study

We compared seemingly unrelated regression(SUR) and ordinary least squares(OLS) estimators in analyzing blood pressure.Disturbances measured at the same time especially in cross sectional studies are often correlated. Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) are measured simultaneously; it will therefore be a statistical fallacy to measure this independently since their error might be correlated. The SUR which is capable of dealing with these contemporaneous disturbances is then employed rather than estimating the effects of SBP and DBP separately which might yield consistent but inefficient estimates.This is achievable because different variables affect DBP and SBP which is one of the conditions for SUR model. Some identified risk factors used to capture SBP are age, sex, weight, waist, profession, history, Triglycerides(TRS), and Body Mass Index (BMI) while for DBP are exercise, sex, weight, waist, profession, history, TRS and BMI (Sudijanto, 2007).

A Seemingly Unrelated Regression system comprises several individual relationships that are linked by the fact that their disturbances are correlated Moon and Perron (2006). Such models have found many applications.The correlation among the equation disturbances could come from several sources. Equations explaining some phenomenon in different cities, states, countries, firms or industries provide a natural application as these various entities are likely to be subject to spillovers from economy-wide or worldwide shocks. It is in this case that a SUR model is a collection of two or more regression relations that can be analyzed with data on the dependent and independent variables.SUR model explains the variation of not just one dependent variable, but the variation of a set of m dependent variables Zellner (2006).There are two main motivations for use of SUR. The first one is to gain efficiency in estimation by combining information on different equations. The second motivation is to impose and/or test restrictions that involve parameters Zellner (1962), Srivastava and Giles (1987) and Fiebig (2001)

Zellner(1962) showed that SUR is efficient over separate equation by equation when the correlation between disturbances is high and explanatory variables are uncorrelated in two-stage approach. He found that definite gains are obtained for all sample sizes when $|\rho|>0.3$ where ρ is the contemporaneous correlation for the disturbances in the equations.

Adebayo (2003) claimed that the larger the contemporaneous correlation among disturbances , the more efficient SUR is than OLS using Bayesian Approach. He discovered that definite gains are obainted when$|\rho|>0.333$ which confirmed Dieliman(1989) who used a frequestist approach. Alaba *et al.* (2010) showed that the standard errors of the SUR estimator is consistently lower than the OLS estimator. Therefore, the SURE performs better than OLSE when the errors are correlated between the equations. Zellner (2003), Kmenta & Gilbert (1968), Telser (2004), Kunitomo(1977) and Adebayo(2003) showed that SUR is more efficient than OLS when $|\rho| \geq 0.3$ and for at least sample size of 23 for cross sectional data (Mehta and Swamy, 1976)

In this work, the above statistical methods when used will give us insight to efficiency of SUR over OLS.

The framework Consider,

$$y_1 = X_1\beta_1 + \varepsilon_1$$

$$y_1 = X_2\beta_2 + \varepsilon_2$$

$$\vdots$$

$$y_M = X_M\beta_M + \varepsilon_M$$

that is,

$y_i = X_i\beta_i + \varepsilon_i$, i = 1… M equations with T observations. Where Y_i are response variables, X_i are explanatory variables, β_i are regression coefficients ε_i are error terms

$$\varepsilon = (\varepsilon_1, \varepsilon_2 ......\varepsilon_M)\ with\ E\{\varepsilon / X_1, X_2,....X_{Mi}\} = 0$$

$$E\{\varepsilon\varepsilon / X_1, X_2,........X_{Mi}\} = \Omega$$

$E\{\varepsilon_{it}\varepsilon_{js} / X_1, X_2,.....X_{Mi}\} = \sigma_{ij}$ if s=t and 0 otherwise.

The different estimator of SUR is the Generalized Least Squares (GLS).

The inverse of $\Omega = \sum \otimes I$ is $\Omega^{-1} = \sum^{-1} \otimes I$

$$\hat{\beta} = \left(X'\hat{\Omega}^{-1}X\right)^{-1} X'\hat{\Omega}^{-1}y = \left(X'\left(\hat{\sum}^{-1}\otimes I\right)X\right)^{-1} X'\left(\hat{\sum}^{-1}\otimes I\right)y \quad (4)$$

Expansion of the kronecker product gives

(5)

This is the asymptotic covariance matrix for GLS estimator.

Assume that $X_i = X_j = X$ so that $X_i'X_j = X'X$ in (4), the inverse matrix becomes $[(\Sigma]^{-1} \otimes X'X)^{-1} = [\Sigma \otimes (X'X)^{-1}]$ and each term $X'Y_j = X'Xb_j$. If we then move the common term $X'X$ out of the summations, we obtain.

$$(X'X)\sum_{1}^{M} j\sigma^{1l}b_l @ (X'X)\sum_{1}^{M} j$$

(6)

The SUR model stacked together is given as

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ y_M \end{bmatrix} = \begin{bmatrix} X_1 & 0 ....0 \\ 0 & X_2 ....0 \\ . & \\ . & \\ 0 & 0 ....X_M \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ . \\ . \\ \beta_M \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ \varepsilon_M \end{bmatrix} = X\beta + \varepsilon$$

The variance- covariance matrix formulation is

$$E\{\varepsilon_i\varepsilon_j / X_1, X_2,.....X_{Mi}\} = \sigma_{ij}I_T = \Omega = \begin{bmatrix} \sigma_{11}I & \sigma_{12}I & ...\sigma_{1M}I \\ \sigma_{21}I & \sigma_{22}I & ...\sigma_{2M}I \\ . & & \\ . & & \\ \sigma_{MI}I & \sigma_{M2}I & ...\sigma_{MM}I \end{bmatrix} = \sum \otimes I$$

Where
$$\sum = \begin{bmatrix} \sigma_{11} & \sigma_{12}.........\sigma_{1M} \\ \sigma_{21} & \sigma_{22}.........\sigma_{2M} \\ . & \\ . & \\ \sigma_{MI} & \sigma_{M2}........\sigma_{MM} \end{bmatrix}$$

Therefore, OLS is the same as GLS. This implies that disturbances are uncorrelated across observation. The OLS is used to estimate one equation at a time, that is, each equation is a classical regression.

When Is SUR preferred to OLS?

1. The equations are actually related by the errors

2. The equations have different independent variables.

In these instances the regressions are not "seemingly," but actually, unrelated.

Zellner (2003), Kmenta & Gilbert (1968) have shown that when |ρ| = 0, OLS is preferred while SUR is more efficient than OLS when |ρ| ≥0.3 where $\rho = \frac{\sigma_{ij}}{\sqrt{\sigma_{ii}\sigma_{jj}}}, \sigma_{ij} \neq 0$ (See Revankar, 1974)

The asymptotic covariance matrix of $\hat{\beta} =$ in (5) is given by

Est. Asy Cov

$$\left(\hat{\beta}_i, \hat{\beta}_j\right) = \hat{\sigma}_{ij} \left(X' X\right)^{-1} \; i, j = 1, ..., M$$

Editor0)

$$\hat{\sum}_{ij} = \hat{\sigma}_{ij} = \frac{1}{T} e_i' e_j$$

Statistical Analysis

Analysis was performed for comparison study between SUR and OLS ondata collected on the reading of systolic and diastolic blood pressureon age, sex, weight, waist, profession, history, Triglycerides (TRS) and Body Mass Index (BMI) from 100 patients in Olabisi Onabaanjo University Teaching Hospital using statistical software(STATA). We developed model for systolic and diastolic BP that included above mentioned independent variables. To deal with correlation of errors between different equations (systolic and diastolic equation), we used statistical methods which are SUR and OLS estimators and also to estimate the effects on dependent variables; descriptive statistics and scatter diagram were also employed. Blood Pressure Model:Systolic$_i$= $\beta_0 + \beta_{1AGE\ i} + \beta_{2SEX\ i} + \beta_{3WEIGHT\ i} + \beta_{4WAIST\ C.\ i} + B_{5PROFESSIONi} + \beta_{6HISTORY\ i} + \beta_{7TRSi} + \beta_{8BMI\ i} + \varepsilon_i$ and Diastolic$_j$ = $\beta_0 + \beta_{1SEX\ j} + \beta_{2WEIGHT\ j} + \beta_{3WAIST\ C.\ j} + B_{4PROFESSION\ j} + \beta_{5HISTORY\ j} + \beta_{6TRSj} + \beta_{7EXERCISE\ j} + \beta_{8BMI\ j} + \varepsilon_j$

Results

Table 1 gave general characteristics of the study of dependent variables with their risk factors of small sample sizes of 100.The mean of systolic blood pressure 131.56(SD. 2.561341) was high normal and diastolic blood pressure 79.81(SD.1.617811) was normal with CI of 126.477-136.6423 and 76.5991-83.02009 respectively. The average age of patients was 44years which means that the patients were middle aged people and in their economically active age.The averagely body mass index of patients was 27.48(SD=0.5398) and this consequently means that they were overweight.Mean, standard deviation(SD), Confidence Interval(CI) reported confirmed high normal blood pressure(systolic, 130-140 and diastolic, 85-90), suggested optimal for normal blood pressure (systolic, 120 and diastolic, 80) and BMI=weight(kg)/height(m)^2(overweight, 25-29).Table2 shows the comparison between SUR and OLS. Here it was apparent that SUR outperformed and more efficient than OLS; the estimates were consistently smaller in SUR than in OLS. Figuer1 showed the systematic nature of relationship among identified risk factor and of course presence of outliers which are also for further research work.Table3 and 4 showed that the coefficients of determination 23, 27 percent variations in systolic and diastolic blood pressure respectively explained by identified risk factors. The risk factors that are significant to systolic are sex, weight, BMI and to diastolic are exercise, weight and TRS with (P=0.05).Table3 and 4 show thatsystolic and diastolic equations are ificant with 0.0017 and 0.0003Table5 reveals that error correlation between systolic and diastolic with identified risk factors is ρ=0.4434 which confirmed what many researcher reported in the literature.

Tables referred to in tis article are place after References due to their complexity (Editor). .

Table 3 reveals the coefficient of multiple correlations. R-squared shows that 23%, 27% percent of total variations in systolic and diastolic BP respectively associated with identified risk factors while 67% and 63% for unidentified risk factors. R-squared is significant(systolic, p=0.0017and diastolic, p=0.0003) at 5 percent level of significance. Adjusted R-squared in both scenarios are not due to chance. The adjusted coefficients are considerably smaller than the unadjusted coefficients because of the relatively large number of parameters in systolic and diastolic regression functions with the identified risk factors

Table4 reveals the coefficient of multiple correlations. R-squared shows that 23%, 27% percent of total variations in systolic and diastolic BP respectively associated with identified risk factors while 67% and 63% for unidentified risk factors. R-squared is significant(systolic, p=0.0005 and diastolic, p=0.0001) at 5 percent level of significanc

Discussion of Results

The results of the study indicatethat SUR performed better than OLS in modeling blood pressure**.** The study is intended as a quick method of simultaneously handling systolic and diastolic blood pressures under different identified risk factors affecting them.The cross sectional data for the study were relatively small; and while the study was not only intended to establish a model that appropriately capture risk factors affecting blood pressure but also to ascertain the efficiency of joint estimator over separator estimator, the possibility of biasness cannot be overlooked. Correlations among risk factors could be differed between systolic and diastolic blood pressure. The based population from which the subjects were drawn cannot be enumerated with any accuracy because major medical assessment was taking place within Olabisi Onabanjo University Teaching Hospital and private hospital in Ibadan

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Table 1. Summary of Continuous Variables

Variable Names	Means	Standard Error
Systolic	131.56	2.5613
Diastolic	79.81	1.6178
Age	44.46	1.3219
Weight	69.90	1.3838
Waist	92.05	1.3838
Trs	6.79	1.1639
BMI	27.48	26.4089

Table 1 shows average systolic(131.56mm) and diastolic(79.81mm) with average age, 44.46 and average BMI, 27.48 which means the patients examined are slightly overweight.

Figure1 is a scatter plots showing the systematic pattern of the regression relationship between BPs and the identified risk factors

Table2: Estimated Coefficients and Standard Deviation of β_{ij} of Comparison Study

Risk factors	Systolic(SUR)	Systolic(OLS)	Diastolic(SUR)	Diastolic(OLS)
Age	0.3293(0.1962)	0.3865(0.2259)		
Sex	-14.5568(6.9657)	-15.0945(0.2259)	-3.2849(1.5315)	-4.2039(1.7634)
Weight	0.7803(0.3764)	0.8163(0.3988)	0.5149(0.2193)	0.5098(0.230)
Waist	0.2980(0.4698)	0.1427(0.4876)	-0.1626(0.2729)	1.5773(0.2866)
Profession	0.1891(1.9406)	0.1427(2.0358)	1.6256(1.1936)	1.5773(1.2518)
Trs	1.9532(1.1468)	1.8714(1.2095)	2.1073(0.7018)	2.1998(0.7394)
Bmi	-2.1705(0.8763)	-2.1688(0.9186)	-0.8421(0.5396)	-0.8449(0.5656)
History	-0.7548(1.9524)	-0.6615(2.0523)	0.2775(1.1961)	-0.8449(0.5656)
Exercise	-3.2849(1.5315)	-4.2039(1.7634)		

Table2: Estimated Coefficients and Standard Deviation of β_{ij} of Comparison Study

Risk factors	Systolic(SUR)	Systolic(OLS)	Diastolic(SUR)	Diastolic(OLS)
Age	0.3293(0.1962)	0.3865(0.2259)		
Sex	-14.5568(6.9657)	-15.0945(0.2259)	-3.2849(1.5315)	-4.2039(1.7634)
Weight	0.7803(0.3764)	0.8163(0.3988)	0.5149(0.2193)	0.5098(0.230)
Waist	0.2980(0.4698)	0.1427(0.4876)	-0.1626(0.2729)	1.5773(0.2866)
Profession	0.1891(1.9406)	0.1427(2.0358)	1.6256(1.1936)	1.5773(1.2518)
Trs	1.9532(1.1468)	1.8714(1.2095)	2.1073(0.7018)	2.1998(0.7394)
Bmi	-2.1705(0.8763)	-2.1688(0.9186)	-0.8421(0.5396)	-0.8449(0.5656)
History	-0.7548(1.9524)	-0.6615(2.0523)	0.2775(1.1961)	-0.8449(0.5656)
Exercise	-3.2849(1.5315)	-4.2039(1.7634)		

Table 3: Estimated Coefficients and Standard Errors on OLS

Risk Factors	Models	Coefficients	Standard errors	P value
Age	Systolic	0.3865	0.2259	0.090
	Diastolic			
Sex	systolic	-15.0945	7.3545	0.043
	diastolic	-2.6981	4.4064	0.542
Weight	systolic	0.8160	0.3988	0.0239
	diastolic	0.5098	0.2866	0.029
waist	systolic	0.2583	0.4876	0.598
	diastolic	-0.1881	0.2866	0.513
Profession	systolic	0.1427	2.0358	0.944
	diastolic	1.5773	1.2560	0.211
Trs	systolic	1.8714	1.2095	0.125
	diastolic	2.1998	0.7394	0.004
Bmi	systolic	-2.1688	0.9186	0.021
	diastolic	-0.8449	1.2518	0.884
History	systolic	-0.6615	2.0523	0.020
	diastolic	0.1842	1.2518	0.884
Exercise	systolic			
	diastolic	-4.2039	1.7634	0.019

Table 4. Estimated Coefficients and Standard Errors on SUR

Risk Factors	Models	Coefficients	Standard errors	P value
Age	Systolic	0.3292	0.1962	0.095
	Diastolic			
Sex	systolic	-14.5568	6.9657	0.038
	diastolic	-3.2849	4.1921	0.460
Weight	systolic	0.7803	0.3764	0.040
	diastolic	0.5149	0.2193	0.020
Waist	systolic	0.2989	0.4608	0.517
	diastolic	-0.1626	0.2728	0.543
Profession	systolic	0.1891	1.9405	0.922
	diastolic	1.6256	1.1936	0.175
Trs	systolic	1.9532	1.1467	0.090
Bmi	diastolic	2.1073	0.7018	0.003
	systolic	-2.1705	0.8763	
History	diastolic	-0.8421	0.5396	0.014
	systolic	-0.7548	1.9524	0.120
Exercise	diastolic	0.2775	1.1961	0.700
	systolic			0.817
	diastolic	-3.2849	1.7634	
				0.033

Table5. Correlation Matrix of Residuals

Equation	Systolic	Diastolic
Systolic	1.0000	
Diastolic	0.4434	1.0000

Table 5 shows that systolic and diastolic equations are not insignificant, 0.0005 and 0.0001 with 5 percent level of significance with error correlation, $\rho = 0.4434$ between the equations

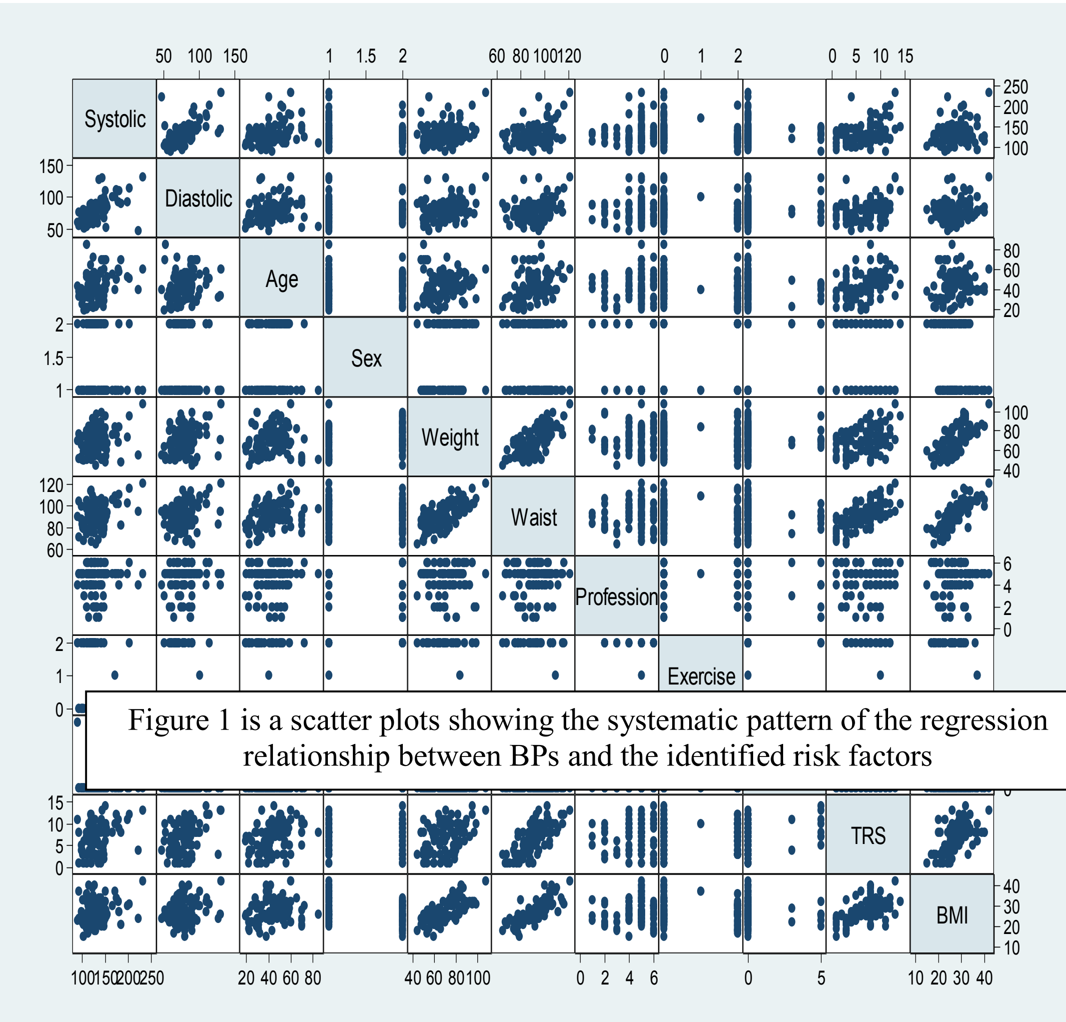

Figure 1 is a scatter plots showing the systematic pattern of the regression relationship between BPs and the identified risk factors