NEW ALTERNATIVE STATISTIC FOR TESTING SEVERAL INDEPENDENT SAMPLES OF CORRELATION MATRICES IN HIGH DIMENSION DATA

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Abstrak

Statistik Jennrich adalah salah satu statistik sedia ada yang digunakan untuk menguji kesamaan bagi beberapa sampel bebas matriks korelasi. Statistik tersebut semakin mendapat perhatian dalam beberapa bidang ekonomi dan pasaran kewangan.Dalam bidang penyelidikan ini, kebiasaannya bilangan pemboleh ubah, *p*, lebih besar daripada saiz sampel, *n*, yang dikenali sebagai data berdimensi tinggi. Selanjutnya, penganggaran pekali penentu bagi matrik korelasi dan kovarians akan mengalami kegagalan akibat daripada masalah kesingularan. Apabila ini berlaku, statistik Jennrich tidak akan berfungsi kerana pengiraannya melibatkan songsangan matrik korelasi. Oleh itu, bagi mengatasi kelemahan tersebut, kajian ini membangunkan satu statistik alternatif untuk menguji kesamaan matriks korelasi bagi beberapa sampel bebas dalam data berdimensi tinggi. Untuk tujuan itu, pendekatan aljabar berdasarkan operator *vec*, matriks komutasi dan elemen norma Frobenius keluar-pepenjuru-atas digunakan untuk menerbitkan taburan asimptotik baharu bagi statistik alternatif, yang dikenali sebagai statistik Z^*. Kajian simulasi dilakukan dengan mengambil kira bilangan pembolehubah, saiz sampel, dan anjakan korelasi yang berbeza untuk menilai prestasi statistik baharu. Sebagai tambahan, data sebenar bagi struktur mata wang Asia Pasifik semasa gempa bumi Tohoku digunakan untuk mengesahkan statistik Z^* baharu. Kuasa bagi statistik Z^* dibandingkan dengan statistik Jennrich dan juga statistik T^* yang sedia ada melalui kajian simulasi. Hasilnya, kuasa statistik Z^* mendominasi kuasa statistik Jennrich dan statistik T^* dalam semua keadaan, terutamanya, apabila perubahan dalam matrik korelasi adalah sekurang-kurangnya 0.3. Kesimpulannya, hasil dari segi teori ataupun simulasi menunjukkan keputusan yang mantap disokong oleh kuasa ujian yang diperlukan. Manakala, kajian terhadap data sebenar menunjukkan statistik alternatif baharu boleh memenuhi kondisi data berdimensi tinggi.

Kata kunci:. Matrik korelasi, Operator *vec*, Matrik komutasi, Norma Frobenius.

Abstract

Jennrich Jennrich statistic is one of the existing statistics which is used for testing the equality of several independent samples of correlation matrices. The statistic is gaining considerable importance in several areas of economics and financial markets. In these research areas, the number of variables, *p*, is usually larger than the sample size, *n*, which is known as high dimension data $p > n$. Subsequently, the estimation of correlation and covariance determinant will breakdown due to singularity problem. When this happens, Jennrich statistic is unable to function as the calculation involves the inversion of correlation matrix. Therefore, to resolve the aforementioned problem, this study develops an alternative statistic for testing several independent samples of correlation matrices in high dimension data. For this reason, the algebraic approach on the basis of *vec* operator, commutation matrix and Frobenius norm of upper-off-diagonal elements are used to derive the new asymptotic distribution for the new alternative statistic, namely Z^* statistic. Simulation study was conducted by considering different number of variables, sample sizes, and correlation shifts to evaluate the performance of the new statistic. In addition, real data on Asia Pacific currencies structure during the Tohoku earthquake were applied to validate the new Z^* statistic. The power of the Z^* statistic is compared with the existing Jennrich statistic, and T^* statistic through simulation study. As a result, the power of Z^* statistic dominates the power of Jennrich statistic and T^* statistic in all conditions, especially, when the shift in correlation matrix is at least 0.3 As a conclusion, the theoretical and simulation results are established and supported by desirable power of test. Meanwhile, investigation on real data indicates that the new alternative statistic can accommodate high dimension data.

Keywords: Correlation matrix, *Vec* operator, Commutation matrix, Frobenius norm.

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Table of Contents

List of Tables

List of Figures

List of Appendices

List of Symbols

$\otimes$	Kronecker product
I_p	Identity matrix
∂	Partial differentiation opretor
r	Sample correlation cofficient
R	Sample correlation matrix
ρ	Population correlation cofficient
Ω	Population correlation matrix
K_{pp}	Commutation matrix
$\left(K_{p,p}\right)_d$	Diagonal elements of commutation matrix
R_p	Pooled of sample correlation matrix
R_U	Upper off diagonal of sample correlation matrix
T	Transformation matrix
Σ	Population covariance matrix
S	Sample covariance matrix
S_d	Diagonal elements of sample covariance matrix
Σ_d	Diagonal elements of population covariance matrix
σ^2	Population variance
$v(R)$	Vectorization of R
$v(R_U)$	Vectorization of R_U
Tr	Trace
$\|\| \ \|\|$	Norm
$\xrightarrow{d}$	Convergence in distribution
$\left\|v(R)\right\|^2$	Squared Frobenius norm of sample correlation matrix
$\left\|v(\Omega)\right\|^2$	Squared Frobenius norm of population correlation matrix

$\left\Vert v\left(R_U\right)\right\Vert^2$	Squared Frobenius norm of upper-off-diagonal elements of sample correlation matrix
$\left\Vert v\left(\Omega_U\right)\right\Vert^2$	Squared Frobenius norm of upper-off-diagonal elements of population correlation matrix
$\xrightarrow{p}$	Convergence in probability

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Recently, testing the equality of several correlation matrices has become an important subject in the economic and financial industry research areas. Various researchers have implemented this test for diagnosing the structure of several independent samples of correlation matrices.

Applications have been found in equity markets, asset businesses, stock markets, real estate analysis, risk management, portfolio analysis and financial markets. However, when dealing with a large number of variables in real cases, understanding all their interrelationships simultaneously is a difficult job. Therefore, the correlation structure analysis it becomes very important when dealing with related variables where the number of variables is large.

Several researchers have studied the equality of several correlation matrices, including, for example, Cho and Taylor (1987), Tang (1995), Meric and Meric (1997), Lee (1998), Tang (1998) and Da Costa Jr, Nunes, Ceretta, and Da Silva (2005). All these researchers studied stability in stock returns to understand the behavior of a sequence of the correlation structures based on independent samples in certain time periods by applying Box's *M* statistic proposed by Box (1949) and Jennrich's statistic proposed by Jennrich (1970). Furthermore, Deblauwe and Le (2000) studied risk credit and portfolio analysis using the same analysis of

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Appendix A

Matlab Programing Code of Performance Z* Statistic

```
clear all
clc
tic
format long
disp ('rho - value T_power ')
for j=0:8

n1=50; n2=n1; n=n1+n2;  %sample size
p=10;                    %variables

rho=j/10;                %Covariance shift
k=1.0;                  %Constant value
I=eye(p,p);
R2=eye(p);
T=Tp(p);
mu=repmat([0],1,p);
               %Number of contaminated
Sigma0=eye(p);
R1 = ones(p)*k*rho;
R1(logical(eye(size(R1)))) = 1;
Sigma=R1;
Re=10000;              %replication
alpha=0.05;             %Significance level
```

```
my_stat1=[ ];
for r1=1:Re

    Z2=mvnrnd(mu,Sigma0,n1);

%     OM=corr(Z2);

    RA2=corr(Z2);
    RA1=(n1*R1+n2*RA2)/n;
    rr1=T'*T*vec(RA1);
    OU=reshape(rr1,p,p);
    rr2=T'*T*vec(R1);
    R2U=reshape(rr2,p,p);
    l=T'*T*vec(RA1);
    L=reshape(l,p,p);
    d=diag(RA1*L);
    D=diag(d);
    dd=diag(L*RA1);
    DD=diag(dd);

sigma3=2*[2*trace(L'*RA1*L*RA1)+2*trace(L'*RA1*L'*RA1)
        -4*trace(L'*RA1*DD*RA1)-4*trace(L*RA1*D*RA1)

+2*trace(D'*RA1*DD*RA1)+trace(D'*RA1*D*RA1)+trace(DD*RA1
*DD*RA1)];
    b=sqrt((1/(n-1))*sigma3);
    Zi1=(sumsqr(R2U)-sumsqr(OU))/b;
    my_stat1=[my_stat1;Zi1];

end
```

```
y1=sort(my_stat1);%To arrange the values in ascending
order

%       CV1=y1(9500)

%To find Type I error rate and power
  C1=0;

 for i=1:Re
     if (y1(i)>   CV1)
         C1=C1+1;
    end

 end
  T_POWE1=C1/Re;
fprintf( '%2.7f % 7.6f\n',rho,T_POWE1 )
 end

 toc
```

Appendix B

Matlab Programing Code of Z* Statistic

```
 tic
close all
clear all
clc

load matlab
%    m=m1;%change m=m1 refer to what we need
k=2;
[r,s]=size(m1);
[t,u]=size(m0);
n1=r;
n2=t;
p=s;
 n=n1+n2;  %sample size
 I=eye(p,p);
 T=Tp(p);
 R1=corr(m1);
 R2=corr(m0);
 RA1=(n1*R1+n2*R2)/n;
 rr1=T'*T*vec(RA1);
 OU=reshape(rr1,p,p);
 rr2=T'*T*vec(R1);
 R2U=reshape(rr2,p,p);
 l=T'*T*vec(RA1);
 L=reshape(l,p,p);
 d=diag(RA1*L);
 D=diag(d);
 dd=diag(L*RA1);
```

```
    DD=diag(dd);

sigma3=2*[2*trace(L'*RA1*L*RA1)+2*trace(L'*RA1*L'*RA1)
        -4*trace(L'*RA1*DD*RA1)-4*trace(L*RA1*D*RA1)
+2*trace(D'*RA1*DD*RA1)+trace(D'*RA1*D*RA1)+trace(DD*RA1
*DD*RA1)];
    b=sqrt((1/(n-1))*sigma3);
    Zi1=(sumsqr(R2U)-sumsqr(OU))/b;
```