Multivariate Tests for Autocorrelation in the Stable and Unstable VAR Models[1]

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Abstract

This study investigates the size and power properties of three multivariate tests for autocorrelation — namely portmanteau test, Lagrange Multiplier (LM) test and Rao F-test — in the stable and unstable vector autoregressive (VAR) models, with and without autoregressive conditional heteroscedasticity (ARCH) using Monte Carlo experiments. Many combinations of parameters are used in the simulations to cover a wide range of situations in order to make the results more representative. The results of conducted simulations show that all three tests perform quite well in stable VAR models without ARCH. In unstable VAR models portmanteau test has serious size distortions. LM and Rao tests perform very well in unstable VAR models without ARCH. These results are true irrespective of sample size or order of autocorrelation. Another clear result that the simulations show is that none of the tests have correct size when ARCH is present irrespective of VAR models being stable or unstable and regardless of the sample size or order of autocorrelation. The portmanteau test seems to have slightly better power properties than the LM test in almost all scenarios.

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1. Introduction

In order to be able to draw valid inference based on the estimated parameters in a regression model it is important that the error terms are white noise, i.e. expected zero mean, no autocorrelations, constant variance, and normal distribution of errors. In applied work it has usually been assumed that these assumptions are fulfilled without explicitly testing for them. Since the pioneering work by Durbin and Watson (1950) diagnostic testing has been increasingly emphasized in the literature.[3] The assumption of no autocorrelation in time series analysis can be invalidated since observations are usually time dependent. In the literature several tests have been developed to test for autocorrelation both singlewise and systemwise. The purpose of this study is to investigate the performance (regarding size and power) of the portmanteau test (Ljung and Box (1978)), Lagrange Multiplier (LM) test (Breusch (1978), Godfrey (19789), and Rao (1973) F-test for autocorrelation in the vector autoregressive (VAR) model in different situations like stability and instability, moderate or small sample sizes, and with and without conditional heteroscedasticity. To the author's best knowledge the properties of these tests in the multivariate case have not been investigated for unstable and heteroscedastic cases. Since these conditions are usually present when time series data are used, more research on this important issue is warranted. The portmanteau and LM tests are the most applied tests for autocorrelation in the VAR models and more information about their properties can be useful for applied research. According to Edgerton and Shukur (1999) Rao test performs well for system of simultaneous equations. For this reason we also investigate the properties of this test in several circumstances that were not investigated by Edgerton and Shukur (1999). A comparison of the results of the current study with that previous study will be made. Monte Carlo simulation techniques for this purpose will be applied using GAUSS. [4]

This study focuses on the size and power of each test in each situation. It is well known in the literature that the data generating process for many time-series may be characterized by stochastic trends that result in unstable VAR models. Thus, it is of paramount importance to investigate the properties of different tests when the VAR model is stable or not. Since the seminal work by Engle (1982) it is also well known that many time series (specially in the field of financial economics, but also many macro-aggregates like inflation rates and exchange rates) possess occasional periods of high volatility that are time dependent. For this reason it is also important to check the performance of tests for autocorrelation in situations of conditional heteroscedasticity in addition to homoscedastic cases.

This paper is structured as follows. Section 2 will present the portmanteau test, Breusch-Godfrey test and Rao test. In Section 3 describes the Monte Carlo simulation

[3] According to Hendry and Mizon (1999) DW test is only powerful with correct size when all independent variables in the regression are weakly exogenous. However, this test has wrong size and low power when a lagged dependent variable is present in the model as in our case. See also Durbin (1970). It should be mentioned that DW test can be applied only for autocorrelation of degree one. Our focus of interest is autocorrelation higher than degree one in this study.

[4] We would like to thank David Edgerton for providing his useful procedures written in GAUSS. We also would like to thank Scott Hacker for his programming support. His excellent skills in programming have made the simulations possible.

procedure. Section 4 presents the estimated results. Conclusions will be provided in the last Section. Tables are presented in the Appendix.

2. The Portmanteau, LaGrange Multiplier and Rao Tests

This section presents three multivariate tests for autocorrelation starting with the portmanteau test, which was introduced by Box and Pierce (1970) and Ljung and Box (1978). Most economic data consist of time series and the error terms in the model are very often dependent on each other for successive time periods. This is known as the problem of autocorrelation and the reason can be omitted variables, misspecification of the dynamic process, etc. The commonly used statistic for testing the presence of autocorrelation is the Durbin-Watson (D-W) statistic. The D-W tests only for autocorrelation of the first order, and it is not valid in dynamic models. Box and Pierce (1970), suggest the *Q*-statistic, which looks at not just the first-order autocorrelation but autocorrelations of all orders. Ljung and Box (1978) extended the *Q* test statistic to adjust for small sample sizes. This test was originally developed to test for autocorrelation in an single equation. This study will, however, considers Ljung-Box test for VAR models in a system perspective. Consider the following *k*-dimensional VAR model of order *L*:

$$y_t = v + A_1 y_{t-1} + \ldots + A_L y_{t-L} + \varepsilon_t \,, \tag{1}$$

where y_t is $k \times 1$ vector of variables, L is the maximum lag in the VAR model[5], v is a $k \times 1$ vector of constants, A_i is a $k \times k$ matrix of parameters corresponding to lag order i (i = 1, …, L), and $\varepsilon_t = \left(\varepsilon_{1t}, ..., \varepsilon_{kt}\right)'$ denotes the vector of error terms that are assumed to be white noise. To test the null hypothesis that ε_t is independent of $\varepsilon_{t-1}, \cdots, \varepsilon_{t-s}$ the Ljung-Box portmanteau test for autocorrelation can be applied. This test statistic in its multivariate form is defined as the following according to Hosking (1980):

$$LB(s) = T\left(T+2\right)\sum_{j=1}^{s} \frac{1}{T-j} tr\left\{C_{0j} C_{00}^{-1} C_{0j}' C_{00}^{-1}\right\} \sim \chi^2_{k(s-L)}\,, \tag{2}$$

where

$$C_{0j} = T^{-1} \sum_{t=j+1}^{T} \varepsilon_t \varepsilon_{t-j}' \,. \tag{3}$$

Under the null hypothesis (of independence) the Ljung-Box test statistic has approximately a χ^2 distribution with $k^2(s\text{-}L)$ degrees of freedom. Here T is the length of the series, and s denotes the order of autocorrelation. It is important to note that the test can be implemented only when the order of autocorrelation is higher than the lag length in the VAR model, i.e. $s > L$.

[5] For a new information criterion to choose the lag order in the stable and unstable VAR models see Hatemi-J (2002).

Another test that is commonly used to test for autocorrelation is the Breusch-Godfrey (See Breusch, 1978, and Godfrey, 1978) LM test statistic. This test can be utilized to test for any autocorrelation order at any significance level. It can also be used to test for autocorrelation in dynamic models. The test is based on the following auxiliary regression:

$$\varepsilon_t = v + A_1 y_{t-1} + \ldots + A_k y_{t-L} + \rho_1 \varepsilon_{t-1} + \ldots + \rho_s \varepsilon_{t-s} + u_t . \tag{4}$$

where u_t is an error term which is assumed to be white noise. The null hypothesis of no multivariate autocorrelation of degree s is $H_0 : \rho_1 = \rho_2 = \cdots = \rho_s = 0$ and the alternative hypothesis is $H_1 : \rho_1 \neq 0, \rho_2 \neq 0, \cdots, or\ \rho_s \neq 0$. There are several test statistics available in the literature that can be used to test the above null hypothesis. According to Edgerton and Shukur (1999) Rao's F-test (Rao, 1973) has the best performance for autocorrelation of order one in system of equations for stationary variables. This test is of the following form:

$$RAO = \left(\frac{\phi}{q}\right)\left(U^{\frac{1}{x}} - 1\right) \sim F(q, \phi) \tag{5}$$

where

$$\phi = \Delta\, x - r\,, \tag{6}$$

$$\Delta = T - (k\,(k+1) - sk) + ½[k(s-1) - 1]\,, \tag{7}$$ [6]

$$r = q/2 - 1\,, \tag{8}$$

and

$$U = \frac{|C_R|}{|C_U|}. \tag{9}$$

It should be pointed out that $q = s \times k^2$ is the number of restrictions that will be tested under H_0. Note that C_R is the estimated variance covariance matrix of the residuals in equation (4) when null hypothesis is imposed and C_U is the estimated variance covariance matrix of the residuals in equation (4) when null hypothesis is not imposed. It should be mentioned that:

$$x = \sqrt{\frac{q^2 - 4}{k^2(s^2+1) - 5}}\,. \tag{10}$$

RAO is approximately distributed as $F(q,\ \phi)$ under the null hypothesis, and is equivalent to a standard F statistic when the number of equations is one, i.e. $k = 1$.

[6] Here we have adjusted for the numbers of parameters following by making use of Edgeworth expansion suggested by Anderson (1958). This adjustment was used by Edgerton and Shukur (1999) also.

However, the multivariate LaGrange Multiplier (LM) test is used extensively in the literature because it is simpler to estimate and several econometric packages have an automatic procedure to estimate the LM test. For this reason we will also examine the properties of the LM test. This test is defined as follows according to Johansen (1996):

$$LM(s) = \Delta \log\left(\frac{|C_R|}{|C_U|}\right) \sim \chi^2_{s\times k} \tag{11}$$

Δ is defined in equation (7). Under the null hypothesis of no serial correlation of order s, the LM statistic is asymptotically distributed as χ^2 with $s\times k^2$ degrees of freedom.

3. Monte Carlo Simulation

The focus of this study is on a bivariate VAR(1) model with autocorrelation of second degree described below:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} 1.0 \\ 1.0 \end{bmatrix} + \begin{bmatrix} \alpha_{1,11} & \alpha_{1,12} \\ \alpha_{1,21} & \alpha_{1,22} \end{bmatrix} \times \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \tag{12}$$

and

$$\begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} = \begin{bmatrix} \rho_{1,11} & \rho_{1,12} \\ \rho_{1,21} & \rho_{1,22} \end{bmatrix} \times \begin{bmatrix} \varepsilon_{1t-1} \\ \varepsilon_{2t-1} \end{bmatrix} + \begin{bmatrix} \rho_{2,11} & \rho_{2,12} \\ \rho_{2,21} & \rho_{2,22} \end{bmatrix} \times \begin{bmatrix} \varepsilon_{1t-2} \\ \varepsilon_{2t-2} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \tag{13}$$

The variance-covariance matrix of the error terms vector (ε_t) is assumed to be normally distributed. Under the null hypothesis of no autocorrelation all of the parameter matrixes in equation (13) are zero matrixes and $\varepsilon_t = u_t$. We run thousands of simulations assuming the null hypothesis is true with different values for the parameters in equation (12) to determine how close the actual size (the simulation-based rejection rate under the null hypothesis) of each test statistic is to its nominal (asymptotically-based) size. We also run thousands of simulations assuming nonzero values for the parameters in equation (13) to check the power. In some simulations we assume constant variance in the errors and in others we assume the following autoregressive conditional heteroscedasticity (ARCH) process describes the variance of the errors:

$$\begin{bmatrix} Var[\varepsilon_{1t} \mid \varepsilon_{1t-1}] \\ Var[\varepsilon_{2t} \mid \varepsilon_{2t-1}] \end{bmatrix} = \begin{bmatrix} 1.0 - b_{11} & 0 \\ 0 & 1.0 - b_{22} \end{bmatrix} \times \begin{bmatrix} Var[\varepsilon_{1t}] \\ Var[\varepsilon_{2t}] \end{bmatrix} + \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix} \times \begin{bmatrix} \varepsilon^2_{1t-1} \\ \varepsilon^2_{2t-1} \end{bmatrix}. \tag{14}$$

This formulation is based on a simple version of Engle's ARCH model following Greene (2001) presented below:

$$\varepsilon_t = w_t \times \left[b_0 + b_1 \varepsilon^2_{t-1}\right]^{\frac{1}{2}} \tag{15}$$

Here w_t is assumed to be standard normal. By using the above equation we can see that the conditional mean of ε_t is zero, i.e.:

$$E[\varepsilon_t \mid \varepsilon_{t-1}] = 0, \tag{16}$$

and the conditional variance is defined as:

$$Var[\varepsilon_t \mid \varepsilon_{t-1}] = E[\varepsilon_t^2 \mid \varepsilon_{t-1}] = E[w_t^2] \times [b_0 + b_1 \varepsilon_{t-1}^2] = b_0 + b_1 \varepsilon_{t-1}^2 \tag{17}$$

thus, conditional on ε_{t-1}, ε_t is heteroscedastic. The unconditional variance of ε_t is equal to the following:

$$Var[\varepsilon_t] = E[Var[\varepsilon_t \mid \varepsilon_{t-1}]] = b_0 + b_1 E[\varepsilon_{t-1}^2] = b_0 + b_1 Var[\varepsilon_{t-1}] \tag{18}$$

Assuming that the data generating process for the error terms is characterized by variance stationarity then the unconditional variance is not changing across time. Hence, we can write the following relationship:

$$Var[\varepsilon_t] = Var[\varepsilon_{t-1}] = b_0 + b_1 Var[\varepsilon_{t-1}] = \frac{b_0}{1 - b_1} \tag{19}$$

This equation makes it possible to express the intercept (b_0) as in form of the following measure:

$$(1 - b_1) \times Var[\varepsilon_t] = b_0 \tag{20}$$

Be combining equations (17) and (20) the following equation is obtained:

$$Var[\varepsilon_t \mid \varepsilon_{t-1}] = [1 - b_1] \times Var[\varepsilon_{t-1}] + b_1 \varepsilon_{t-1}^2 \tag{21}$$

The above relationship is used to generate the two dimensional ARCH model of degree one expressed in equation (14). It should be mentioned that the value for b is chosen to be equal to 0.5 for each variable.

To cancel the effect of starting up values, 100 presample observations were generated. This provides us the possibility to have the same number of observations in estimating the VAR model regardless of the number of lags.

One of the important but rather more difficult tasks in a Monte Carlo simulation like the present one is choosing a variety of parameters that as a group can approximately represent those of the infinite space of possible parameters. Here all the combinations shown in Table 1 for the coefficient matrices are taken into consideration. There are 3528 ($6\times7\times7\times3\times4$) possible combinations of the elements when the size and power properties are investigated.

Table 1.
Parameter values for VAR model of equations (7) and (8)

$\alpha_{1,11}$	-1	-0.6	-0.2		0.2	0.6	1.0
$\alpha_{1,22}$	-0.8	-0.5	0.1	0.0	0.1	0.5	0.8
$\alpha_{1,12} = \alpha_{1,21}$	-0.8	-0.5	0.1	0.0	0.1	0.5	0.8
$\rho_{1,11}=\rho_{1,22}$	0.0	0.2	0.8				
$\rho_{1,21}=\rho_{1,12}$	0.0	0.0	0.0				
$\rho_{2,11} = \rho_{2,22}$	0.0(1-ρ_1)	0.2(1-ρ_1)	0.5(1-ρ_1)	0.8(1-ρ_1)			
$\rho_{2,21}=\rho_{2,12}$	0.0	0.0	0.0				

Clearly some of the combinations of the parameters in the VAR model result in stable VAR models and others result in unstable ones. Whether the VAR model is stable or unstable, has important implications, since standard asymptotic theory can only be applied if the VAR model is stable. To separate stable VAR models from unstable ones, the modulus of the following companion matrix is calculated:

$$A = \begin{bmatrix} \alpha_{1,11} & \alpha_{1,12} \\ \alpha_{1,21} & \alpha_{1,22} \end{bmatrix} \tag{22}$$

If the modulus (the square root of the summed squares of the real and imaginary eigenvalue components) of each eigenvalue of A is less than one, then the VAR model is stable. If any modulus is equal to or higher than one, then the VAR model is unstable. The unstable VAR models are often of interest because the DGP for many economic time series is characterized by unit roots.

In total eight scenarios are investigated. These scenarios consist of stable and unstable VAR models with and without conditional heteroscedasticity for both small sample sizes (T = 40) and moderate sample sizes (T = 100).

Table 2 presents for each of the eight scenarios the number of cases and the distribution of the maximum absolute-value modulus in the scenario. Each row in the table is relevant for two scenarios, a small sample one and a moderate sample one.

Table 2.
Summary descriptions of scenarios regarding size properties.

Scenario[a]	Number of Cases	Percent of cases with maximum absolute-value modulus falling within Range.						
		<0.25	[0.25,0.5)	[0.5,0.75)	[0.75,0.95)	[0.95,1)	1	(1≤)
Stable	136	10.29	2.94	39.71	41.18	5.88	0.00	0.00
Unstable	58	0.00	0.00	0.00	0.00	0.00	24.14	75.86

[a]Each of the situations below is simulated with 40 and 100 observations separately, for a total of 8 scenarios. For each case 10000 iterations are performed. The total number of iterations is 7760000 when size properties are investigated.

In these study two measures are used to check the size properties of the tests. The first measure is to calculate a 95% confidence interval for each case that are estimated by utilizing an approximation of the following equation (see Edgerton and Shukur, 1999):

$$\hat{\eta} \pm 2\sqrt{\frac{\hat{\eta}(1-\hat{\eta})}{\mathbf{N}}} \tag{23}$$

$\hat{\eta}$ signifies the estimated size and N represents the number of iterations. The second measure is average absolute deviations from the true size.

4. The Results of the Monte Carlo Experiments

The simulation results of size properties of tests for autocorrelation in each scenario are presented in Tables A1-A16 in the Appendix. Generally speaking, the LM test has in many cases better size properties than the other tests because the estimated size is closer to the nominal size. It should be pointed out that for lower autocorrelation degrees (especially for autocorrelation of degree one) Rao F-test performs quite well and sometimes even better than the LM test. This confirms the results obtained by Edgerton and Shukur (1999). The multivariate portmanteau test has relatively worse size properties compared to the other two tests. However, it usually performs well for tests of higher order of autocorrelation. A general picture of the Monte Carlo experiments is that the tests perform better regarding the size for stable cases compared to unstable cases. The presence of conditional heteroscedasticity disturbs seriously the size properties for all three tests and these negative effects are even stronger in unstable cases. All the tests have size distortions in unstable cases combined with conditional heteroscedasticity irrespective of the sample size. However, the LM test and the Rao test are less sensitive. In the presence of conditional heteroscedasticity all test methods have empirical (actual) size that is greater than nominal size when the standard chi-square or F distributions are used. This implies that all the three tests overreject the null hypothesis if the ARCH effects are present.

Regarding the power properties of the tests the following can be observed. The LM test and the Rao test have identical power properties so here we concentrate on the power properties of only LM test compared to the portmanteau test. The simulation results for power are presented in Tables A17-A24 in the Appendix. It should be pointed out that the size properties are more important than the power properties. If a test has correct size properties then it is interesting to discover its power properties. If two tests have the same size properties then the one with the higher power should be applied. However, in this study we present the power properties for the portmanteau test also, despite size distortions in many cases.

Generally speaking, the power of the tests increases with respect to the order of autocorrelation. Instability results in increasing the power enormously regardless of the sample size. There seems also to be a positive effect from conditional heteroscedasticity on the power properties of the tests. The power of the tests tends to be positively related to the values of the parameters. Generally speaking, the higher the value of the parameters of autocorrelation the higher is the power. When comparing the power of the LM test with portmanteau test it can be concluded that the portmanteau test has usually higher power than the LM test. However, in most cases the difference between the powers of the two tests is rather low.

5. Conclusions

The purpose of this simulation study is to investigate the size and power of three multiviariatrate tests for autocorrelation in the stable and unstable VAR models — namely Ljung-Box portmanteau test, Breusch-Godfrey LM test and Rao F-test — under circumstances of homoscedasticity and autoregressive conditional heteroscedasticity (ARCH). Simulations are conducted for both small sample sizes (T = 40) and moderate sample sizes (T = 100). In total eight scenarios are dealt with.

Regarding the size properties two measures are used. The first measure is a 95% confidence interval. If the nominal size is within the 95% confidence interval of the empirical size then it is in the acceptance range. The acceptance (or reasonable) rates for all three tests are calculated in each scenario. Since many combinations of the parameters are used in each scenario the results are presented on average. Three different sizes are considered here, i.e. 1% 5% and 10% significance levels. It should be pointed out that the size properties of the tests are investigated when the order of autocorrelation is one to five. Another measure that is used to compare the size performance of the tests is the average absolute deviation of the empirical size from the nominal size. Naturally, the lower the average absolute deviation is the more correct the size. Based on the Monte Carlo experiments one can conclude that all three tests perform quite well in stable VAR models without ARCH. In unstable VAR models portmanteau test has serious size distortions. LM and Rao tests perform very well in unstable VAR models without ARCH. These results are true irrespective of the sample sizes. Another clear result that the simulations show is that none of the tests have correct size when ARCH is present irrespective of VAR models being stable or unstable and regardless of the sample sizes.

The power properties for each test were also investigated. It should be noted that the power properties of Rao test are the same as LM test. Here we present the power properties of the LM test and the portmanteau test for the sake of comparison. The power for each test is calculated using the five percent significance level. The overall results show that the portmanteau test has better power properties than the LM test. However, the difference in power is usually not significantly large.

Since the LM test has better size properties it should be the test that should be used in applied research. However, since this test (as well as the other alternative tests) is sensitive to ARCH effects, it is important to test for ARCH effects before conducting tests for autocorrelation. If the conducted tests show that ARCH effects are present then one possible remedy is to standardize the error terms before tests for autocorrelation are conducted. The estimation of the LM test seems to be easier compared to the Rao test, which makes the LM test the preferred one even though in many cases Rao has as good size properties as LM (and sometimes it is even better, especially for test of lower orders of autocorrelation). The portmanteau test has serious size distortions in unstable VAR models irrespective of having ARCH effects or not. One possible way to improve on the size properties for this test could be making use of the bootstrap simulation techniques.

It should be mentioned that the same qualitative results are obtained when the dimension of the VAR model is increased to the case of three variables. The simulation results of the three dimensional VAR model are not presented here to save space but they are available on request.

Appendix

Tables

Table A1.
The percentage that is in a 95% confidence interval for actual size for each test when T = 40, stable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.765	0.919	0.949	0.978
LM		0.993	1.000	1.000	1.000	1.000
RAO		0.993	1.000	1.000	1.000	0.993
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.301	0.691	0.794	0.809
LM		0.985	1.000	1.000	0.963	0.934
RAO		0.985	1.000	0.985	0.897	0.529
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.037	0.544	0.721	0.824
LM		1.000	1.000	0.993	0.978	0.838
RAO		1.000	1.000	0.978	0.868	0.360

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A2.
The average absolute deviation from the nominal size when T = 40, stable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
LB			0.004	0.003	0.003	0.002
LM		0.001	0.001	0.001	0.001	0.002
RAO		0.001	0.001	0.001	0.002	0.003
		The average absolute deviation from the nominal 5% size for each test when.				
LB			0.027	0.009	0.007	0.007
LM		0.003	0.002	0.004	0.005	0.006
RAO		0.003	0.002	0.004	0.007	0.010
		The average absolute deviation from the nominal 10% size for each test.				
LB			0.059	0.021	0.012	0.010
LM		0.004	0.004	0.006	0.007	0.011
RAO		0.004	0.004	0.007	0.010	0.016

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A3.
The percentage that is in a 95% confidence interval for actual size for each test when T = 100, stable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.662	0.882	0.963	0.971
LM		1.000	1.000	1.000	1.000	1.000
RAO		1.000	1.000	1.000	1.000	1.000
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.426	0.647	0.831	0.8897
LM		1.000	1.000	1.000	1.000	1.000
RAO		1.000	1.000	1.000	1.000	1.000
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.243	0.551	0.801	0.846
LM		1.000	1.000	1.000	1.000	1.000
RAO		1.000	1.000	1.000	1.000	1.000

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A4.
The average absolute deviation from the nominal size when T = 100, stable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
BL			0.005	0.002	0.002	0.002
LM		0.001	0.001	0.001	0.001	0.001
RAO		0.001	0.001	0.001	0.001	0.001
		The average absolute deviation from the nominal 5% size for each test.				
BL			0.026	0.010	0.006	0.005
LM		0.002	0.002	0.002	0.003	0.004
RAO		0.002	0.002	0.002	0.003	0.004
		The average absolute deviation from the nominal 10% size for each test.				
BL			0.049	0.019	0.011	0.009
LM		0.003	0.003	0.004	0.005	0.007
RAO		0.003	0.003	0.004	0.005	0.007

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A5.
The percentage that is in a 95% confidence interval for actual size for each test when T = 40, stable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.147	0.522	0.625	0.699
LM		0.000	0.000	0.007	0.066	0.213
RAO		0.000	0.000	0.015	0.103	0.581
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.000	0.103	0.287	0.500
LM		0.000	0.000	0.000	0.022	0.324
RAO		0.000	0.000	0.000	0.103	0.743
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.000	0.000	0.154	0.449
LM		0.000	0.000	0.007	0.096	0.588
RAO		0.000	0.000	0.007	0.316	0.831

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A6.
The average absolute deviation from the nominal size when T = 40, stable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
LB			0.0016	0.008	0.005	0.004
LM		0.018	0.014	0.010	0.008	0.006
RAO		0.018	0.013	0.010	0.007	0.005
		The average absolute deviation from the nominal 5% size for each test.				
LB			0.067	0.034	0.021	0.014
LM		0.045	0.034	0.024	0.018	0.012
RAO		0.045	0.033	0.023	0.016	0.008
		The average absolute deviation from the nominal 10% size for each test.				
LB			0.049	0.062	0.037	0.025
LM		0.063	0.046	0.033	0.024	0.015
RAO		0.063	0.046	0.031	0.020	0.008

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A7.
The percentage that is in a 95% confidence interval for actual size for each test when T = 100, stable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A8.
The average absolute deviation from the nominal size when T = 100, stable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
BL			0.040	0.028	0.022	0.018
LM		0.035	0.031	0.026	0.022	0.018
RAO		0.035	0.031	0.026	0.022	0.018
		The average absolute deviation from the nominal 5% size for each test.				
BL			0.106	0.073	0.056	0.044
LM		0.076	0.067	0.056	0.047	0.039
RAO		0.076	0.067	0.056	0.047	0.038
		The average absolute deviation from the nominal 10% size for each test.				
BL			0.153	0106	0.081	0.063
LM		0.101	0.089	0.075	0.062	0.051
RAO		0.101	0.089	0.075	0.062	0.050

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A9.
The percentage that is in a 95% confidence interval for actual size for each test when T = 40, unstable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		1.000	1.000	1.000	1.000	1.000
RAO		1.000	1.000	1.000	1.000	1.000
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		1.000	0.983	0.966	0.966	0.966
RAO		1.000	0.983	0.966	1.000	0.810
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		1.000	0.931	0.983	0.966	0.914
RAO		1.000	0.966	0.983	0.966	0.724

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A10.
The average absolute deviation from the nominal size when T = 40, unstable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
LB			0.034	0.019	0.015	0.014
LM		0.001	0.001	0.001	0.001	0.001
RAO		0.001	0.001	0.001	0.001	0.002
		The average absolute deviation from the nominal 5% size for each test.				
LB			0.0137	0.008	0.063	0.052
LM		0.002	0.003	0.004	0.004	0.005
RAO		0.002	0.003	0.004	0.004	0.006
		The average absolute deviation from the nominal 10% size for each test.				
LB			0.222	0.138	0.0108	0.090
LM		0.004	0.006	0.007	0.007	0.008
RAO		0.004	0.005	0.007	0.006	0.010

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A11.
The percentage that is in a 95% confidence interval for actual size for each test when T = 100, unstable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		1.000	1.000	1.000	1.000	1.000
RAO		1.000	1.000	1.000	1.000	1.000
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		1.000	1.000	1.000	1.000	1.000
RAO		1.000	1.000	1.000	1.000	1.000
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		1.000	1.000	1.000	1.000	1.000
RAO		1.000	1.000	1.000	1.000	1.000

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A12.
The average absolute deviation from the nominal size when T = 100, instable VAR models without ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
LB			0.035	0.020	0.0016	0.0013
LM		0.001	0.001	0.001	0.001	0.001
RAO		0.001	0.001	0.001	0.001	0.001
		The average absolute deviation from the nominal 5% size for each test.				
LB			0.125	0.075	0.057	0.047
LM		0.002	0.002	0.002	0.002	0.003
RAO		0.002	0.002	0.002	0.002	0.003
		The average absolute deviation from the nominal 10% size for each test.				
LB			0.198	0.124	0.096	0.079
LM		0.003	0.003	0.003	0.003	0.004
RAO		0.003	0.003	0.003	0.003	0.005

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A13.
The percentage that is in a 95% confidence interval for actual size for each test when T = 40, unstable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A14.
The average absolute deviation from the nominal size when T = 40, unstable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
LB			0.008	0.049	0.038	0.032
LM		0.025	0.022	0.015	0.012	0.009
RAO		0.025	0.021	0.014	0.011	0.007
		The average absolute deviation from the nominal 5% size for each test.				
LB			0.224	0.143	0.110	0.090
LM		0.061	0.055	0.038	0.032	0.023
RAO		0.061	0.054	0.036	0.029	0.018
		The average absolute deviation from the nominal 10% size for each test.				
LB			0.320	0.215	0.167	0.136
LM		0.083	0.077	0.054	0.067	0.033
RAO		0.083	0.076	0.052	0.043	0.026

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao's multivariate F-test. The shadowed areas indicate best relative performance.

Table A15.
The percentage that is in a 95% confidence interval for actual size for each test when T = 100, unstable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The percentage that is in a 95% confidence interval for actual 1% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000
		The percentage that is in a 95% confidence interval for actual 5% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000
		The percentage that is in a 95% confidence interval for actual 10% size for each test.				
LB			0.000	0.000	0.000	0.000
LM		0.000	0.000	0.000	0.000	0.000
RAO		0.000	0.000	0.000	0.000	0.000

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A16.
The average absolute deviation from the nominal size when T = 100, unstable VAR models with ARCH.

Test ↓	Autocorrelation order →	1	2	3	4	5
		The average absolute deviation from the nominal 1% size for each test.				
LB			0.132	0.091	0.072	0.060
LM		0.053	0.049	0.040	0.033	0.027
RAO		0.053	0.049	0.039	0.033	0.026
		The average absolute deviation from the nominal 5% size for each test.				
LB			0.280	0.201	0.161	0.135
LM		0.106	0.102	0.085	0.073	0.060
RAO		0.106	0.102	0.084	0.072	0.059
		The average absolute deviation from the nominal 10% size for each test.				
LB			0.365	0.270	0.220	0.185
LM		0.136	0.133	0.112	0.097	0.080
RAO		0.136	0.133	0.112	0.096	0.079

LB signifies Ljung-Box portmanteau test, LM stands for Breusch-Godfrey test and RAO represents Rao’s multivariate F-test. The shadowed areas indicate best relative performance.

Table A17.
The power for each test at 5% significance level and for different values of autocorrelation parameters when T = 40, stable VAR and without ARCH.

		ρf2=0.0		ρf2=0.2		ρf2=0.5		ρf2=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ_1=0.0	1		0.050		0.72		0.419		0.857
	2	0.050	0.049	0.126	0.080	0.758	0.576	0.994	0.976
	3	0.050	0.050	0.092	0.076	0.643	0.498	0.986	0.961
	4	0.050	0.050	0.086	0.071	0.582	0.433	0.978	0.941
	5	0.050	0.050	0.086	0.070	0.550	0.382	0.970	0.919
ρ_1=0.2	1		0.086		0.108		0.328		0.697
	2	0.071	0.073	0.143	0.101	0.585	0.410	0.947	0.860
	3	0.071	0.068	0.107	0.090	0.461	0.348	0.900	0.808
	4	0.070	0.046	0.100	0.084	0.411	0.301	0.862	0.755
	5	0.069	0.063	0.098	0.079	0.382	0.266	0.834	0.706
ρ_1=0.8	1		0.641		0.650		0.668		0.686
	2	0.689	0.609	0.713	0.624	0.748	0.648	0.783	0.675
	3	0.599	0.558	0.626	0.575	0.668	0.604	0.708	0.632
	4	0.557	0.511	0.582	0.529	0.624	0.561	0.665	0.591
	5	0.531	0.473	0.554	0.493	0.593	0.527	0.635	0.557

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

Table A18.
The power for each test at 5% significance level and for different values of autocorrelation parameters when T = 100, stable VAR and without ARCH. .

		ρf_2=0.0		ρf_2=0.2		ρf_2=0.5		ρf_2=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ$_1$=0.0	1		0.050		0.206		0.879		0.990
	2	0.050	0.050	0.411	0.287	0.999	0.995	1.00	1.00
	3	0.050	0.051	0.307	0.237	0.997	0.990	1.00	1.00
	4	0.050	0.051	0.259	0.208	0.993	0.984	1.00	1.00
	5	0.050	0.050	0.234	0.185	0.989	0.975	1.00	1.00
ρ$_1$=0.2	1		0.192		0.339		0.835		0.970
	2	0.148	0.147	0.453	0.354	0.984	0.955	1.00	1.00
	3	0.130	0.126	0.355	0.298	0.963	0.930	1.00	1.00
	4	0.121	0.114	0.312	0.262	0.941	0.904	1.00	1.00
	5	0.116	0.104	0.287	0.232	0.921	0.877	1.00	0.999
ρ$_1$=0.8	1		0.879		0.887		0.904		0.924
	2	0.899	0.872	0.909	0.880	0.929	0.896	0.952	0.915
	3	0.873	0.856	0.886	0.866	0.909	0.884	0.934	0.902
	4	0.857	0.842	0.870	0.853	0.894	0.873	0.920	0.892
	5	0.844	0.829	0.857	0.841	0.883	0.862	0.910	0.883

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

Table A19.
The power for each test at 5% significance level and for different values of autocorrelation parameters when *T* = 40, stable VAR and with ARCH.

		ρf$_2$=0.0		ρf$_2$=0.2		ρf$_2$=0.5		ρf$_2$=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ$_1$=0.0	1		0.050		0.060		0.288		0.709
	2	0.049	0.051	0.101	0.064	0.609	0.401	0.970	0.908
	3	0.050	0.050	0.077	0.064	0.501	0.354	0.947	0.879
	4	0.049	0.050	0.073	0.062	0.543	0.314	0.928	0.847
	5	0.050	0.050	0.088	0.063	0.429	0.285	0.911	0.815
ρ$_1$=0.2	1		0.075		0.082		0.208		0.514
	2	0.067	0.068	0.073	0.079	0.428	0.263	0.857	0.699
	3	0.067	0.065	0.111	0.075	0.331	0.234	0.784	0.646
	4	0.067	0.062	0.086	0.072	0.297	0.211	0.740	0.598
	5	0.066	0.061	0.082	0.070	0.280	0.192	0.708	0.556
ρ$_1$=0.8	1		0.485		0.485		0.492		0.509
	2	0.506	0.442	0.524	0.446	0.558	0.465	0.597	0.493
	3	0.431	0.403	0.446	0.410	0.477	0.431	0.520	0.463
	4	0.398	0.367	0.412	0.377	0.441	0.401	0.484	0.435
	5	0.381	0.340	0.393	0.353	0.417	0.377	0.454	0.413

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

Table A20.
The power for each test at 5% significance level and for different values of autocorrelation parameters when T = 100, stable VAR and with ARCH.

		ρf_2=0.0		ρf_2=0.2		ρf_2=0.5		ρf_2=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ_1=0.0	1		0.050		0.206		0.879		0.990
	2	0.050	0.050	0.411	0.287	0.999	0.995	1.000	1.000
	3	0.051	0.051	0.307	0.237	0.997	0.990	1.000	1.000
	4	0.051	0.051	0.259	0.208	0.993	0.984	1.000	1.000
	5	0.051	0.050	0.234	0.185	0.989	0.975	1.000	1.000
ρ_1=0.2	1		0.192		0.339		0.835		0.970
	2	0.148	0.147	0.453	0.354	0.984	0.955	1.000	1.000
	3	0.130	0.126	0.355	0.298	0.963	0.930	1.000	1.000
	4	0.121	0.114	0.312	0.262	0.941	0.904	1.000	1.000
	5	0.166	0.104	0.287	0.232	0.921	0.877	1.000	0.999
ρ_1=0.8	1		0.879		0.887		0.904		0.509
	2	0.899	0.872	0.909	0.880	0.929	0.896	0.952	0.915
	3	0.837	0.856	0.886	0.866	0.909	0.884	0.934	0.902
	4	0.857	0.842	0.870	0.853	0.894	0.873	0.920	0.892
	5	0.844	0.829	0.857	0.841	0.883	0.862	0.910	0.883

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

Table A21.
The power for each test at 5% significance level and for different values of autocorrelation parameters when T = 40, unstable VAR and without ARCH.

		ρf_2=0.0		ρf_2=0.2		ρf_2=0.5		ρf_2=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ_1=0.0	1		0.050		0.082		0.339		0.761
	2	0.050	0.050	0.119	0.077	0.713	0.576	0.991	0.980
	3	0.050	0.050	0.105	0.073	0.634	0.498	0.983	0.965
	4	0.051	0.050	0.098	0.069	0.590	0.426	0.976	0.945
	5	0.050	0.050	0.098	0.068	0.566	0.381	0.969	0.923
ρ_1=0.2	1		0.108		0.149		0.341		0.628
	2	0.091	0.087	0.168	0.114	0.568	0.430	0.928	0.871
	3	0.089	0.078	0.142	0.103	0.490	0.370	0.885	0.820
	4	0.089	0.073	0.134	0.092	0.448	0.316	0.8856	0.764
	5	0.088	0.070	0.131	0.086	0.428	0.282	0.835	0.717
ρ_1=0.8	1		0.958		0.960		0.962		0.962
	2	0.942	0.924	0.948	0.928	0.958	0.937	0.963	0.939
	3	0.906	0.889	0.916	0.898	0.933	0.911	0.940	0.916
	4	0.880	0.849	0.894	0.863	0.914	0.880	0.923	0.889
	5	0.863	0.816	0.879	0.831	0.901	0.855	0.910	0.868

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

Table A22.
The power for each test at 5% significance level and for different values of autocorrelation parameters when T = 100, unstable VAR and without ARCH.

		ρf_2=0.0		ρf_2=0.2		ρf_2=0.5		ρf_2=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ_1=0.0	1		0.050		0.147		0.689		0.938
	2	0.049	0.049	0.379	0.292	0.999	0.998	1.000	1.000
	3	0.051	0.050	0.306	0.241	0.997	0.995	1.000	1.000
	4	0.050	0.050	0.268	0.208	0.994	0.990	1.000	1.000
	5	0.050	0.051	0.248	0.187	0.991	0.948	1.000	1.000
ρ_1=0.2	1		0.321		0.485		0.834		0.958
	2	0.362	0.239	0.588	0.486	0.991	0.983	1.000	1.000
	3	0.254	0.197	0.508	0.413	0.982	0.969	1.000	1.000
	4	0.216	0.173	0.460	0.361	0.972	0.952	1.000	1.000
	5	0.197	0.155	0.430	0.324	0.961	0.936	1.000	1.000
ρ_1=0.8	1		1.000		1.000		1.000		1.000
	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

Table A23.
The power for each test at 5% significance level and for different values of autocorrelation parameters when T = 40, unstable VAR and with ARCH.

		ρf_2=0.0		ρf_2=0.2		ρf_2=0.5		ρf_2=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ_1=0.0	1		0.051		0.076		0.243		0.590
	2	0.049	0.050	0.106	0.066	0.540	0.388	0.953	0.910
	3	0.050	0.050	0.097	0.067	0.490	0.353	0.929	0.885
	4	0.049	0.049	0.090	0.065	0.458	0.315	0.918	0.853
	5	0.050	0.048	0.088	0.063	0.447	0.288	0.905	0.824
ρ_1=0.2	1		0.089		0.110		0.217		0.416
	2	0.080	0.079	0.130	0.089	0.395	0.267	0.799	0.688
	3	0.080	0.075	0.115	0.086	0.349	0.245	0.745	0.642
	4	0.079	0.071	0.109	0.082	0.324	0.222	0.714	0.593
	5	0.079	0.068	0.109	0.079	0.315	0.206	0.695	0.552
ρ_1=0.8	1		0.641		0.770		0.773		0.764
	2	0.737	0.700	0.748	0.697	0.769	0.703	0.778	0.704
	3	0.678	0.649	0.687	0.648	0.711	0.659	0.728	0.665
	4	0.644	0.601	0.654	0.600	0.675	0.615	0.691	0.624
	5	0.625	0.560	0.636	0.563	0.653	0.578	0.666	0.593

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

Table A24.
The power for each test at 5% significance level and for different values of autocorrelation parameters when T = 100, unstable VAR and with ARCH.

		ρf2=0.0		ρf2=0.2		ρf2=0.5		ρf2=0.8	
	AC↓	LB	LM	LB	LM	LB	LM	LB	LM
ρ_1=0.0	1		0.050		0.114		0.552		0.860
	2	0.050	0.049	0.242	0.175	0.981	0.965	1.000	1.000
	3	0.050	0.049	0.212	0.160	0.968	0.951	1.000	1.000
	4	0.049	0.048	0.197	0.150	0.959	0.936	1.000	1.000
	5	0.048	0.048	0.190	0.142	0.950	0.921	1.000	1.000
ρ_1=0.2	1		0.193		0.284		0.596		0.823
	2	0.167	0.163	0.366	0.286	0.919	0.874	0.999	0.999
	3	0.156	0.149	0.327	0.261	0.889	0.844	0.999	0.998
	4	0.146	0.139	0.306	0.243	0.868	0.814	0.999	0.998
	5	0.149	0.132	0.296	0.229	0.852	0.789	0.998	0.997
ρ_1=0.8	1		0.991		0.992		0.992		0.989
	2	0.990	0.987	0.991	0.988	0.993	0.990	0.993	0.989
	3	0.986	0.983	0.987	0.985	0.990	0.987	0.991	0.987
	4	0.982	0.979	0.984	0.980	0.988	0.983	0.989	0.984
	5	0.978	0.974	0.981	0.976	0.985	0.979	0.987	0.981

AC represents the order of autocorrelation. ρ_1= the parameter value for autocorrelation of degree one in each equation in the true model. ρf_2 is the fraction that is multiplied by (1-ρ_1) to specify the parameter value for autocorrelation of degree two in each equation in the true model. LB stands for Ljung-Box portmanteau test and LM stands for Breusch-Godfrey test. The shadowed areas indicate best relative performance.

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