Year: 2011

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DOI: https://doi.org/10.1108/17539261111129470

Originally published at:
Constantinescu, Mihnea (2011). How important is that footnote on page 3? Understanding the effect of autocorrelation on the calculation of expected shortfall. Journal of European Real Estate Research, 4(1):online.
DOI: https://doi.org/10.1108/17539261111129470

The cost of autocorrelation in real estate returns
- Working paper -

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April 23, 2010

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†I wish to thank the Schweizerischer Versicherungsverband for the generous support offered in conducting my research, my Phd supervisor, Prof. Thorsten Hens for the continuous guidance and HansJoerg Germann and Andreas Loepfe for useful insights.

Abstract

This paper presents the impact that autocorrelation has on the computation of risk measures (VaR or ES) in an ALM framework when the risk-management framework used to compute the risk-based capital is similar to the RiskMetrics methodology. A potential solution is offered to account for the empirically observed autocorrelation. This solution departs from the existing literature on autocorrelation in returns (particulary from the unsmoothing procedures used for real estate time series). In dealing with the autocorrelation we do not make any assumptions on the causes of the smoothing thus no "filtering" method is used. Given a smoothed time-series of returns we try to focus on the proper estimator of the correlation coefficient used in the computation of the risk-measure. The concrete analysis is done for real estate return data though the methodology applies equally well to other asset classes that have smoothed returns (hedge funds for example.)

1 Introduction

When referring to risk management frameworks or systems we are thinking of integrated solutions which aim at evaluating the risk of a given portfolio composed of various types of assets. Think about the portfolio as being composed of investments in equity, bonds, real estate and commodities. These types of assets may represent particular types of risks which need to be assessed in a joint manner. Accounting for the individual and the joint uncertainty of the constituent parts of the portfolio one gets a better idea of the potential sources of risk and value for the entire holding. Thus the philosophy of a risk management framework is to try to understand the individual sources of risk and the way they interact among each other (usually using a correlation matrix of returns of the constituents of the portfolio) and then to derive a measure (Value-at-risk or Expected Short-fall) describing the risk for the entire portfolio. Frequently used measures are for example Value at Risk (VaR) or Expected Shortfall (ES). Risk management frameworks address the problem of risk for investments, answering questions like "How much can my portfolio lose in the upcoming one week?" but they address also the problem of risk in an asset-liability framework answering questions like "Given the liabilities I have to pay and the income I get from my investments in the following week, will the liabilities exceed my income?". The second question is a bit more difficult to answer as in this case one needs to model two different families of stochastic process, one for liabilities (such payments of pensions, insurance or bank deposits) and one for assets (income from equity, bonds and so on). The present study looks at the way real estate is modeled in an asset-liability risk management framework. The focus is on Swiss institutional investors like insurance companies or pension plans which invest in direct real estate (physical ownership of buildings) and which face a capital requirement from a regulatory institution. In Switzerland, the insurance regulator is the FINMA. This institution makes sure that the policyholders will receive their amounts due regardless of the financial stability of the insurance company that has to pay them. This goal is achieved with a set of measures going from recommendations on which assets may be purchased to minimum capital that needs to be available at any point in time. The risk management framework employed in evaluating the risks faced by insurance companies is a collection of models and methodologies assembled together as a test of financial healthiness called the Swiss Solvency Test (SST). The backbone of the SST is the RiskMetrics methodology. This methodology was the first widely-used risk management system which, allowing for a time-varying volatility, had an integrated view on the risk evaluation for a given portfolio. Given its importance and its use in the SST, the next section looks at the main characteristics of this framework.

2 The RiskMetrics methodology

The first ingredients needed in the evaluation of risk are the risk factors (Mina, Xiao). These are the primary entities which drive the value of the portfolio constituents. Some examples of risk factors are prices of equity, spot and forward exchange rates, spot and future commodity prices, interest rates and so on. Thus if a portfolio contains both equities and options on equities then the risk factor "price of equity" will drive both the value and risk of the equity investment and of the option investment.

The RiskMetrics methodology employs the above-mentioned risk factors in various way. Of these, three are the focus of this paper, namely the multivariate normal model for returns, the historical simulation and the scenario-analysis.

The *multivariate normal model* is a direct application of the Efficient Market Hypothesis. If we ascertain that markets are efficient then asset prices incorporate all relevant information up to the present and so any change in price is caused by surprises. These surprises (denote by $\{\epsilon\}_t$ the surprise at time t) are randomly distributed according to a normal distribution with

$\{\epsilon\}_t \sim N(0, \sigma^2)$ where the variance can be time-dependent. This in turn implies that asset returns will follow a Geometric Brownian Motion (GBM from now on) [cite Fin Eco book]. Thus if P_t^i is the price of asset i at time t then

$$\frac{dP_t^i}{P_t^i} = \mu^i dt + \sigma^i dW_t \tag{1}$$

For horizons shorter than 3 months it makes sense to set $\mu = 0$ (Mina,Xiao). In this way one only needs an estimate for the volatility. This estimate is computed using an exponentially weighted moving average (EWMA) of squared returns. This allows for a time-dependent volatility. Given a sample of $m+1$ past returns from $t-m$ to m, the volatility estimate at time t is given as:

$$\sigma = \frac{1-\lambda}{1-\lambda^{m+1}} \sum_{i=0}^{m} \lambda^i r_{t-i}^2 \tag{2}$$

Each time a new data point is available, the formula adds the newest and drops the oldest allowing so for the volatility estimate to be updated. The parameter λ is called the decay factor with $\lambda \in (0, 1]$. Formula (2) can be rewritten as

$$\sigma_t^2 = \lambda \sigma_{t-1}^2 + (1-\lambda) r_t^2 \tag{3}$$

In this form one can see why λ is called the decay factor. If n assets are present in the portfolio then equation (1) is valid for all asset (as $i = 1, \ldots, n$). The link between the n assets is specified through the correlation of each asset's surprise. Thus $corr(\epsilon_t^i, \epsilon_t^j)$ will be all the information needed to model the dependence between the return of asset i and j. The information on how all the risk factors move together is captured in a correlation matrix Σ computed using the EWMA estimate of volatility.

$$\Sigma_{i,j} = \sigma_i \sigma_j \rho_{i,j} = \frac{1-\lambda}{1-\lambda^{m+1}} \sum_{k=0}^{m} \lambda^k r_{t-k}^{(i)} r_{t-k}^{(j)} \tag{4}$$

The presence of the EWMA ensures that the computations are conditional of the state of the market. The working assumptions underlying the GBM is that all ϵ's are independent over time and are normally distributed. The normal distribution assumptions fails fairly easy as most risk factors exhibit fat tails. This feature is accounted for through the use of scenario analysis and simulations. One needs to make sure that the assumption of no autocorrelation is also satisfied. This assumption doesn't come so often under scrutiny as its failure implies that arbitrage opportunities exist due to forecastable returns (cite Fin Eco book). Direct real estate markets on the other hand do not share the same degree of efficiency and liquidity as stock and bond markets(cite paper by Geltner). In the following sections we will try to show that the risk factor describing the Swiss direct real estate market is autocorrelated in a form which requires the standard GBM assumption to be modified.

The *historical simulation* selects a sample of past returns for risk factor j for example and computes the future distribution of prices using the samples valued of past returns. The *scenario analysis* answers hypothetical "What if..." questions, such as "What happens to my portfolio if there is an equity crash as the one from '87".

2.1 The SST methodology

The White Paper and the Technical Document describe in detail the goal and the implementation of the SST. Its principles are briefly cited here: "The goal of the Swiss Solvency Test (SST) is to obtain a picture of 1) the amount of risks borne by an insurance undertaking, and 2) its financial capacity to bear these risks. The amount of the risk assumed is measured with the target capital (TC), and the capacity to bear risks is measured with the risk-bearing capital (RBC)." The risk- bearing capital is defined as the difference between the market-consistent value of assets and the discounted best estimate of the liabilities. The expected shortfall of the RBC is the measure of the overall risk for a given institutional investor. To compute the RBC one needs a model for the assets and one for the liabilities. For the assets the SST uses the RiskMetrics methodology . Thus given a model for the changes of the risk factors (the GBM) the variance of the risk-bearing capital is computed as

$$\sigma_{RBC} = (s_1\sigma_1 \dots s_{81}\sigma_{81}) \begin{pmatrix} 1 & \rho_{1,2} & \dots & \rho_{1,81} \\ \rho_{2,1} & 1 & \dots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \rho_{81,1} & \dots & \dots & 1 \end{pmatrix} \begin{pmatrix} s_1\sigma_1 \\ s_2\sigma_2 \\ \vdots \\ s_{81}\sigma_{81} \end{pmatrix} \quad (5)$$

where σ_i is the standard deviation of the risk factor i, s_i is the sensitivity of the RBC to the risk factor i and $\rho_{i,j}$ is the correlation between risk factor i and j. Given a time-series of length T, the estimator of the variance of the risk factor i is computed as:

$$\widehat{\sigma_i^2} = \frac{1}{T-1}\sum_{t=1}^{T}(r_{it} - \overline{r_i})^2 \quad (6)$$

with $\overline{r_i}$ the sample mean. The correlation between i and j $\rho_{i,j}$ is estimated using the standard sample estimator:

$$\widehat{\rho_{i,j}} = \frac{1}{T-1}\frac{\sum_{t=1}^{T}(r_{it} - \overline{r_i})(r_{jt} - \overline{r_j})}{\widehat{\sigma_i}\widehat{\sigma_j}} \quad (7)$$

At the moment the market model consists of 81 risk factors with direct real estate investment risk proxied by the SWX IAZI Investment Real Estate Performance Index. Two more indices are used for real estate funds and real estate investment companies (Rued Blass Immobilienfonds-Index and the Wuest & Partner WUPIX A respectively). The variance of the RBC in (5) is computed using time series spanning over the past 10 years of monthly continuously-compounded returns. Since 1986 the IAZI index is available on a quarterly basis [how exactly is the matrix computed Quarterly or monthly - official answer still awaited?].

3 Are amendments needed for the standard SST model

The foundation of the RiskMetrics and implicitly of the SST is the Efficient Market Hypothesis (EMH). This mainstream of financial economics views markets as being composed of perfect-foresight rational agents capable of perfectly interpreting all relevant information available to them at the time a trade takes place. The finance and financial economic literature has devoted large spaces to bringing proof in favor of the EMH [cite Fama French]. Once this proof is considered sufficient then one should blindly trust the market for performing its functions in the best interest of all those trading. For equities [quote Shefrin, Hens,etc.] the behavioral finance literature brought to light some interesting features of the market like momentum, the disposition effect, the weekend effect, under- and over-reaction just to name a few. All these market characteristics give evidence that the EMH should not be accepted prima facie even for markets that a have a long history and tradition and which incorporate plenty of product innovation and research.

The structure and functioning of the real estate market can barely be compared to those of equity markets. High informational asymmetries, low degree of liquidity and market localization are a few of the market's characteristics. All these features have to do with the very nature of the real estate asset: each property is unique, not fungible, not transportable, large in value and volume and indivisible. On top of this, the real estate asset is not priced only according to its intrinsic value-creating properties (stream of housing services or rents) but also according to very consumer-specific criteria. Location and quality of the surroundings can make a large portion of the asset's value regardless of the quality of the housing services. This together with high transaction costs (averaging 5% of the asset value) and capital gain taxes makes arbitrage a relatively difficult task. The high capital gain taxes can also be seen a cause of the low liquidity. Considering the previous arguments one sees that efficiency cannot be taken for granted.

The appraisal process is of paramount importance for the real estate market because appraisers supplement the price-discovery function of real estate markets when these do not fulfill their duty. Their judgements are used in determining the values of mortgages that can be granted to a potential house buyer or the value of large portfolios that transact infrequently. Diaz and Wolverton [cite papers] have shown that a large spectrum of biases is present in the appraisal process. Either through the use of lab experiments or field studies these authors indicate how the value estimation process is corrupted by anchoring and adjusting, the recency bias, or by the upward adjusting bias just to mention a few. As appraisers are present in many transactions giving always a price estimate one sees the effect of this biases when aggregating at the market level [cite Geltner - errors from individual appraisers do not "cancel out" on average]. Several studies have shown how these biases at the individual level impact the development of appraisal-based indices [cite Geltner] like the NCREIF index in the U.S.A. or the IPD index in the U.K. The main empirical observation is a certain lagging of the appraisal indexes behind market-based indexes and a lower volatility of appraisal based indexes when compared to transaction based indexes constructed from similar samples. This translates in the appearance of autocorrelation in the returns of appraisal based indexes. Several techniques have been developed that deal with the issue of autocorrelation in returns. The principal idea behind the technique of unsmooth appraisal based index returns is that as appraisers introduce the smoothing due to the biases one can try to eliminate the bias and render the appraisal based return "bias-free". The assumption is that by de-biasing the index one is able to see the actual market development. Blundel-Ward develops an unsmoothing filter based on the previous idea. Following this Geltner develops the idea further and creates also another filter which inflates the volatility of the index up to an expected market volatility [cite Blundell-Ward]. These filters consider the amount of smoothing (or autocorrelation) existing in an index and recalculates the index so as to eliminate the smoothing, rendering the index closer to its efficient-market version. The underlying assumption used in the de-smoothing process is that the research knows the nature and structure of the bias and is able to back out from the appraised value only the current market value and leave out the past information. The Blundell-Ward use the specification given in equation 8 for the smoothing process.

$$A_t = \alpha \overline{P}_t + \underbrace{(1-\alpha)}_{smoothing} A_{t-1} \tag{8}$$

where A_t is the appraised value at time t, $\overline{P}_t$ is the expected market transaction price at time t and α is a smoothing parameter that is obtained by regressing, most of the time, the appraisal based returns on their first lag. The philosophy of this approach is that the autocorrelation in returns can translate in arbitrage opportunities which should not exist in a properly functioning market. Thus the un-smoothed returns series should give the actual state and dynamic of the market.
The alternative to using appraisal-based indices is to use transaction-based indexes as these should not be affected by the above mentioned appraisal biases. Nevertheless, simply using a transaction-based index will not put us in pole-position when trying to properly measure value and changes in value in real estate. Liquidity still remains an important issue which needs to be dealt with [cite Fisher]. To a relatively large extent the liquidity problem is tackled in the SST through the use of historical simulation (the simulation is made using returns from illiquid markets) and scenario analysis.

For the SST only transaction-based indices are used meaning that un-smoothing techniques are not necessary. The index measuring the direct real estate market is the SWX IAZI Investment Real Estate Performance Index [1]. The levels of the index and the quarterly continuously-compounded returns are depicted in Figure 1. The IAZI index is one of the 81 risk factors used in the correlation matrix needed to compute the RBC. This is equivalent to

[1] Index available at http://www.iazi.ch/web/Indizes/SWX/SWXIAZIInvestmentRealEstatePerformanceIndex/tabid/173/Default.aspx

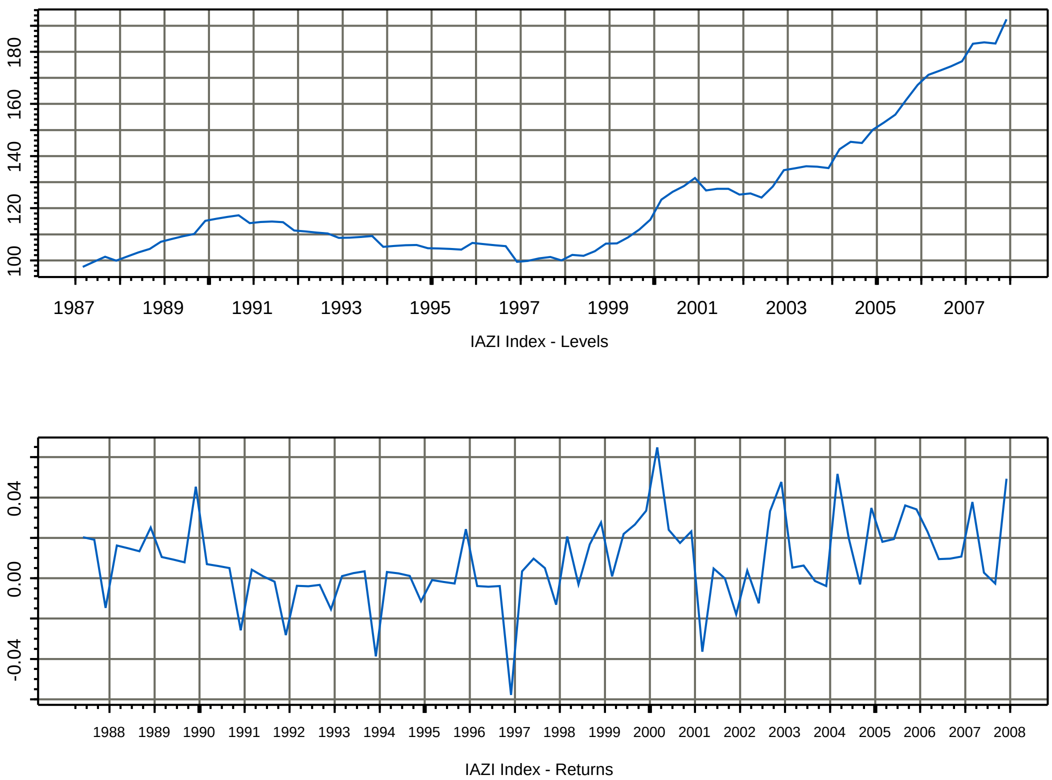


Figure 1: The IAZI Performance Index

saying that the GBM model is a good description of the market dynamics, so that the volatility of the IAZI index and its correlation to the other 80 factors can be estimated using the standard sample estimators. From the perspective of the market model, the direct real estate market is considered as having a similar type of behavior as the equity or the bond market. If the necessary assumptions needed for the GBM model are met then clearly the (contemporaneous) correlation matrix will capture most of what is necessary to describe the influence of these risk factors on the RBC. As mentioned in Section 1.1, the random component in the GBM model, the $(\epsilon_t^i)_{t=1}^{t=T}$, should be normally distributed with zero mean and no auto-correlation. Thus if these two conditions are met then the use of the GBM model is legitimate. Non-normality is acknowledged and dealt with in the SST through the use of simulations and scenario analysis. The failure of this condition is not a fundamental problem at this stage, yet it should not be left out of sight. The lack of autocorrelation is a pretty safe assumption for stocks, bonds and forex returns, but how does is work for direct real estate? Figure 2 shows the autocorrelogram of the time series of quarterly returns of the IAZI and of the Swiss Performance Index (SPI)[2] index. As expected, the equity market

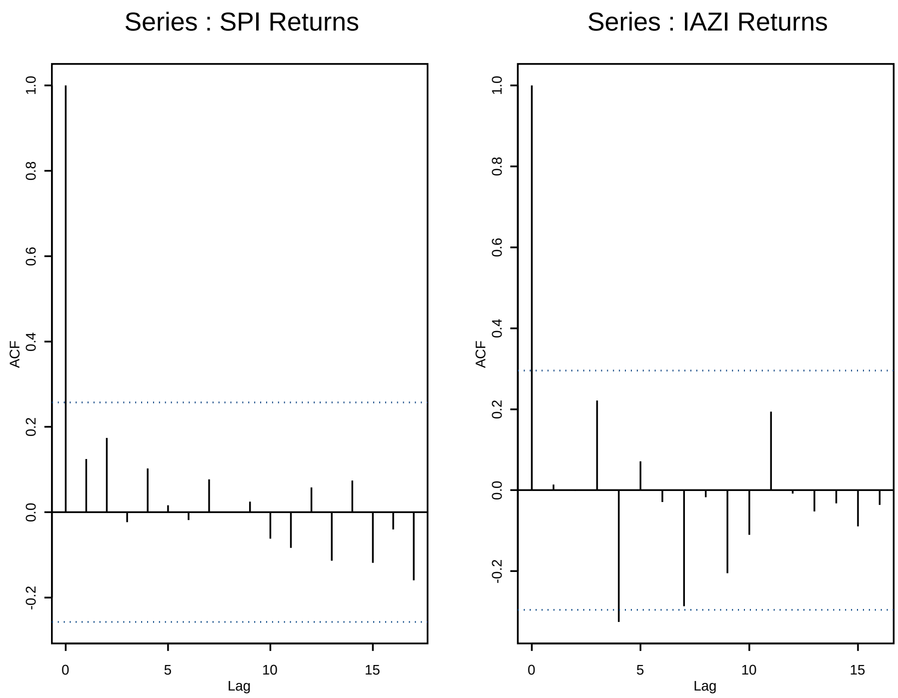


Figure 2: The autocorrelation of the IAZI Performance Index and of the SPI index

lacks any type of linear predictive structure at quarterly intervals, yet not the same can be said about the IAZI index. For the GBM to make sense one needs the increments of the Brownian Motion to be independent [cite

[2]This index is used as a measure of the Swiss equity market

Shreve]. The correlogram shows that even the weaker assumption of linear independence is not satisfied.

3.1 Tackling the issue of autocorrelation

Is the presence of autocorrelation really important at this stage? Can't we simply use the standard solution from the SST and compute the variances and correlations using the usual estimators? The example below will try to answer these questions.

Example: Let ϵ_t^x and ϵ_t^y be two White Noise processes with zero mean and variances σ_x^2 and σ_y^2 respectively. This is the case one assumes in the standard set-up: asset returns are white noise processes. Then $cov(\epsilon_t^x, \epsilon_{t-i}^x) = cov(\epsilon_t^y, \epsilon_{t-i}^y) = 0, \forall i > 0$. Let $cov(\epsilon_t^x, \epsilon_t^y) = \gamma$ (the example thus assumes that the two assets do have a contemporaneous correlation). Let also $x_t = \epsilon_t^x$ and $y_t = \epsilon_t^y$ be the returns for two different assets as assumed in the RiskMetrics. Then $cov(x_t, y_t) = \gamma$ and the computation of the correlation matrix using the standard estimator given in equation 7 is just.

Now consider the case when one of the assets, say x_t is autocorrelated while the other asset remains a WN

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \epsilon_t^x, \alpha < 1 \tag{9}$$

$$y_t = \epsilon_t^y \tag{10}$$

$$\epsilon^x \sim WN(0, \sigma_x^2) \quad , \quad \epsilon^y \sim WN(0, \sigma_y^2) \tag{11}$$

One can solve the difference equation for x to obtain

$$x_t = \frac{\alpha_0}{1 - \alpha_1} + \sum_{i=0}^{\infty} \alpha_1^i \epsilon_{t-i}^x \tag{12}$$

In this case, the sample covariance $cov(x_t, y_t)$ will be different than the long-run or population covariance $cov(\epsilon^x, \epsilon^y)$ as long as the sample mean is different than the long-run mean. This means that the computation of the correlation matrix needs to be amended to account for the presence of autocorrelation. If one believes that the time-series of returns is a white-noise when actually there is an ARMA-type of structure in it then one risks making a mistake when using the estimators in equation (6) and (7). If the structure of the autocorrelation can be determined and the estimates are stable and statically significant then as the example before shows one needs to use the time-series of residuals (the ϵ^xs) from the AR model for the computation of the correlation matrix and not the time-series of returns. Also important is the fact that the estimate of variance has to be changed. If x_t follows the AR(1) given above then the unconditional variance to be used will be:

$$\sigma_x^2 = \frac{\sigma_\eta^2}{1-\alpha_1^2} \tag{13}$$

This variance will clearly be different from the variance of the white noise process as long as $\alpha \neq 0$. The economic intuition for using the time series of ϵ^ys might be explained by realizing that the residuals proxy the new information and it is the impact of this new information that one wants to assess through the use of the correlation matrix.

3.2 A simulation exercise

The potential impact of ignoring the AR structure in computing the correlation coefficient has been evaluated using a simulation of the example presented in the previous subsection. A pure Gaussian WN(0,1) series is generated using the statistical software S-Plus (this is the ϵ^y; the series contains 500 draws). The ϵ^x series is constructed using the draws from ϵ_y and another uncorrelated white noise so that $\epsilon^x = 0.5\epsilon^y + noise$. The AR(1) is then generated as $x_t = 0.5 + 0.75x_{t-1} + \epsilon_t^x$. A sample of the two series (100 points) is graphed in figure (3). The population covariance, variance and correlation of the two series are computed (these are the values one obtains when using the entire series of 500 points). The values are close the expected theoretical values with the correlation coefficient being of 0.323. A sample of 50 points is drawn from the two series and the correlation coefficient is computed using the standard sample estimate given in (7). The value of the

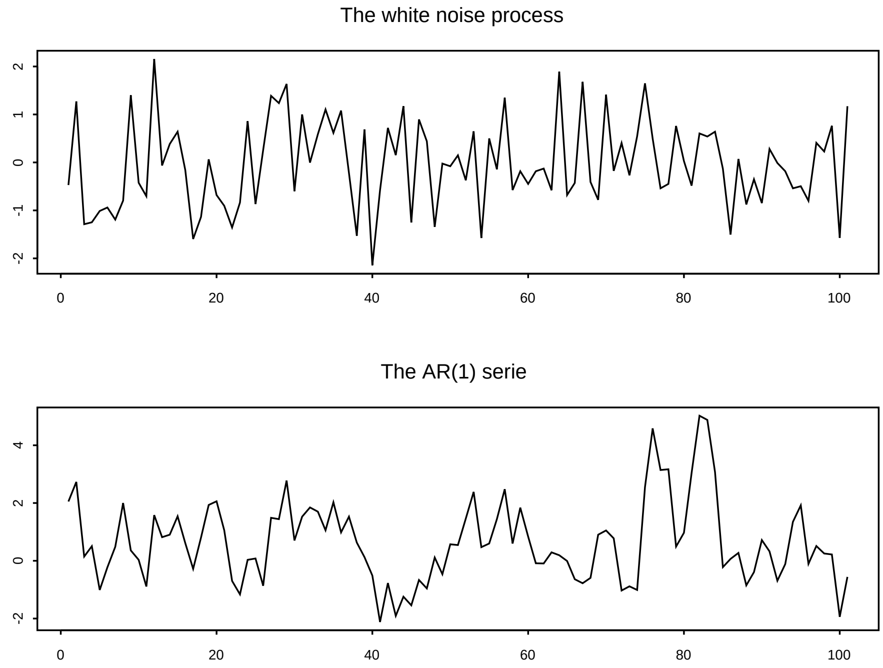


Figure 3: The two simulated time series

correlation is 0.44. When the AR(1) model is fitted and the residuals are used to compute the correlation coefficient (using also the variance given in (13)) the value is 0.361. This value is much closer to the actual (population) value of 0.323 than the sample value which ignores the presence of the linear structure. This shows that once the AR structure is properly identified in the sample, this can help in estimating the actual population correlation.

The differences in the estimated correlation coefficients have important implications in both asset allocation and risk management. In the first case a too high estimated correlation underestimates the diversification benefits whereas in the second case leads to improper calculation of the actual risk faced by a portfolio containing the two assets. This problem can have even more severe implications when the autocorrelation is present in the time-series of more than one asset [the impact on the VaR will also be computed].

3.3 Estimation of the AR process

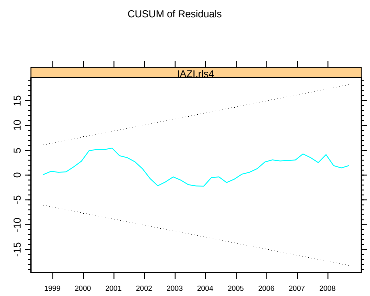
Using the Bok-Jenkins procedure several AR structures have been examined [ARMA?]. The main selection criteria has been not so much the actual fit of the model (R^2 or other measures of fit). Main emphasis was put on statistical significance of the parameters and fulfillment of the assumptions of normally-distributed non-autocorrelated residuals. This is because the correlation matrix is computed on the assumption that the time-series are white-noise processes (i.e. an iid normal) and the residuals will be replacing the actual returns in the correlation matrix. Once the white-noise assumptions are met, stability of the estimates is the next criterion in the selection of the model.
The best-yielding model is presented in equation (**??**). The estimated model is:

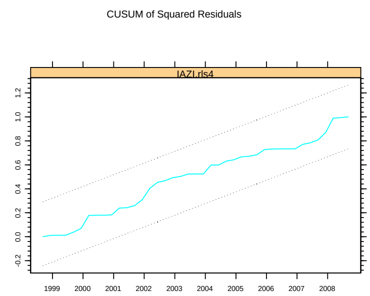
$$r_t = \alpha + \beta_4 r_{t-4} + \epsilon_t \tag{14}$$

The test statistics are presented in Table 1. What is very interesting to observe at this transaction-based index is that the 4th quarter parameters are highly significant implying that the presence of autocorrelation observed in the ACF is not a statistical coincidence. The period over which the regression is made is 1998 to 2008 (10 years as recommended by the SST). The cause of this autocorrelation still needs to be determined. As previously mentioned, the stability of the estimates is of crucial importance. Any potential change in the value of the parameters will lead to a change in the correlation matrix and therefore ultimately to a different value of the risk measure. To check the stability of the parameters of interest the CUMSUM and the CUMSUMQ tests are performed. The results indicate that the over the entire time-span ([1]) the intercept and the fourth-lag coefficient are stable. The CUMSUM of both the residuals and of the squared residuals stay within the bands.

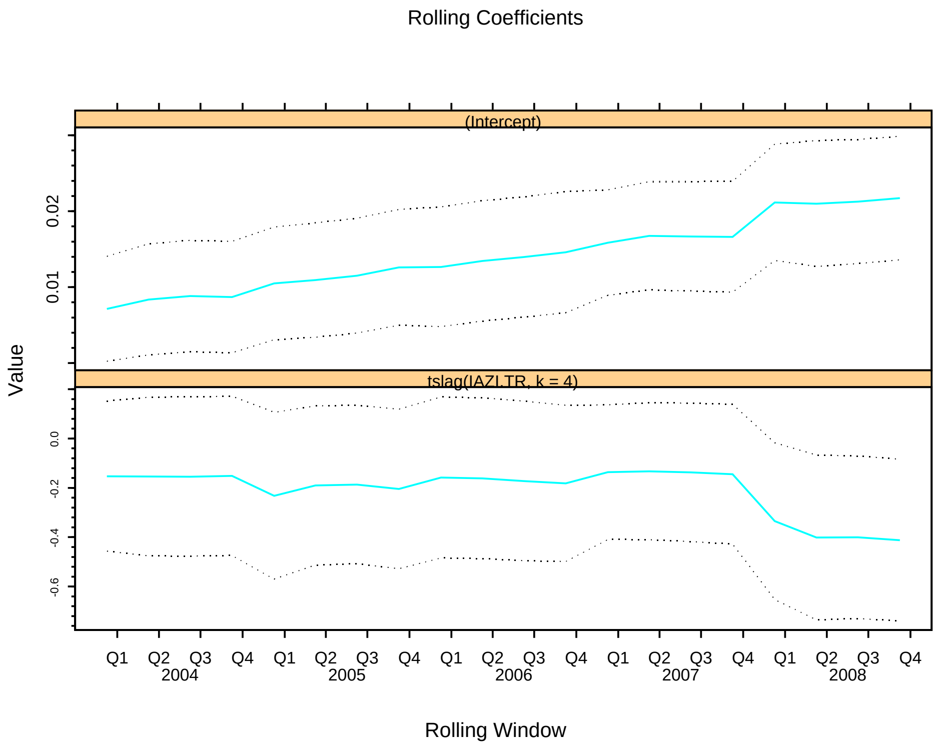
Parameter	Value	p-value
α	0.0211	(0.0000)
β_4	-0.4051	(0.0145)
Jarque-Bera	0.4648	(0.7926)
Ljung-Box	16.118	(0.4448)
Durbin-Watson	1.61	
R-squared	0.1370	
Adj. R-squared	0.116	

Table 1: Parameter values and test statistics





The AR model is also estimated using a rolling regression. This can indicate how the parameter of interest varies over the time span of interest. The window size for the regression is of 40 data points starting in 1994. The sample increment is of one point corresponding thus to one quarter. The results indicate that the autoregressive coefficient was hovering around -0.1 up to 2007. In 2007 one can observe an increase in the intercept and a decrease in the autoregressive coefficient. The 95% confidence bands indicate that the 4th lag coefficient has an increased statistical significance after 2007 and that the trend is towards the estimated value of -0.4.



4 Results

The SST White Document states on page 19 ([11]): "The asset model is conceptually similar to the well-know RiskMetrics approach (see [RM1] and [RM2])." This means that asset prices are being modeled as a random walk (see pg. 50 of the RiskMetrics Technical Document, eq. 4.14 and the following section for explanations). This assumption implies further that asset returns are assumed to be a white noise process or IID [independent and identically distributed].Working with the assumption of IID returns shows the need to test for both normality and no serial correlation of the returns. The issue of non-normality is already dealt with in the present SST by the use of simulations. The first step we implement is thus a test of the assump-

tion of returns being IID (as required by the RiskMetrics methodology). The test shows that the IAZI index has a stable autocorrelation at the fourth lag. We therefore identify and test the stability of the autocorrelation coefficient. The rolling regression performed for the fourth-quarter lag shows that this parameter is stable and significant starting with the end for 2007. The difference between the correlation parameters with and without autocorrelation are non-trivial. More important is the fact that not accounting for the autocorrelation present in the sample leads to a misestimation of the actual population correlation. This problem can be resolved by properly computing the sample correlation as shown in the previous section.
The interesting question arising is what is the estimated impact of the correlation misestimation in a standard ALM framework. To this end we use the SST template to compute the risk-based capital a company would need when its assets would be 80% in bonds, 15% in real estate and 5% in equity. The allocation is meant to show the impact in the case of a conservative investor (pension plan or insurance company). We use this allocation and compute the risk bearing capital using a correlation matrix that does not account for the presence of autocorrelation in returns and the risk bearing capital of the same allocation using a correlation matrix that considers the problem of autocorrelation. The risk based capital is 1% higher in the later case. The increase might not seem overwhelming in the beginning yet this may change once the allocation to the assets having autocorrelated returns series increases. The effect will be even more clear when several series will be autocorrelated. This is the case when both real estate and hedge funds are present among the assets of the investor.

5 Conclusion

In this paper we have showed the impact of ignoring autocorrelation in returns when computing the risk based capital need for the Swiss Solvency

Test. Using both simulations and a hypothetical asset allocation we show that not accounting for autocorrelation leads to a misestimation of the population correlation. The increase in the risk based capital is of roughly 1% when the correlation matrix used to compute the Expected Shortfall is computed such as to take in consideration the presence of autocorrelation in the time series of returns.

References

[1] Brown, R., J. Durbin and J. Evans, *Techniques for Testing the Constancy of Regression Relationships over Time*, Journal of the Royal Statistical Society, Series B, 37, 149-172, (1976).

[2] De Bondt, W.F.M., Thaler, R.H., *Does the stock market overreact?* Journal of Finance 40, 793805, (1985).

[3] Diaz, J. III, *The process of selecting comparable sales", The Appraisal Journal*, Vol. 58 No. 4, pp. 533-40, (1990b).

[4] Diaz, J. III and Hansz, J.A. , *How valuers use the value opinions of others'*, Journal of Property Valuation and Investment, Vol. 15 No. 3, pp. 256-60, (1997).

[5] Jegadeesh, N. Titman, S., *Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency*, Journal of Finance, American Finance Association, vol. 48(1), pages 65-91, March, (1993).

[6] Fama E., *Efficient Capital Markets: A Review of Theory and Empirical Work*, Journal of Finance 25: 383417, (1970).

[7] Geltner, D., *Bias in Appraisal-Based Returns*, AREUEA, vol. 17, no. 3, 338-352, (1989b).

[8] Geltner, D., *Smoothing in Appraisal-Based Returns*, Journal of Real Estate Finance and Economics, vol.4, no.3, 327-345, (1991).

[9] Samuelson P., *Proof That Properly Anticipated Prices Fluctuate Randomly*, Industrial Management Review 6: 4149, (1965).

[10] Shefrin H., Statman M. *The Disposition to Sell Winners Too Early and Ride Losers Too Long: Theory and Evidence*, Journal of Finance, Vol. XL, No. 3, (l985).

[11] FINMA, *White Paper of the Swiss Solvency Test* http://www.bpv.admin.ch/themen/00506