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In chapter III, a combination of an empirical and simulation-based evaluation of the theory of long-run purchasing power parity (PPP) is conducted. It is demonstrated that the traditional unit root tests of PPP are non-robust to the empirically identified GARCH distortions in the real exchange rates (RER). Therefore, based on this study and currently existing research, it appears virtually impossible to empirically come to a credible conclusion regarding whether long-run PPP holds or not.

In chapter IV certain financial stability requirements of the Basel (II) Accord are scrutinized. It is concluded that the Basel requirement of an estimation period that is at least one year long for the calculation of minimum capital risk requirements is not empirically justified.

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PÄR SJÖLANDER

Simulation-Based Approaches in Financial Econometrics

JONKOPING INTERNATIONAL BUSINESS SCHOOL JONKOPING UNIVERSITY
To my parents, my brother, my Sara, 
and Berta who passed away 
before the thesis was completed
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Pär Sjölander,
Jönköping, 1st of September (± 2 s.e.)
Abstract

This doctoral thesis consists of four chapters all related to the field of financial econometrics. The main contributions are based on the empirical evaluation of theories in or related to financial economics supported by the recent advances of models and simulation-based methods in time-series econometrics.

In chapter II, following the summarizing introductory chapter, a new unit root test is developed which by the use of simulation is demonstrated to be robust in the presence of generalized conditional heteroscedasticity (GARCH) distortions. In the presence of GARCH disturbances, for empirically relevant sample sizes, this new test exhibits superior statistical size and power properties compared with a sample of eight commonly used traditional unit root tests.

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Introduction and Summary of the Thesis

1. Introduction

The essential purpose of all theoretical models in economics must be the possibility to apply these finding in practice. Therefore, the development of appropriate econometric techniques is necessary in order to overcome the boundaries between theoretical and empirical economics. In modern economics, econometrics is an essential complementary tool in order to evaluate whether economic theories obtain empirical support. As has been clearly established by the Nobel committee at numerous occasions, research in econometrics is definitely a relevant and essential part of economics. It is simply not meaningful to empirically test or apply the research findings of economic theory if incorrect econometric methods are used or if the statistical assumptions are not satisfied. Without the progressively ongoing development of econometric tools, the contributions of research in economic theory cannot be optimally utilized in practice. Therefore, research in econometrics is a necessary part of the development and evaluation of theories in economics.

In mathematics, relationships are primarily expressed by the use of deterministic variables that are known by certainty. By the middle of the last millennium it became clear that many variables had to be measured with the use of probabilities instead of exact deterministic methods. Consequently, a relatively significant sub-area within mathematics evolved – statistics. Due to its general usefulness statistics was practiced on many fields, and those statistical methods applied on economic data later became known as econometrics.

Econometrics literally means “economic measurement”, and it is a branch of economics that applies statistical methods to verify economic theories and numerical relationships. It is a combination of economic theory, economic statistics, statistics, and mathematical economics. The term econometrics appears to have been first applied by Paweł Giompa as early as 1910, although it is Ragnar Frisch who claimed he coined the term and established the subject in the sense in which it is known in present time (Geweke, Horowitz and Pesaran, 2006).
This dissertation focuses on a sub-field of econometrics that applies to time-series observations, which is referred to as time-series econometrics. Time-series analysis is a bundle of statistical methods designed to take into account time-dependency in the data. Several of the techniques used in time-series econometrics are elaborations originally developed in physics, engineering, and biometrics. In time-series econometrics, researchers use data in the form of chronological sequences of observations of one or more variables. Data for a variable, for instance an exchange rate, can be collected at multiple time periods; every minute, hour, day, week, month, or year etc, and at a certain frequency the observations can be lined up in a so-called time-series variable. The time-series econometrician uses the collected data set to evaluate whether previously stated economic theories are supported by the movement of one variable or by the relationships between the time-series variables. In general, time-series econometrics is usually applied for testing economic theories, for forecasting, and for policy analysis. The purpose of econometrics is definitely not to invent new economic theories through empirical data mining. However, it can be used to test new or already existing theories in economics.

In this thesis I use empirical time-series data and simulated experimental data in order to, by the use of econometric techniques, validate econometric methods and economic theories. In financial economics, time-series econometrics is an indispensable tool. This is one reason why a substantial part of the attention of this thesis is focused on problems and remedies related to time-series econometrics. A sizeable part of the important economic decisions in the world are based on conclusions reached by econometric methods. Consequently, it is of crucial importance to scrutinize these methods’ adequacy by the use of empirical studies in combination with simulation methods. If the technical assumptions are not satisfied the conclusions from a study may be totally misleading and generate incorrect and expensive economic decisions. Therefore, it is essential that the assumptions are satisfied and that accurate methods are applied in the analysis. In this thesis economic theories are analyzed by the use of methods primarily based on, or related to, non-stationarity processes, structural breaks, time-varying heteroscedasticity models, and experimental simulation methods.

2. Empirical Regularities in Asset Returns

According to financial theory (see Mandelbrot, 1963), the daily return of an asset can be written as the sum of the intraday returns, that is

\[ r_t = \sum_{i=1}^{m} x_i \]
where \( m \) is the number of price changes within day \( t \), and

\[ x_i = \ln P_i - \ln P_{i-1} \]

is the intraday log price change, with \( P_i \) is the \( i \)th intraday price.

If we can assume that these intraday price changes are independent and identically distributed (i.i.d.), the Central Limit Theorem (CLT) says that the daily returns should be normally distributed. However, especially for data in financial economics, there is overwhelming evidence that the returns are not normally distributed. Therefore, the central limit theorem is apparently not applicable in this context. This implies that standard methods cannot be applied on this type of data. In fact there are some well documented empirical regularities of asset returns, thus, returns from financial markets can be described by some specific stylized facts. There is a high probability that empirical asset-return series may be characterized by non-stationarity, volatility clusters, non-normality, leptokurticity, and structural breaks. These features are problematic and can distort econometric analysis, which implies that standard regression methods are not applicable. Therefore, this thesis aims to further develop, apply and evaluate new and already existing econometric methods that can reduce the effects caused by these empirical problems.

### 3. Non-Stationarity and Cointegration Models

The results of traditional econometric theory are derived under the assumption that the time-series variables of concern are (covariance) stationary. Standard econometric techniques may produce misleading conclusions in the presence of non-stationary variables. The presence of non-stationary data, in the form of deterministic or stochastic (unit root) trends, induce the potential risk of falsely detecting spurious (non-existing) regression relationships. In layman’s terms, the stationarity assumption implies, that the mean and the variance of a time-series cannot drift too far away from a constant equilibrium or a trend (trend-stationarity) in the long run. If a variable’s mean or variance systematically increases/decreases over time, the variable is a function of time and hence non-stationary. Furthermore, the covariance should be unaffected by a change in the time origin.

More formally, a variable \( y_t \) is covariance stationary, or weakly stationary, if the following conditions are satisfied (Enders, 2004):

\[ E(y_t) = E(y_{t+s}) = \mu \]
Various definitions of non-stationary processes exist. In order to simplify this introduction, consider the following simple expression.

\[ y_t = \varphi y_{t-1} + \varepsilon_t \]

It can easily be seen that successive substitutions of lags of \( y_t \) into (6) will lead to:

\[ y_t = \varphi^T y_{t-T} + \varphi \varepsilon_{t-1} + \varphi^2 \varepsilon_{t-2} + \varphi^3 \varepsilon_{t-3} + \ldots + \varphi^T \varepsilon_{t-T} + \varepsilon_t \]

[That is, use \( y_{t-1} = \varphi y_{t-2} + \varepsilon_{t-1}, y_{t-2} = \varphi y_{t-3} + \varepsilon_{t-2}, \ldots \) and make substitutions into (6)].

In the case of \( \varphi < 1 \), shocks in the system will gradually die away since \( \varphi^T \to 0 \) as \( T \to \infty \). The case of \( \varphi > 1 \) is usually not relevant for economic data, since in that case shocks become increasingly more influential over time. When \( \varphi = 1 \), the above equation represents one of the most basic and fundamental non-stationary processes, that is, a random walk or a unit root process. The unit root process is a common feature for macroeconomic and financial series. Shocks persist in the system and never die away. If \( \varphi = 1 \) with \( \varphi^T = 1 \ \forall \ T \) (for all time periods), we obtain \( y_t = y_0 + \sum \varepsilon_t \) as \( T \to \infty \). This expression is an infinite sum of all past shocks added together with a starting value \( y_0 \). Consequently, a shock in the system never dies away, and the variable cannot be used for traditional regression analysis. A unit root process is impossible to predict since, by definition, it is a formalization of the intuitive idea of taking successive steps in a stochastic process, each in a complete random direction.

In the past, it was common practice to estimate equations involving non-stationary variables using standard regression models. It was not until Granger and Newbold (1974), in a seminal paper which coined the term “spurious regression”, that the research community became aware of the potential problems. Granger and Newbold reached their conclusion by generating and studying the relationships between totally independent non-stationary series. For each series they generated the simplest case of a random unpredictable stochastic process, which is known as a random walk or a unit root process. These entirely unrelated unit root processes were regressed on each other.
Introduction and Summary of the Thesis

Despite the fact that the variables in the regression were independent, Granger and Newbold found that the null hypothesis of a zero coefficient was rejected more often than what standard econometric theory predicts. Thus, this experiment showed that non-stationary variables (used in standard regression techniques) falsely may appear to be significantly related, more often than what the statistical size stipulates. They also identified an extremely strong positive autocorrelation relationship in the residuals. Granger and Newbold (1974) reached their conclusions by simulations. Later, Phillips (1986) confirmed their ideas and worked out the asymptotic distribution theory valid for their experiment.

Already before Granger and Newbold (1974) published their seminal paper regarding spurious regressions it was in fact recognized that the econometric inference theory required a stationary error term. However, it was not known that non-stationary variables induced a risk for detection of completely spurious and non-existing relationships. Thus, at this point in time, a substantial share of economic theory had been verified only by the use of spurious regressions. If a variable is non-stationary, the model must be adjusted in order to be used for regression analysis. This revolutionary insight led to a great deal of re-evaluation of empirical work, particularly in macroeconomics, to see if apparent relationships were spurious or not.

There are many approaches for how to detect the presence of non-stationary economic variables. One of the most utilized so-called unit root tests, that can test for both stochastic and deterministic trends, is the Dickey-Fuller test (see Dickey and Fuller, 1979). This test recognizes the fact that the assumptions for asymptotic analysis are invalid and that the $t$-statistics will not follow a Student’s $t$-distribution under the null hypothesis of a unit root – they will instead follow a Dickey-Fuller (DF) distribution. Under the assumption of independently and identically distributed (i.i.d.) errors, Fuller (1976) conducted Monte Carlo experiments to compute the critical values of the $t$-test statistic associated with the null hypothesis of a unit root. The distribution of the test statistic was found to be skewed to the left and has many more large negative values relative to a $t$-distribution (or a normal distribution). For economic time-series we can rule out the possibility that this test statistic is positive, so the Dickey-Fuller test for detection of non-stationarity is a one-tailed test. The DF critical values are much larger in absolute terms (i.e. more negative) compared with the $t$-distribution. Thus, more evidence against the null hypothesis is required in the context of unit root tests than under the standard $t$-tests. This is due to the inherent instability of the unit root process, the fatter distribution of the $t$-ratios, and the resulting uncertainty in the inference. General problems for unit root tests are: (i) the low power to (correctly) reject a false null hypothesis, (ii) the difficulty to distinguish between a random walk plus drift and a trend-
stationary process, and (iii) the under-rejection of the unit root hypothesis in the presence of structural changes (Perron, 1989).

Despite the extremely common existence of non-stationary variables in finance and macroeconomics, still in these days, there is no consensus for what is the optimal model-selection strategy for non-stationarity tests. A full model-selection strategy should be applied since it is not obvious if, for instance, an intercept, an intercept and a trend, or if no intercept and trend should be included in the Dickey-Fuller test specification. Therefore, this decision should be based on a formal and systematic model-selection strategy. There are many different suggested model-selection procedures, see e.g. Ayat and Burridge (2000), Dolado, Jenkinson, and Sosvilla-Rivero (1990), Elder and Kennedy (2001), Enders (2004), Holden and Perlman (1994), and Perron (1988). Due to the severe potential consequences of bypassing a formal model-selection strategy for unit root tests, this should be a standard procedure for all practitioners in time-series econometrics. Actually, in many papers it is very common that practitioners do not report any unit root tests at all, and certainly no model-selection procedures for that matter. A likely reason is that model-selection procedures of unit root tests are often fairly sophisticated and complicated techniques. Another problem is that some strategies may cause mass significance problems, or propose processes that are very unlikely from a theoretical standpoint in economics. For instance, Perron (1988, p. 304), and Holden and Perlman (1994, p. 63), who point out that a unit root with a deterministic time-trend is an unlikely process in economics. These problems are avoided in this thesis, since the unit root model-selection strategy by Elder and Kennedy is applied. Elder and Kennedy (2001) have developed a unit root model-selection strategy, that, as a complement to the significance testing, utilizes prior knowledge to rule out processes that are not realistic.

It is important to make a distinction between two different types of non-stationary processes, since they require different remedies to induce stationarity. A non-stationary variable can follow a deterministic trend or a stochastic trend (unit root). If a series is non-stationary simply because of the deterministic trend (i.e. it is stationary around the deterministic trend), then stationarity can easily be accomplished by removing the deterministic trend by regressing the deterministic trend variable on a deterministic (polynomial) time trend, and using the residuals as the adjusted variable. A variable with a deterministic trend is sometimes referred to as a trend-stationary process (TSP), if a detrending procedure results in a series of stationary residuals. This implies that residual values are stationary around the regression line. However, when a stochastic trend (unit root) is detected in a variable there are many suggestions for how to deal with this situation. The first suggested remedy was to take the first differences of the series to induce stationarity. Thus, if \( \Delta y_t = (y_t - y_{t-1}) \) is stationary [\( \Delta y_t \sim I(0) \)], then we say that \( y_t \) is integrated of order 1 [\( y_t \sim I(1) \)] and that \( y_t \)
Introduction and Summary of the Thesis

follows a unit root process. Therefore, a series with a unit root is sometimes called a difference stationary process (DSP) since it can be transformed into a stationary series by differencing. However, this leads to some unattractive problems with the interpretation of the parameter estimates, since economic theories are often stated in levels ($y_t$) and not in first differences ($\Delta y_t$). Nelson and Plosser (1982) challenged the traditional view by demonstrating that important macroeconomic variables (RNP, NGNP, Industrial production, and unemployment rate) tend to be DSP rather than TSP.

Therefore, it was a major breakthrough in econometrics, and consequently in economics, when it was established that if ordinary least squares (OLS) residuals from a regression between integrated (unit root) variables of the same order are stationary this may lead to superconsistent estimates of the coefficients in that regression. The problem of spurious relation is also avoided in this case. Granger (1981) named the phenomena cointegration and later explained this concept as “ways to discover that two large boats are drifting with the same current or that two macroeconomies are moving together.”

Cointegration analysis is especially important in systems where the short-run dynamics is influenced by large random distortions for the variables (e.g. random news and events), while in the long run the variables are converging together by economic equilibrium relationships. Examples of variables that are tied together in the long run (cointegrated), but not necessarily in the short run are e.g. dividends and stock prices, and interest rates of different maturities. For analysis of short-run relationships along with long-run ones, Granger (1981) developed the so-called error-correction model (ECM). The error correction model is a dynamic model in which the movements of the variables in any periods are related to the previous period’s gap from long-run equilibrium. The long-run relationship is represented by the cointegration technique originally formulated by the Nobel laureates Engle and Granger (1987).

The importance of cointegration in the modeling of non-stationary economic processes becomes understandable in the so-called Granger representation theorem originally formulated by Granger and Weiss (1983). Consider the following bivariate autoregressive system of order $p$, where $\varepsilon_{1t}$ and $\varepsilon_{2t}$ are white noise.

\[
x_t = \sum_{j=1}^{p} (\gamma_{ij} x_{t-j}) + \sum_{j=1}^{p} (\delta_{ij} y_{t-j}) + \varepsilon_{1t}
\]

\[
y_t = \sum_{j=1}^{p} (\gamma_{2j} x_{t-j}) + \sum_{j=1}^{p} (\delta_{2j} y_{t-j}) + \varepsilon_{2t}
\]
The Granger representation theorem states that the I(1) processes, $y_t$ and $x_t$, are cointegrated if and only if there exists an ECM representation of their relations. Consequently, the system can be expressed as follows.

$$
\begin{align*}
\Delta x_t &= \sum_{j=1}^{p-1} (\gamma_{1j} \Delta x_{t-j}) + \sum_{j=1}^{p-1} (\delta_{1j} \Delta y_{t-j}) + \alpha_1 (y_{t-1} - \beta x_{t-1}) + \varepsilon_{1t} \\
\Delta y_t &= \sum_{j=1}^{p-1} (\gamma_{2j} \Delta x_{t-j}) + \sum_{j=1}^{p-1} (\delta_{2j} \Delta y_{t-j}) + \alpha_2 (y_{t-1} - \beta x_{t-1}) + \varepsilon_{2t}
\end{align*}
$$

where (A) represents short term dynamics, (B) symbolize the impact from equilibrium and (C) is the noise. All terms ($\Delta x_t$, $\Delta y_t$, and $y_{t-1} - \beta x_{t-1}$) are I(0) so traditional statistical time-series methods apply. Obviously, there can be inclusions of deterministic parts, constants, trends, seasonal components, in the system. Granger’s representation theorem offers a testable procedure for its existence. The deviation from equilibrium is equal to $z_t = y_t - \beta x_t$. A test for the stationarity of $z_t$, while $y_t \sim I(d)$ and $x_t \sim I(d)$ with $d > 0$, is therefore a test for cointegration. A cointegration technique developed by Johansen and Juselius (1990) and Johansen (1991, 1995), with the use of maximum likelihood, is currently a cornerstone in modern econometrics and solves many of the difficulties found in spurious regressions (Brooks, 2002). In summary, it is of essential importance to determine whether a variable is stationary or not. In the present thesis, in chapter 2, a new test method is developed that tests for unit roots in the presence of distortions from time-varying heteroscedasticity errors. By simulations it is demonstrated that traditional unit root tests are only valid for very large sample sizes in the presence of these so-called time-varying GARCH distortions, which will be discussed later.

4. Time-Varying Heteroscedasticity Models

A central paradigm in finance is that we must take risks to achieve rewards but not all risks are equally rewarded. Thus, we optimize our behavior to maximize rewards and minimize risks. The risk of an investment is generally measured by volatility of the return, or as the covariance between the return on the investment and one or several factors representing some sort of systematic risk. According to the Capital Asset Pricing Model (CAPM) of Sharpe (1964), Lintner (1965), and Black (1976) the systematic risk is entirely captured by the covariance between the return on a security and the market portfolio. Therefore, the expected return of the market portfolio is determined by the variance of the market portfolio itself. However, it is necessary to empirically
estimate the variances or covariances for these theoretical asset pricing models. Originally, Fama and MacBeth (1973) and Fama and French (1992) relied on unconditional moments to estimate the values of the sample statistics for variances and covariances. Traditional unconditional models do not recognize the dynamic behavior in variances and covariances. The most commonly applied option pricing formula, by Black and Scholes (1973), assumes a constant volatility during the life of the option, which leads to well documented biases. Hull and White (1987), Chesney and Scott (1989), Ball and Roma (1994), and Duan (1995) show that the mispricings can be reduced by the use of time-varying volatilities.

OLS regression modeling is the classical method in econometric research, and can for instance be used to determine how much one economic variable will change in response to a change in another variable. A critical requirement in this regression is the assumption that the expected values of the squared error terms are constant over time. If this assumption of so-called homoscedasticity is not satisfied, these varying variances are identified as heteroscedastic. The consequence is that the OLS regression coefficients are still unbiased but standard errors will be misleading. Usually heteroscedasticity will cause the confidence intervals to be too narrow giving a false sense of precision. True null hypotheses will be falsely rejected more often than what the significance level stipulates. Even a cursory look at financial data suggests that certain time periods are more risky than others. Therefore, the assumption of a constant variance has usually no bearing in real empirical time-series data. The so-called historical volatility approach is the simplest, but still a widely used, method to estimate volatility by the use of variances. The volatility is estimated by the sample standard deviation of returns over a short period. A fundamental problem is that if the sample period is too long, then it will not be very relevant for today and if it is too short, it will be too noisy. However, volatility that is one-year old may not be relevant for a short-run prediction. Consequently, the constant-variance historic-volatility model does not function properly for financial data.

Another problem is that the empirical distributions of asset returns are often defined as leptokurtic, that is, more peaked and fat-tailed than the normal or t-distribution. In addition, the returns are often clustered over time. Small price changes tend to be followed by small price changes, and large price changes tend to be followed by large price changes. Expressed differently, the squared returns are autocorrelated. This has been known for some time, see e.g. Mandelbrot (1963) and Fama (1965). However, it was not until 1982 that Robert F. Engle introduced these features in his autoregressive conditional heteroscedasticity (ARCH) model. The fundamental key insight offered by the ARCH model lies in the distinction between the conditional and the unconditional second order moments. The unconditional covariance matrix for
the variables of interest may be time invariant, while the conditional variances and covariances often depend non-trivially on the past states of the world. Instead of the optimization dilemma of using short or long sample standard deviations, the ARCH model weights the averages of the past squared forecast errors, thus providing a type of weighted variance. These weights may allocate more influence to recent information and less to the distant past. ARCH is a generalization of the sample variance where outdated information is not considered as important as new information. A problem with the ARCH model is that it is difficult to determine the number of parameters to estimate. Another difficulty is that the model often breeches non-negativity constraints, with illogical negative variances as a consequence. In applications in these days, the ARCH model is replaced by the generalized ARCH (GARCH) model that Bollerslev (1986) and Taylor (1986) developed independently of each other. This model solves the parsimony problem, and is less likely to breech the non-negativity constraints.

The conditional heteroscedasticity depends not only on the observed previous volatility (the ARCH term), it is also a function of the conditional heteroscedasticity in previous periods (the GARCH term). The conditional heteroscedasticity is a function of three terms that are individually weighted. The GARCH(1,1) specification, with p=q=1 and η~i.d.d.N(0,1), is presented below:

\[
\begin{align*}
\varepsilon_t &= \eta_t \sqrt{h_t} \\
\eta_t &= \omega + \sum_{j=1}^{q} (\alpha_j \varepsilon_{t-j}^2) + \sum_{j=1}^{p} (\beta_j h_{t-j}) \\
\end{align*}
\]

where (A) is the long-term variance and (B) represents news about volatility from the previous period, measured as a weighted sum of the lags of the squared residual from the mean equation. The term (B) is the information about volatility observed in the previous period (the ARCH term). The expression in (C) represents a weighted sum of the previous period’s forecasted heteroscedasticity \( h_{t-1}, h_{t-2}, h_{t-3}, \ldots \) (the GARCH term). Also, it is useful to recognize that the \( h_t \) part in the variance equation follows an ARMA(1,1) process (see Box and Pierce, 1970).

The following parameter stationarity constraints are necessary for the GARCH(1,1) model. \( 0 \leq \alpha < 1, 0 \leq \beta < 1, h_t > 0 \forall t, \sum (\alpha + \beta)^{-1} < 1 \). If \( \sigma^2 = \omega(1-\alpha-\beta)^{-1} > 0 \) is satisfied, then \( \sigma^2 \) is defined, which is implied by the constraints \( \omega > 0 \) and \( \sum (\alpha + \beta) < 1 \) (Gourieroux and Jasiak, 2002).
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Since the model is no longer of the usual linear form, we cannot use OLS. We use another technique known as maximum likelihood where the log-likelihood function is estimated (maximized) by finding the most likely values of the parameters given the actual data.

It can, under some restrictions be proven that an infinite ARCH(p) model, where \( p \to \infty \), is equal to a GARCH(1,1) process. Bollerslev’s GARCH modification of the ARCH model is by Engle (2001) considered the generally most robust variant in the entire ARCH-volatility family. One of the most interesting features regarding this family of models is that they adjust for leptokurtosis. A leptokurtic distribution exhibits fat tails and excess peakedness at the mean. The GARCH process generates a substantially greater number of extreme values than what would be expected from a standard normal distribution or a \( t \)-distribution, since the extremes during the high volatility period are greater than could be anticipated from a constant volatility process. This implies that the model adjusts for the magnitudes of extreme values which are empirically common especially in financial data.

Another feature that the GARCH model adjusts for is the tendency for volatility to appear in bunches in financial market data. This phenomenon is defined as volatility clustering, which means that large returns (of either sign) are expected to follow large returns, and small returns (of either sign) to follow small returns. That is, when the volatility is high in the market it is expected that the market will remain volatile in the near future, and when the market is tranquil the volatility is likely to remain low (until new random information reaches the market). A GARCH process produces dynamic, mean reverting patterns in volatility that can be predicted. In the price discovery process, volatility clustering is simply clustering of information arrivals, which essentially is a statement that news is typically clustered in time.


Models from the ARCH family are used within many areas. Value-at-risk (VaR) analysis is one of these areas where ARCH plays an important role. Value-at-risk models can for instance be used to estimate capital requirements for market risks according the so-called Basel II rules.
The VaR measure tells us what is the maximum percentage the portfolio can, with e.g. 99% confidence, expect to lose over a certain time period (for instance within 10 days). Thus, this risk control measure gives us an estimate of the expected capital requirements to cover certain potential losses. This measure is normally applied by security houses or investment banks to measure the market risk of their asset portfolios (that is, market VaR). However, the actual concept is very general that can be applied in many different areas. One advantage with VaR is that the risk measure, associated with a portfolio of assets, can be easily understood since it can be presented with only one single number for an entire portfolio. In the final paper of this thesis, extensions from the ARCH-family model are applied on VaR to examine validity of the Basel II rules with the use of a bootstrap approach.

5. Simulation-Based Experiment Methods

The use of simulation experiments as a research tool in economics is not a new invention. As early as during the Manhattan project of World War II, Nicholas Metropolis coined the name “Monte Carlo simulations”, because of the similarity of statistical simulation to games of chance. Over time, the popularity of simulation methods has increased as a function of the accelerating advances for computer processors, but only in the last few years these methods have gained the status of a matured numerical technique capable of addressing the most complex applications.

There are some research issues in applied empirical economics that are unsolvable. Some of these problems can be solved, or may at least be easier to solve, by the use of Monte Carlo simulations (random-number methods based on artificial data) or by Bootstrap methods (resampling methods based on real data). In this dissertation, there are some research questions that are scrutinized by the application of Monte Carlo simulations or by bootstrapping methods. Therefore, these two approaches play a central role in this thesis.

5.1. Monte Carlo Simulations

Monte Carlo methods are a widely used class of computational algorithms for simulating the behavior of processes, and for solving various kinds of computational problems, by the use of pseudo-random numbers. The random numbers are generated according to probability distributions that are assumed to be associated with a source of uncertainty in the studied problem.
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As a simplified illustration, a Monte Carlo simulation can be performed in accordance with the following principles.

1. Generate the data according to the preferred data generating process (DGP), with the errors being drawn from some given probability distribution.
2. Estimate the regression model and the relevant test statistic(s).
3. Save the test statistic(s) or whatever parameter(s) of interest.
4. Go back to stage 1 and repeat T times.

In the above process a wide variety of properties can be studied. Just to name a few possibilities, robustness features can be examined, critical values of test statistics can be calculated, Value-at-risk models can be stress tested, or the prices of exotic options can be simulated in the cases where analytic formulas are unavailable.

The reason behind the popularity of simulation methods in economics can partly be explained by the fact that empirical time-series econometrics is fairly complicated. It is unquestionable that observations from time-series data sets often are distorted by unattractive and systematic patterns. Important statistical assumptions are often not satisfied, and therefore the estimated parameter values and/or the inference will be misleading or less reliable. By contrast, a simulation model is the econometrician’s opportunity to design a controlled experiment. In a simulation experiment it is possible to study the effect of changing one or many factors or aspects of a problem, while leaving all other aspects unchanged. If a similar experiment would be conducted empirically, the analysis would most likely be distorted by many other empirical disturbances such as e.g. structural breaks, autocorrelation, heteroscedasticity, bi-directional causality, or uncertainty whether the true data generating process (DGP) follows a non-stationary unit root process or a stationary near integrated (near unit root) process etc. However, in a simulation experiment these properties can be methodologically and individually studied with full control over all parameters.

Another reason for using simulations is that the asymptotic properties of a test statistic, derived by analytical mathematics, are valid for large samples but not necessarily for medium or small sample sizes. At times there are economic situations where the problem has no analytical solution (or when the mathematical expression is too complex to be easily solved), and then simulation methods can be an essential tool in order to obtain an approximation of the solution. In econometrics, simulation is particularly useful...
when sample sizes are small or when models are very complex. Simulations can also be used to illustrate how an economy would react to events possibly taking place in the future. This issue cannot be considered with empirical data alone, simply because the event has not happened yet. However, based on some assumptions, the effect of those events on the economy can be simulated by the use of Monte Carlo simulations (even if it is important that all of the assumptions are satisfied). Simulations offer total flexibility, and can be used for many different purposes. For instance, in chapter II and III Monte Carlo simulations are used to create critical values and to evaluate the size and power properties of a new test statistic.

5.2. Resampling and Bootstrap Methods

In many situations, Monte Carlo simulations are the optimal approach to solve a great variety of research questions. However, there are at least a couple of drawbacks with the use of Monte Carlo methods, especially on financial data. For instance, bootstrapping is applied in chapter IV since a Monte Carlo approach is somewhat limited by the strict assumptions regarding the true probability distribution of the errors.

In the literature, VaR estimations are often based on Monte Carlo simulation where asset prices are assumed to follow a unit root process, or a unit root process with drift, where the errors are drawn from a Gaussian distribution. However, in contrast to this assumption it is well documented that empirical asset returns are fat-tailed, and not normally distributed, which implies that extreme values are much more likely to occur compared to the case of normally distributed errors. As a consequence the VaR will be systematically underestimated if this is not adjusted for. A common remedial alternative is to conduct error draws from a fat-tailed distribution such as from the $t$-distribution (as a substitute to the normal distribution). Another option is to examine whether the asset returns follow some form of autoregressive conditional heteroscedasticity process, e.g. a (fat-tailed) GARCH process (with i.i.d. $N(0,1)$ innovations). However, it is well known that both of these solutions still face the potential problem of assuming the inappropriate distribution because we a priori cannot know the true probability distribution. In cases when the incorrect error distribution is assumed the conclusions from traditional Monte Carlo studies have questionable credibility. In order to deal with this fundamental dilemma, we must find a way to draw residuals that are more representative of the unknown actual error distribution. A feasible solution is to apply a bootstrapping approach where the unknown error distribution is “estimated” by empirical resamples from the model’s own residuals.
Efron’s (1979) bootstrapping method is similar to pure simulation methods, but the former involves resampling from real data rather than sampling from an assumed probability distribution. Thus, the bootstrap technique can be described as a statistical simulation methodology that resamples from the original data set. If this error distribution is unknown, Monte Carlo simulations are not applicable. However, bootstrapping assumes that the original sample is a reasonable representative of the population from which it comes. The bootstrap approach treats the data as if it is equivalent to the population; it is said that a pseudo-population is created. Therefore, in contrast to Monte Carlo simulations, only mild assumptions regarding these distributional properties are necessary. Bootstrap can be used as an alternative approach when it is difficult to analytically derive the asymptotic distribution of different test statistics. Since the empirical distribution is close to the population distribution when the sample size is large, the bootstrap consistently estimates the asymptotic distribution of a wide range of important statistics (Geweke, Horowitz and Pesaran, 2006).

As a simplified illustration of a bootstrap procedure, residuals can be resampled by the use of the following approach.

Consider the standard regression model $\mathbf{y} = \mathbf{X}\beta + \mathbf{e}$ where $\mathbf{X}$ is a vector.

(1): Estimate the model on the empirical data set. Obtain the fitted values $\hat{\mathbf{y}}$, and calculate the residuals $\hat{\mathbf{e}}$. (2): Draw, with replacement, $T$ of those residuals where $T$ is the sample size. Call this drawn sample $\hat{\mathbf{e}}^*$, and generate the bootstrapped dependent variable: $\mathbf{y}^* = \hat{\mathbf{y}} + \hat{\mathbf{e}}^*$. (3): Regress this new dependent variable on the original independent data ($\mathbf{X}$) to obtain a bootstrapped coefficient vector $\hat{\mathbf{\beta}}^*$. (4): Go back to step 2 and repeat this loop $T$ times.\footnote{This example is based on Brooks (2002).}

Since asset returns often do not follow the standard statistical distributions assumed in usual Monte Carlo simulations, bootstrapping is regularly applied in the area of financial economics. Thus, due to the distributional uncertainties of asset prices, bootstrapping is applied instead of Monte Carlo simulations in chapter IV in this thesis.\footnote{Furthermore, the iterative bootstrap approach in chapter IV allows for the distributional properties of the errors to be continuously updated over time. In order to adjust for serial dependence in the data, moving blocks bootstrap is applied. Moreover, structural change in the variance is adjusted for in this approach. The method is originally based on a paper by Inclán and Tiao (1994), where dummy variables are included in the GARCH process to adjust for variance breaks over time.}
6. Summary and Outline of the Thesis

This doctoral thesis consists of four chapters including the introductory chapter. The essays are all related to the field of financial econometrics.


In this chapter (II) a new unit root test is developed which is robust in the presence of generalized conditional heteroscedasticity (GARCH) distortions. According to previous research standard unit root tests are in fact considered robust to stationary GARCH distortions (see Diebold (1986), Diebold and Nerlove (1989), Godfrey and Tremayne (1988), Pantula (1986, 1988), Phillips and Perron (1988)). These conclusions are in fact correct when the number of observations is extraordinarily high. However, simulation experiments in this study, using more common sample sizes, reveal that eight commonly applied unit root tests exhibit considerable bias in the size in the presence of fairly moderate GARCH distortions. Moreover, there is still reduced power in the presence of stationary GARCH distortions. The examined traditional tests are: Dickey and Fuller’s test (1979), Phillips-Perron’s test (1988), Elliott, Rothenberg and Stock’s Dickey-Fuller-GLS test (1996), Elliott, Rothenberg and Stock’s Point-Optimal test (1996), and Ng-Perron’s (2001) modified unit root tests $MZ_{a}$, $MZ_{d}$, $MSB_{d}$, and $MP_{d}$. As a remedy for the disturbances from GARCH, new size-corrected unbiased critical values for all these examined tests are presented. However, the main contribution in chapter II is the development of a completely new remedial test which simultaneously models unit roots and the interconnected parameters of GARCH risk. For empirically relevant sample sizes, this new test exhibits superior size and power properties compared with all the traditional unit root tests in the presence of GARCH disturbances.


This paper in chapter III is an empirical application of the findings from chapter II. By agents on the currency markets, exchange rates are often considered overvalued or undervalued with respect to the purchasing power parity (PPP) theory. Currently, the long-run form of the theory attains its strongest support in more than thirty years. In this chapter, the validity of the PPP revisionists’ scientific evidence supporting long-run PPP is questioned...
based on the replication of an influential review study that is considered by PPP
revisionists to exhibit “some of the strongest evidence” in favor of the PPP
theory. By simulation experiments it is demonstrated that the traditional PPP
unit root tests are non-robust to the empirically identified (G)ARCH
distortions in the empirical real exchange rates (RER). Due to (G)ARCH
distortions, over-rejections for the traditional unit root tests are shown to be a
problem that potentially misleads researchers to believe that long-run PPP
holds under circumstances when it is in fact not valid. As a potential remedy to
this problem, the new unit root test from chapter II is applied since it is robust
to conditional heteroscedasticity disturbances. In contrast to traditional unit
root tests, it exhibits no significant empirical support for the PPP theory.
Furthermore, the study illustrates that the PPP revisionists’ traditional unit root
tests cannot reliably test the PPP hypothesis in the presence of (G)ARCH
distortions, due to bad size and power properties. Thus, based on the currently
existing research, presumably it is virtually impossible to empirically come to a
credible conclusion regarding whether long-run PPP holds or not.
Consequently it is recommended that more solid evidence needs to be
established in favor of (long-run) PPP before any convincing financial
investment recommendations can be made based on this theory.

Chapter IV consists of the article “Are the Basel (II) Requirements Justified in
the Presence of Structural Breaks?”. A minor revision is required before this
paper is formally accepted for publication in *Applied Financial Economics*.

In chapter IV it is empirically evaluated whether the requirements in the Basel
Accord are justified. The Basel Accord and the Swedish regulatory authority
Finansinspektionen stipulate that banks and securities firms are obliged to
estimate their internal risk management models based on an estimation period
with a minimum length of one year back in time. In this paper, the minimum
capital risk requirements (MCRRs) are estimated using moving windows of
Swedish long and short OMX index futures positions that are bootstrapped by
the use of VaR-(E)GARCH models. In order to adjust for possible serial
dependence in the data, bootstrapping in blocks is also applied in this study.
Furthermore, it is well documented that there is a significant risk for structural
breaks in financial markets, and volatility shifts which lead to excess volatility
persistence for GARCH models. If the structural changes are not adjusted for
the VaR-(E)GARCH models would mistakenly propose excessive capital
requirements and thus costly and inefficient risk management. In order to
detect and adjust for structural changes, a so-called ICSS-algorithm is applied.
The bootstrap technique is used since the traditional Monte Carlo method is
based on the assumption that the true data generated probability distribution is
known. By the use of the above approach it is concluded that out-of-sample
risk predictions are more accurate when using estimation periods shorter than
one year, probably since relevant information is outdated fairly quickly on the
markets. Therefore, the Basel committee can discard the one-year requirement without increased risk of financial instability.
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A New Test for Simultaneous Estimation of Unit Roots and GARCH Risk in the Presence of Stationary Conditional Heteroscedasticity Disturbances

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Abstract

According to previous research, standard unit root tests are considered robust to stationary GARCH distortions. These conclusions are in fact correct when the number of observations is extraordinarily high. However, simulation experiments in this study, using more normal sample sizes, reveal that eight of the most commonly applied unit root tests exhibit considerable bias in the size in the presence of fairly moderate GARCH distortions. As a remedy for the disturbances from GARCH, this paper presents size-corrected unbiased critical values for all these examined tests. Nevertheless there is still reduced power in the presence of stationary GARCH distortions. As a solution, a completely new test is formulated which simultaneously models unit roots and the interconnected parameters of GARCH risk. For empirically relevant sample sizes, this new test exhibits superior size and power properties compared with all the traditional unit root tests in the presence of GARCH disturbances.
Unreal Exchange Rates: 
A Simulation-Based Approach to Adjust Misleading PPP Estimates

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Abstract

Currently, the theory of long-run purchasing power parity (PPP) attains its strongest support in more than thirty years. In this paper, the validity of the PPP revisionists' scientific evidence supporting long-run PPP is questioned based on the replication of an influential review study that is considered by PPP revisionists to exhibit “some of the strongest evidence” in favour of the PPP theory. By simulation experiments it is demonstrated that the traditional PPP unit root tests are non-robust to the empirically identified (G)ARCH distortions. Due to (G)-ARCH distortions, over-rejections for the traditional unit root tests are shown to be a problem that potentially misleads researchers to believe that long-run PPP holds under circumstances when it is in fact not valid. As a potential remedy to this problem, a new unit root test is introduced which is robust to conditional heteroscedasticity disturbances, and in contrast to traditional unit root tests, it exhibits no significant empirical support for the PPP theory. The study illustrates that the PPP revisionists’ unit root tests cannot reliably test the PPP hypothesis in the presence of (G)-ARCH distortions, due to bad power and size properties. Perhaps it is time to conclude that, based on the currently existing research, it is virtually impossible to empirically come to a credible conclusion regarding whether long-run PPP holds or not.
Abstract

The Basel Accord and the Swedish regulatory authority Finansinspektionen stipulate that banks and securities firms are obliged to estimate their internal risk management models (IRMMs) based on a minimum time-series estimation-period length of one year back in time. In this paper, the minimum capital risk requirements (MCRRs) are estimated using moving windows of Swedish long and short OMX index futures positions that are bootstrapped (in blocks) by the use of VaR-(E)GARCH models. In order to detect and adjust for structural changes in the variance a so-called ICSS-algorithm is applied. By the use of the above approach it is concluded that out-of-sample risk predictions are more accurate when using estimation periods shorter than one year, probably since relevant information is outdated fairly quickly on the markets. Therefore, the Basel committee can discard the one-year requirement without increased risk of financial instability.
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