Risk and return in the Swiss property market

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The Faculty of Economics, Business Administration and Information Technology of the University of Zürich hereby authorizes the printing of this doctoral thesis, without thereby giving any opinion on the views contained therein.

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"The problem of flight with a machine which weighs more than air can not be solved and it is only a chimera."

The French Academy of Sciences, 1903

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Introduction

Real estate catches the spot light only to be held responsible, too often at times, for the financial disaster that threatens the stability and normal development of modern society. The scenario is by no means new: either some fundamentally positive happening sparks a change that completely transforms the society (the Roaring Twenties in the U.S.) or a change in the institutional structure of a society allows liberalization of certain economic sectors (the Control of Office and Industrial Development Act 1965 in the U.K.). The initial effervescence is kept alive by expansion and growth - both social and economical. Starting from this point, credit plays an essential role. Credit allows the society to develop today on hopes that this development will pay back in the future. In the economy this leads to a boom in construction and an increase in production. The income produced by the economic activity of construction starts to push up all sectors of the economy leading eventually to an increase in income and consumption for all social categories. For some time everyone fares better and enjoys levels of consumption above the long-run average they actually can afford. This is not a problem either for governments who cash in larger volumes of taxes or consumers who hedonically enjoy every penny. Neither for the left who sees housing being offered to most citizens nor for the right who takes credit for the accelerating development of all major industries. Everyone fools each other that the development is the wonder of improved political and managerial skills, increased globalization or a better mood of God. The very increase in housing values allows owners to obtain higher values of mortgages either for investment or consumption. The equity markets enjoy the same spots of bright light as the fundamentals do indeed fare well. The myopia of most agents pushes the prices of assets above their long-run averages. They all consider fundamentals (such as production, consumption, employment) at their current levels without discounting for the inherent costs that allowed them to reach those levels and without actually matching the levels of production to the normal level of consumption. If we all agree things will be better and we all act on these expectations, eventually all valuations will be pushed upwards. How much better do things have to be in order to sustain the increased consumption is a question of petty importance at these times. It becomes important when credit is no longer there: either because inflationary fears prompt central banks to increase interest-rates (mostly because of some oil spike or commodities' prices bubbling) or because one key player in the financial markets ruins the trust chain for everybody. Most developments and construction face higher cost of financing, costs they are unable to meet. Leveraged investments dominate the construction industry. When credit dries up the industry virtually halts. The spiral reverses and the engines driving the economy stop along with the flow of capital. Those caught in the "borrow money to develop" game see at the same time a drop in consumption (thus lower rents that usually covered the interest payments) and a lack of a liquid property market that would allow them to sell some part of their portfolio in order to deleverage. It happened in the US several times this century: it started in the 20's with the wave of urbanization to end in 1929 with a terrific crash; it started in the 80's to climax in the savings and loans crisis (S&L crisis) and the ensuing 1990-1991 recession; it started in the mid 2000 to lead to the recession that we witness today. The UK has also had its share: the property boom of 1965 and the crash in 1974. Japan is yet another example. The culprit (at least for the media): the property market.

This work has been developed during the booming period of commodity prices of 2006 and the following recession. My interest in understanding property crystalizes in three papers: two on risk and one on measuring returns. Property is not like equity or bonds. One therefore needs to use with extreme care the tools developed for the traditional asset classes.

One such example is duration. The appeal of the duration concept comes from its simplicity and wide-use in portfolio immunization. Various duration measures are available for fixed income securities with predefined cash flows or interest-rate dependent cash flows. Real estate shares some features with fixed-income securities (relatively stable cash-flows) but it also has very distinct properties (no fixed maturity, possibility to "upgrade" the asset through investment). Furthermore Swiss rental real estate is particular within the real estate universe due to the existing legal restriction of the rent revising process. This implies that the standard duration measures developed for bonds need some adjustments when used with real estate assets. In the first paper I develop an empirical measure of interest rate sensitivity for the Swiss direct residential real estate market starting from the dynamic DCF model of Campbell and Shiller. The estimated long-run sensitivity of direct real estate investments as proxied by the IAZI index with respect to the 10 year Swiss Confederation bond yield is of -4.5%.

The second paper deals with the cost of ignoring the specificity of real estate markets. This paper presents the impact that the autocorrelation in property returns has on the computation of risk measures (VaR or ES) in an ALM framework. I look at the risk-management framework used to compute the risk-based capital of the Swiss Solvency Test. A 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 I do not make any assumptions on the causes of the smoothing thus no "filtering" method is used. Given a smoothed time-series of returns I 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.)

The third paper looks at the long-run development of the Swiss rental market, a market characterized by very few transactions and an incredibly small vacancy rate. The lack of regular transactions renders the measurement of returns a complicated matter. In this paper I construct an index of the Swiss residential market starting as early as 1937. Given the data sample at my disposal of roughly 1000 paired data points I focus on the repeated-measurement methodology to evaluate both an equally-weighted and a value-weighted yearly price index of rental residential property spread across all of Switzerland. I also develop an alternative of the SPAR method (Sale Price Appraisal Ratio) and compute an index based on this new method. The newly developed ISPAR method yields similar results as the repeated-measurement yet is less influenced by the sample size in the years with few data points.

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What is the ”duration” of Swiss residential real estate?

1.1 Introduction

Duration is a measure of how long it takes for the price of a vanilla bond to be repaid by its cash-flows. It is computed as a weighted average of the times that payments are made with weights given by the present value of the payments. It is measured in years and it can be used to evaluate the exposure of the bond's value to fluctuations in interest-rates. Bonds with short maturities face less interest rate risk than bonds with long maturities. The risk arises from not knowing the price at which one might sell his bond, if needed, before maturity. The further into the future the maturity, the greater the uncertainty and thus the risk carried by that bond. If an investor acquires a bond exclusively for its cash flows and does not face any potential need to sell the bond before maturity then the risk he faces is only that related to reinvesting the received cash-flows. Macaulay (Macaulay (1938)) defined duration as

$$D = \sum_{i=1}^{i=N} \frac{PV(t_i)t_i}{PV} \tag{1.1}$$

where $PV(t_i)$ is the present value of the payment made at time t_i and N is the bond's maturity. When the Macaulay duration is divided by (1 + yield-to-maturity) one obtains the *modified duration*

$$D_m = \frac{D}{1+y} \tag{1.2}$$

This measure of duration is important as it represents the price sensitivity of the bond with respect to its yield. The approximate relation is:

$$\Delta P \approx -D_m P \Delta y \tag{1.3}$$

where P is the bond's price and y is the bond's yield. Once the modified duration is computed one can more easily understand the amount of risk borne by the bond. Once the concept is extended to a portfolio of fixed-income securities the idea of portfolio immunization can be implemented.

As soon as the fixed-income security has random cash-flows, the above definitions do not apply anymore. Bonds with embedded options have cash-flows depending on the level or dynamic of interest rates. Two measures have been developed to asses the interest-rate sensitivity in this case, namely empirical and effective duration. The *empirical duration* is a measure of interest-rate sensitivity based on observed(historical) data. It is estimated statistically by regressing usually relative changes in prices on absolute changes in yields. This duration measure was used in estimating the interest-rate exposure of mortgage-backed securities (DeRosa et al. (1993)). *Effective duration* employs simulations to evaluate the interest-rate sensitivity of fixed-income assets with embedded options. A model for the discount rate and for the embedded option is used; through Monte-Carlo simulations one obtains an effective duration by taking into account the expected reaction of the cash-flows with respect to a change in interest-rates (if rates decrease then cash-flows might stop in the case of puttable mortgages). This was used for bonds with call or put options (Kalotay et al. (1993)).

In all the previous cases the bond's value and cash-flows depend exclusively on the interest rates. Evaluating the interest-rate sensitivity in these case is relatively straightforward as one knows with a fair degree of certainty which variables to use in the regression (in the case of empirical duration) or which option to model (in the case of effective duration). When cash-flows and values depend on other economic variables or several inter-related options are present, the issue becomes a bit more complex. Real estate is one such asset: it has relatively stable cash-flows (as compared to equity) which can depend both on the state of the market and on other financial variables (as an example the inflation-indexed contracts in the US and Switzerland or upward-only contracts in the UK can be considered). Real estate values will therefore depend on interest-rates through the discount factor and through its impact on cash-flows but it will also depend on market forces and other financial (inflation) and non-financial variables (construction costs, etc.). This argument shows why the traditional notion of duration cannot be applied to real estate: as the asset value can change due to variables other than the interest rate, using the traditional duration concept can over- or under-estimate the interest-rate sensitivity depending on the real estate market condition and interest-rate environment. One easy example can clarify the point: in an up-market the asset value can increases due to improved expectations of cash-flows (assume that the risk-free rate stays constant). If one uses the classical duration concept (in this case actually the effective duration) than one attributes the entire change in value to changes in interest-rates without looking at the effects from cash-flows. The previous example shows that identifying the important variables and the mechanism through which they affect present values is the "conditio sine qua non" for a proper evaluation of the interest-rate sensitivity for a real estate asset.

1.1.1 Overview of the Swiss rental market

One of the features which renders the real estate asset distinct from the other investment assets is that it has a dual nature being at the same time an investment asset and a consumption good. Investors are interested in its investment features whereas families and individuals are interested in both its consumption and investment characteristics in the case of ownership or just in consumption for those renting. This implies that in the case of rental housing, demand will come through two different channels motivated by relatively different preferences. One of the demand channels is represented by the needs of the those buying real estate for its income-producing ability (the investment channel). This channel reveals the preference for the investments qualities offered by the real estate asset (stable cash-flows, low volatility of capital values, etc,). The second channel is represented by the demand of individuals who want to rent real estate to consume its housing flows (the consumption channel) and so indicates the preferences for the rental real estate good. Anderson (Anderson et al. (1993)) indicates that Swiss pension funds hold 19% of their wealth in real estate. The same study shows that insurance companies hold 21% of their wealth in real estate. The interest of institutional investors in real estate is focused mainly on the inflation-hedging characteristics of this asset class (Hamelink and Hoesli (1996), Liu et al. (1997)) and also on its stable cash flows, apart from the usual diversification benefits(Montezuma and Gibb (2006)). The stable cash flows are an extremely useful feature for investors who need to match the streams from their assets with those to their liabilities.

The influence of the consumption channel is particularly important in the Swiss market. With almost two thirds of the Swiss renting, the consumption pattern of housing services in Switzerland shows a particular strong preference for renting. This inclination for renting coupled with a low vacancy rate (Thalmann (February 2008)) can be seen as the main reasons why real estate provides stable cash flows.

Regulation plays a major role in the determination of allowable rent increases for existing rental agreements. Changes in the gross rent are possible when a set of financial variables selected by the regulator register a change. An increase of the net rent is allowed when the mortgage rate increases while an increase of the operating costs is possible when the CPI increases. Even if the landlord has the possibility to increase his rent he might choose not to do so if the contractual rent is already high as compared to apartments with similar characteristics (size, location, attractiveness, etc.) and the increase might drive out the tenant. The connect to these two financial variables leads to rents on existing contracts departing from market rents (new contract rents). New contract rents depend primarily on real estate market-specific variables like production costs, demand and offer of rental housing and the user cost of renting versus owing. Therefore they have a dynamic different from that of contractual rents which move primarily with mortgage rates and inflation. The gap between contractual and market rent can be closed by total renovation of the property when the discounted value of expected rent increase minus renovation costs is positive (renovation option).

The brief presentation of the Swiss rental housing market shows that this asset has cash flows with several embedded options some depending on the dynamics of interest rates and some depending on the state of the market. This raises the question if one can use the concept of duration with real estate. Clearly the traditional measures of duration used for fixed-income securities (Macaulay or the modified duration) need to be amended for real estate. The presence of the above-mentioned options and the lack of a clear value for the maturity of the asset invalidate the use of the Macaulay duration. Making some assumptions about the maturity of real estate, one answer could be given by the *effective duration*. The effective duration is a discrete approximation of the change in the bond's value given a change in the yield where the value of the bond is computed using some model for the embedded option. This measure is used (as mentioned in the previous section) to evaluate the duration of mortgages that have a prepayment option. Given a change in the discount-rate (yield) one can then determine how the entire bond value changes given the option-linked changes in the cash-flows. If for example interest rates decrease then borrowers will put back the mortgage to refinance at the lower rate. This means that the cash flows stop and the initial value of the bond changes when the borrows decide to exercise their put option. The change in the discount rate is the only driver of both cash-flow and value changes. In the case of real estate, the discount rate causes changes in values and changes in cash flows (as interest-rate movements can be passed on to tenants) yet changes in cash flows and values are also caused by existing market forces (the level of vacancy, the possibility of buying instead of renting, etc). As several options are present, some interlinked (a fall in the interest-rate leads to a fall in rents but also to a fall in the financing costs of a potential renovation) the use of the effective duration requires that all options be modeled. Even if this a priori complex exercise is solved one sees that effective duration is a feasible solution when the discount rate is the only variable that controls the exercising of the options. In the case of Swiss real estate, the triggers are the discount rate but also the construction costs (for the renovation option) or some strategic considerations existing in the interaction between tenant and landlord (for the interest rate option). These arguments indicate that a different measure of interest rate sensitivity is needed for Swiss rental real estate.

1.2 Existing literature

Two distinct streams of literature have been identified. The classification is done according to the tools used in assessing the duration figure. One stream deals with the duration of real estate in a standard DCF setting (these models look mostly at commercial real estate). The value of the real estate asset is given by the discounted value of its future cash-flows. The cash-flows are modeled according to the most pervasive contractual provisions while a constant growth parameter is assumed to model the market rent. The discount factors are fixed over the term of the investment and are set according to the then-prevailing market consensus. The contractual rent is increased to the market at predetermined time-periods (usually after periods of 5 years in the case of U.K. properties). The Macaulay duration is then computed as the derivative of the PV with respect to the discount factor. This analytical approach has the advantage that it identifies the constituents of duration (Hartzell et al. (Fall 1988)) and that it allows the determination of duration according to the provisions present in the rental contract(as in MacLeary and Nanthakumaran (1988) and **?**). In the case of U.K. commercial property Hamelink et al. show the following:

- Duration increase with the term to reversion of the property: the longer it takes until the next rent review the higher the duration.
- Duration increases the more the market rent exceeds the contract rent.
- Duration and the inflation flow-through are inversely proportional.

Given historical averages of the discount rate, of the growth of the market rent and of the inflation flow-through Hamelink et al. compute a duration of 3.57 for the U.K. property. A straightforward regression aims at double-checking this number. The result of the their regression model is 3.036 using the log of the Blundell-Ward de-smoothed version of the IPD index regressed on a constant plus the log of the discount rate. Hartzell et al. on the other hand tackles the problem in a similar fashion. The distinctive feature of their analysis is that they differentiate between a perfect market regime and a market frictions regime. The authors then investigate the impact of the two market structures on the effective duration of U.S. commercial property. Their results indicate that:

- Effective duration increases with the lease term of the property.
- Investors have some control over the duration of the asset through the lease contracting process.

Table (1) gives an overview of the results from the mentioned studies. The framework used

Study	Duration	Remarks
Hamelink et al.	3.036	Value from the simple log-log regression
Hamelink et al.	3.15	Value computed using the cross-correlation between growth and the discount rates
Hamelink et al.	3.57	Value computed with the cross-correlation between changes in growth and discount rates
Ward	2.77 to 36.05	Duration values depend on the yield level and on the maturity of the investment
Hartzell et al.	4.0	Given a 10 year lease and a discount rate of 11.3% - in the market frictions regime

Table 1.1: Duration values - overview of the existing studies

by both Hamelink et al. and Hartzell et al. needs nevertheless to be modified in order to be implemented for the Swiss residential market. Residential property has different types of contractual conditions as compared to commercial property. Rent reviews are both upwards and downwards and are driven by the mortgage rate. Reaching the market rent is possible only through total renovation and is not granted at termination of an existing contract. Rental contracts can be terminated twice per year provided a timely notification occurs. These issues can be nevertheless included in the framework provided proper data is available. The estimated duration using the Hamelink et al. procedure applies to one property and cannot be extended to a portfolio level without first looking at its exact composition. My first intention was to also analyze the composition of the index on which my empirical analysis is based. The insights that the Hartzell/Hamelink/Ward methodology offers would make this methodology well-suited for my purpose. Knowing the composition of the data-base of transactions that underlie the estimation of the index would actually allow one to compute the theoretical duration of the entire index. Unfortunately no information whatsoever on either the actual composition of the index or some estimates of the cash-flow growth rates or actual vacancy rates could be obtained.

The second stream of literature does not actually deal with duration in a direct way but looks only at one of its interpretations, namely the interest-rate sensitivity Annett (2005); Iacoviello (2005); Sutton (2002); Tsatsaronis and Zhu (2004); Iossifov et al. (2008). Most of these studies identify the interest-rate sensitivity in a larger macro-economic context. Depending on the methodology and the data set employed the results show a clear dependence of the house price on macro variables (GDP, income per capita), social variables (population and immigration growth, changes in the family formation habits) and on financial variables (inflation, credit volume, real and nominal interest rates). Most of the above mentioned studies look at the impact of the three categories of variables mostly on residential property indices or broad market indices which include the value of both owned and rented homes. The methodologies employed are either multiple equation systems or panel regressions and have as primary goal identifying the causes for the observed price development in a broad macroeconomic analysis. The time frequency is in many cases yearly with weight placed mainly on the impact of the housing market on financial stability and long-run growth. A specific analysis of the rental housing segment offers a more stable result as it attempts to isolate the changes in cash flows from the changes in discount rates. Table 2 summarizes some of the findings (Iossifov et al. (2008)) with respect to the interest-rate sensitivity of real estate: The Iossifov et al. (2008) paper offers the argumentation for the observed

Study	Interest-rate sensitivity	Remarks
Annet (2005)	-0.01 to -0.03	eight countries
Ayuso et. al. (2003)	-4.5	Spain
Egert and Mihaljek (2007)	-0.002 to -0.015	OECD countries
	-0.001 to -0.046	CEE countries
Hoffman (2005)	-9.42	Netherlands
Hunt and Badia (2005)	-6.0	U.K.
Iossifov et al. (2008)	-3.6	average over 86 countries
Meen (2002)	-1.3	U.S.
	-3.5	U.K
Nagahata et al.	-0.6 to -4.5	Japan
OECD (2004a)	-7.1	Netherlands
Sutton (2002)	-0.05 to -1.5	
Terrones and Otrok (2004)	-0.5 to -1.0	
Verbruggen et al. (2005)	-5.9	Netherlands

Table 1.2: Interest-rate sensitivity values - overview of the existing studies

variation in the estimates across countries. Their best estimate for the interest-rate sensitivity of real estate is -3.6

1.3 Data

The selection of the index measuring the Swiss direct real estate market is motivated by the recommendations of the SST (Swiss Solvency Test). The SST is a risk management framework which determines the risk capital an insurance company needs to hold in order to be able to fully cover its liabilities FINMA (2009). Real estate is one of the asset classes present on the balance sheet of the insurance companies and therefore a measure of interest rate sensitivity is needed in order to estimate any potential mismatch between assets and liabilities.
The performance of the direct real estate market is measured by the SWX IAZI Investment Real Estate Performance Index (available on www.iazi.ch). This is quarterly performance index based on transaction data starting in 1987.
For the cash-flows no appropriate index was found. A proxy is used instead, namely an index of rents provided by the Swiss Statistical Office (BFS). This introduces some arbitrariness in the analysis as the focus is on net cash-flows and I have a measure of gross cash-flows. A preliminary look at the growth rates of the index over time shows that a regime change may have taken place around 1994-1995 (see figure in the Appendix). This implies that the stability of the econometric estimate of the interest-rate sensitivity will have to be checked over different time periods. Also of interest is the empirical connect between the growth rate in rents and changes in the mortgage rate and the inflation rate. As the regulation specifies that a change in rents needs to be announced to the tenant three months in advance (and should occur only when mortgage rates change) a regression of the rent growth rates on differences in the mortgage rate (lagged by 3 months) and on the inflation rate (also lagged by 3 months) should offer an idea on the market dynamic. The above mentioned regression is performed for the period 1977 to 1993 with results indicating that up to 80% of the volatility in the rental growth rates was explained by changes in the mortgage rate and by the inflation rate. After this date the same regression indicates a much lower power of the model (the R-squared decreases to 30% for the same regression done over 1993 to 2007). This can be seen as an indication that the rent-update behavior has changed after 1993. A possible reason for the observed change might be the revision in the regulatory framework introduced around 1990 which aimed at sanctioning speculation with real estate assets (if a property is sold within a year from its purchase than the tax on capital gains is roughly 60%). Also important from this brief analysis of the BFS rental index is the estimate of the inflation pass-through rate in the case of Swiss residential real estate. The estimated value is 0.29 (p-value below 1%) for the period 1977 to 1993 but then becomes negative and is statistically insignificant afterwards .
For the discount rate the yield of the 10 year Swiss Confederation bond is used. This choice is motivated by a term-matching argument. If the investment is made for a long time period then the discount rate should also reflect changes in the time-preferences over a more or less equally time frame. An additional reason for this choice is also that a major renovation, which changes the quality of the property (and so its required risk-premium), occurs on average every 15 years.

One important remark is needed here. Duration is usually computed using the yield of the bond. This is equivalent to using the total return required for a property: time-discount plus risk-premium. The variation in risk-premium and its impact on the asset's value is one thing which here cannot be properly taken in consideration. On the other hand when the interest is to include real estate in a larger portfolio containing bonds and other assets the sensitivity of real estate values to changes in bond yields will be actually used when computing either expected short-fall or value-at-risk (as is the case with the Swiss Solvency Test). Thus the interest-rate sensitivity obtained using bond-yields is the measure one needs in an ALM framework such as the SST. The sensitivity of the different components of the discount rate can be evaluated in a theoretical framework as described by Hartzell et al. All time series are at quarterly levels over the time period 1987 to 2008.

1.4 Developing an alternative measure of interest rate sensitivity

The discounted cash flow (DCF) paradigm plays an important role in the evaluation of real estate assets due to wide-use and clarity. It also the starting point of the present study because it shows how the price is related to the asset's cash flows and discount rates. The price for a given asset is computed as $PV = \sum_{i=1}^{T} \mathbb{E}\big[\frac{NOI_i}{(1+r_i)^i}\big]$ where NOI_i stands for Net Operating Income at time i and r_i for the discount rate at time i. One of the most frequently used assumptions is that the expected discount rates will stay constant over time. This simplifies the computations as else one would have to look at the joint distribution of the variables NOI_i and r_i in order to compute the expectation of their ratio. The "constant discount-rate" assumption casts doubt on the validity of the DCF model because it is the volatility of discount rates that mostly contributes to the asset's volatility (Shiller (1981)). For real state, cash flows are rather stable and can be forecasted with better accuracy than those of equity. Given an expected vacancy allowance they are known with certainty for some time ahead being specified in the rental contract. Discount rates on the other hand vary due to the attractiveness and risk profile of the real estate asset as compared to the other assets trading in the market. Academic research indicates that real estate returns are to some degree forecastable and that they do have enough volatility over time (Liu and Mei (1994), Mei and Liu (1994)) to reject the "constant returns assumption" frequently used in the DCF model. Once one recognizes the impact of changing discount rates, a measure of interest rate sensitivity can be derived by trying to connect changes in prices to changes in discount rates. In the DCF formula this task is not possible unless one knows the future distributions of the $NOI_i/(1+r_i)^i$ for all the T time periods ahead. Fortunately, Campbell and Shiller (1989) derived an approximation of the present value model (referred to as the log-linear approximation) that allows one to compute the price of an asset as a linear relation between its expected cash-flows and its expected returns. Let p_t, d_t and r_t be the log-price, the log-rent and log-return respectively at time t. Campbell-Shiller transform the definition of the log-return and then use a first-order Taylor approximation around the long-term value of d/p such that the approximate log-return is written as a linear combination of the cash-flows and prices:

$$r_{t+1} \equiv log(P_{t+1} + D_{t+1}) - log(P_t) \tag{1.4}$$

$$= p_{t+1} - p_t + log(1 + exp(d_{t+1} - p_{t+1})) \tag{1.5}$$

$$r_{t+1} \approx k + \rho p_{t+1} + (1-\rho)d_{t+1} - p_t \tag{1.6}$$

Solving the approximation forward and imposing a terminal condition Cambell-Shiller connect the log-price to the separate expected values of the cash-flows and of the discount rates.

$$p_t = \frac{k}{1-\rho} + (1-\rho)\sum_{j=0}^{\infty} \rho^j \mathbb{E}_t[d_{t+1+j}] - \sum_{j=0}^{\infty} \rho^j \mathbb{E}_t[r_{t+1+j}] \tag{1.7}$$

The two linearization constants k and ρ depend on the log values of average rent and return and $\mathbb{E}_t[x]$ is the expectation of the random variable x conditional on the information available at time t. One can see from (1.7) that a change in the price (say $p_{t+1} - p_t$) will actually be the continuously-compounded return provided by the asset over the period $[t, t+1]$. In an efficient market with rational agents this return will depend on the revision in expectations that occur from time t to time $t+1$.

Several studies (Mei and Gao (1995), Liu et al. (1990),) show that real estate markets are not as efficient as the equity or bond markets. The sluggishness of the direct market implies that real estate prices will take a relatively long time to fully incorporate any new information. Of particular importance are news related to the dynamics of the discount rate. The impact of these pieces of information will not be easily observed because of the lack of a transparent and liquid market. The value of property will eventually change according to the new market conditions yet these value changes, when observed, will contain the response to all the information accumulated between two transactions of that property. On top of the difficulties related to the microstructure of the property market, the literature on behavioral real estate (Wheaton and Torto (1989), Daly et al. (2003), Diaz III (1999), Diaz III (1990a), Diaz III (1990b), Born and Phyrr (1994)) indicates that both appraisers and investors anchor on past values of both rents and interest rates when forming estimates for the future. They therefore extrapolate past values and trends into the future using these as expectations. In such a market one expects returns to depend not on expectations but on present and past values of changes in cash flows and on present and past discount rates. This conjecture together with the log-linear approximation form the basis of the econometric model that we test with Swiss direct real estate data.

1.5 Results

The starting point of the model implementation is an autoregressive distributed lag model (ADL). The independent variable is the changes in prices while the exogenous variables are represented by changes in cash-flows and the levels of the discount-rate. As previously mentioned the changes in cash-flows will not be a truly exogenous variable because the discount-rates are connected to changes in cash-flows through the mechanism described in the previous subsection (the mortgage rate is highly correlated with the 20 year yield). The linear structure of the econometric model draws from (1.7) where the autoregressive term allows for the possibility of having some form of return predictability. The starting point of our analysis is a standard ADL specification as the one developed in equation (1.8).

$$x_t = \alpha + \sum_{i=1}^{p} \beta_{1i} x_{t-i} + \sum_{j=0}^{q} \beta_{2j} y_{t-j} + \sum_{k=0}^{m} \beta_{3k} z_{t-k} + \epsilon_t \tag{1.8}$$

The variables in the model are the quarterly continuously compounded returns computed from the IAZI index (x), the quarterly continuously compounded returns computed from the rental index (y) and the quarterly yield values of the 10 year Swiss Confederation bond (z). The lag-length selection procedure is dictated by the data and not imposed a priori (using one of the Information Selection Criteria such as the Akaike or the Schwartz-Bayesian). The parameter β_{30} will be the expected percentage change in the quarterly IAZI return given a 1% change in the contemporaneous yield when all other variables stay fixed. Before finding the best specification for the econometric model the yield data is tested for the presence of an unit root. The augmented Dickey-Fuller test is employed using for the regression a constant and a trend (the automatic Ng and Perron lag length selection procedure is used to select the proper number of lags to be included in the test). The p-value of the test is 0.0084 thus one fails to accept the null hypothesis of a unit root. The value of the Durbin-Watson test indicates that all relevant lags have been accounted for in the ADF test. A first evaluation of (1.8) yields disappointing results with respect

Time Series	T-test value	P-value	Remarks
CHF 20Y yield	-4.133	0.0084	time and constant included
CHF 10 yield	-3.696	0.0284	time and constant included
BFS index returns	-2.904	0.051	constant included
IAZI index returns	-3.44	0.01238	constant included

Table 1.3: The Augmented Dickey-Fuller unit root tests

to β_{30}, the estimated coefficient of the expected change in the IAZI index with respect to a 1% change in the bond yield. The standard error is very large rendering the estimate unreliable. A look at the yield time series indicates the presence of some autocorrelation. As the yield is autocorrelated of order 2 one can try to capture the effect of the change in yield over 3 quarters. The model will therefore include 2 lags of the yield. An F-test shows that the presence of the $t, t-1$ and $t-2$ values of the yield have a jointly significant effect on the IAZI index and thus need to be included in the regression. The estimated model is given by

$$r_t^{IAZI} = \alpha + \beta_{14} r_{t-4}^{IAZI} + \sum_{j=0}^{1} \beta_{2j} r_{t-j}^{rents} + \sum_{k=0}^{2} \beta_{3k} r_{t-k}^{CHF} + \epsilon_t \tag{1.9}$$

If the model is specified without any autocorrelation terms, the Ljung-Box test and the autocorrelation function of the regression residuals indicate that something is missing in the model. The choice of the fourth lag for the return on the IAZI index is thus motivated by the presence of the corresponding spike in the sample autocorrelogram of the errors. This result is particulary interesting as the IAZI index is a transaction-based index. The p-values of the estimated coefficients indicate statistical significance only at the 10% level. The parameter values along with the corresponding p-values (in parenthesis) are given in Table (3). The multi-collinearity of the yield

Parameter	Value	Std. Error	p-value
α	0.05	0.013	(0.0003)
β_{14}	-0.28	0.149	(0.0632)
β_{20}	1.21	0.839	(0.1549)
β_{21}	-1.13	0.859	(0.1911)
β_{30}	-5.52	5.040	(0.2781)
β_{31}	7.19	7.628	(0.3504)
β_{32}	-6.45	4.810	(0.1862)
Jarque-Bera	1.53		(0.4639)
Ljung-Box	24.05		(0.1181)
Durbin-Watson	1.66		
R-squared	0.24		
Adj. R-squared	0.15		

Table 1.4: Regression results - time period 1995-2008

causes the estimates to be unreliable for the period 1995-2008. At this point a transformation of the model is necessary in order to obtain some meaningful results for the interest-rate sensitivity. The estimates for the rent are also fairly unreliable. Recognizing the effect of multi-collinearity the yield lags can to be rewritten as:

$$\begin{aligned} \beta_{30} r_t^{CHF} + \beta_{31} r_{t-1}^{CHF} + \beta_{32} r_{t-2}^{CHF} &= \gamma r_t^{CHF} + \beta_{31}(r_{t-1}^{CHF} - r_t^{CHF}) \\ &+ \beta_{32}(r_{t-2}^{CHF} - r_t^{CHF}) \end{aligned}$$

with $\gamma = \beta_{30} + \beta_{31} + \beta_{32}$. At this stage one recognizes that the original data was not modified, only rearranged (Woolridge). This transformation of the original model will produce a reliable estimate of the long-run propensity γ: given a 1% permanent increase in the yield, the IAZI will change by γ%. The contemporaneous effect unfortunately cannot be estimated with enough precision. The model will therefore use as explanatory variables r_t^{CHF}, $\widetilde{r_{t-1}^{CHF}}$ and $\widetilde{r_{t-2}^{CHF}}$ with

$$\widetilde{r_{t-1}^{CHF}} = r_{t-1}^{CHF} - r_t^{CHF}$$
$$\widetilde{r_{t-2}^{CHF}} = r_{t-2}^{CHF} - r_t^{CHF}.$$

The transformed model now becomes:

$$r_t^{IAZI} = \alpha + \beta_{14} r_{t-4}^{IAZI} + \beta_{21} r_t^{rents} + \beta_{22} r_{t-1}^{rents} + \quad (1.10)$$
$$+ \gamma r_t^{CHF} + \beta_{31} \widetilde{r_{t-1}^{CHF}} + \beta_{32} \widetilde{r_{t-2}^{CHF}} + \epsilon_t \quad (1.11)$$

The results from the transformed model are presented in Table (1.5). The estimate for γ is

Parameter	Value	Std. Error	p-value
α	0.05	0.013	(0.0003)
β_{14}	-0.28	0.149	(0.0632)
β_{20}	1.21	0.839	(0.1549)
β_{21}	-1.13	0.859	(0.1911)
γ	-4.78	1.586	(0.0041)
β_{31}	-7.19	7.628	(0.3504)
β_{32}	6.45	4.810	(0.1862)
Jarque-Bera	1.53		(0.4639)
Ljung-Box	24.05		(0.1181)
Durbin-Watson	1.66		
R-squared	0.24		
Adj. R-squared	0.15		

Table 1.5: Regression results using the transformed model - time period 1995-2008

now highly significant. The error analysis indicates good properties of the OLS residuals. No heteroscedasticity can be observed or any GARCH effects (tests still needed). The appendix contains the graphs of the time series of residuals and of the squared residuals. The estimate for γ indicates that a decrease of 1% in the bond yield will be followed by an approximatively 4.7% increase in the IAZI index after two quarters. The standard error on the estimate is 1.5 implying that the 95% interval is [-1.7, -7.7].

One important question at this point is whether this estimate is indeed a reliable long-run sensitivity. The change in dynamic observed in the rental index could actually indicate a change also in the asset market which inevitably means that the estimate for the period 95-08 might not be so reliable when thinking long term. Therefore the same model is estimated for the entire period in which the data is available, namely 1988 to 2008. The results of the model are stable over the entire period (see Table 1.6) improving in terms of their statistical significance. When the model is estimate over the entire time-span the rent variables become significant at the 5% level. The 95% confidence interval for γ is now [-2.5,-6.5]. These results may be interpreted as the

Parameter	Value	Std. Error	p-value
α	0.04	0.009	(0.0000)
β_{14}	-0.22	0.124	(0.0684)
β_{20}	0.54	0.249	(0.0331)
β_{21}	0.5424	0.246	(0.0689)
γ	-4.56	1.049	(0.0000)
β_{31}	-2.77	5.096	(0.5880)
β_{32}	5.12	3.172	(0.1103)
Jarque-Bera	2.81		(0.2453)
Ljung-Box	18.57		(0.4186)
Durbin-Watson	1.91		
R-squared	0.22		
Adj. R-squared	0.16		

Table 1.6: Regression results using the transformed model - time period 1988-2008

potential equilibrium interest-rate sensitivity. The long-run propensity parameter is considered to be the expected response of the independent variable when the level of dependent variable is the same in all the three quarters considered in the regression equation (Wooldridge (2006)). Let x^* be the equilibrium level of the independent variable and z^* the equilibrium level of the dependent variable. Consider the simple case with only the bond yield as a dependent variable for ease of exposition. In this case the regression equation is written as

$$x^* = \alpha_0 + \beta_{30} z^* + \beta_{31} z^* + \beta_{32} z^* + \epsilon \tag{1.12}$$

One sees now that the change in the equilibrium value of x^* caused by a change in the equilibrium value of z^* is given by

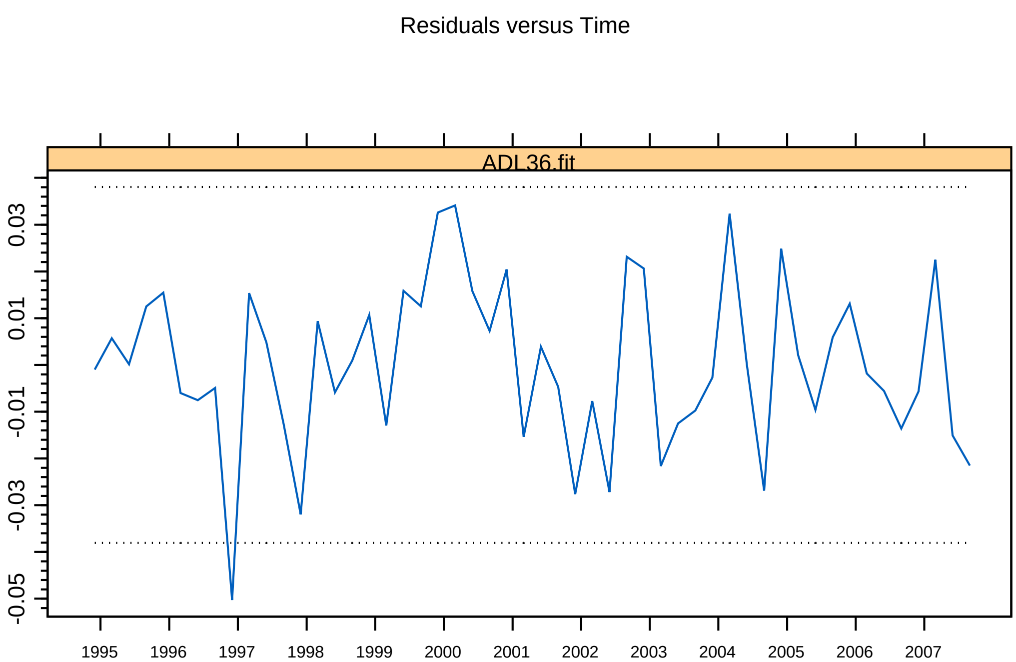
$$\frac{\partial x^*}{\partial z^*} = \beta_{30} + \beta_{31} + \beta_{32} = \gamma \tag{1.13}$$

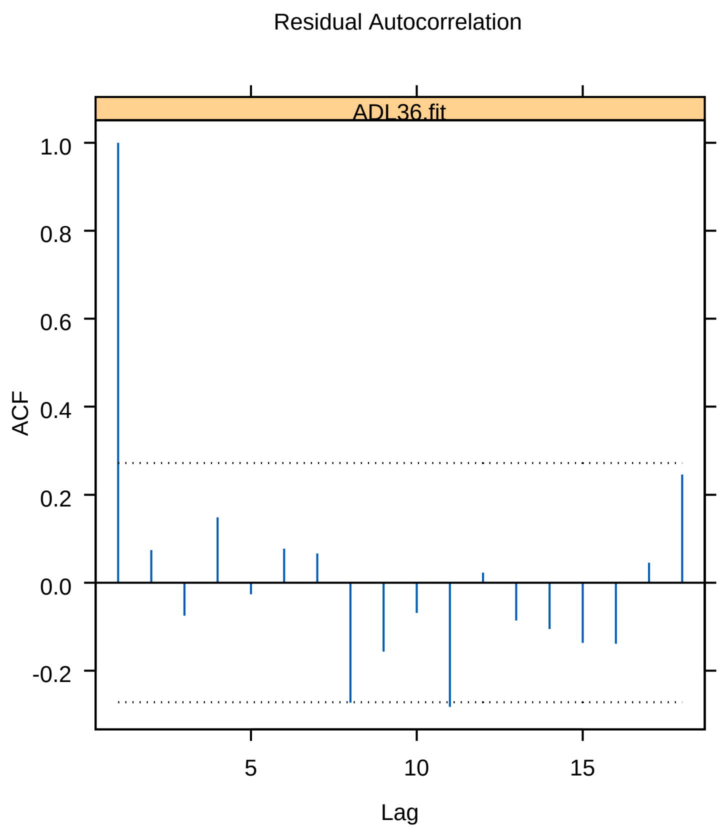
If one is interested in a dynamic measure of interest-rate sensitivity then γ will be the value of interest. If on the other hand the focus is on an average measure then the γ will need to be added to the average value of the return which can be estimate using the sample mean return of the x series.

1.6 Conclusions

In this paper we review the existing methodologies for the computation of the duration of real estate. We see that the Swiss market particularities in conjecture with our goal limit the number of the existing option. We need to focus on the aggregate market as describer by the IAZI index therefore property-specific duration formulas cannot be used. On the other hand the models based on multi-equation systems are too data intensive for our needs. Given the data constraints we develop a new model which builds on the Campbell-Shiller DCF linear approximation. We pay particular importance to the statistical properties of the time series used in the estimation and incorporate results from the behavioral real estate literature in the definition of the econometric model. The main contribution is the precise estimation (p-values below 1%) of the long-run interest rate sensitivity of the IAZI Performance Index. Given a 1% decrease in the yield of the Swiss confederation 10-year bond we expect an increase of roughly 4.5% of the return of the IAZI index. This increase will not be immediate but it will require three quarters to take place (including the quarter in which the interest-rate change occurred). We test the validity of this value on two different samples of data. We compute it for the entire span in which data is available to us as well as on a subsample which excludes a widely-accepted bubble. We find that the interest-rate sensitivity is almost the same in both samples. The result raises the interesting question of whether the monetary policy could have been a driver in the development of the real estate bubble or have little or no influence in its development. One expects a larger interest-rate sensitivity during expansionary periods as the availability of credit and the irrational exuberance push prices above fundamental values. In our case the full-sample results are actually slightly smaller than the post-bubble period. The value of the long-run interest rate sensitivity is of 4.5% for the period 1988 to 2008 and 4.7% for the period 1995 to 2008. More important than the difference in values is the potential hint that for Switzerland the dynamic of the interest-rate was not one of the major contributors to the development of the bubble. These results need nevertheless to be viewed with caution. This is because our sample does not include the entire bubble period as the index is not available in the period prior to the bubble formation. Another reason why care needs to be exercised is the lack of a variable controlling for volume of credit and monetary mass.

1.7 Appendix


Residuals versus Time
ADL36.fit
0.03
0.01
-0.01
-0.03
-0.05
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007


Residual Autocorrelation
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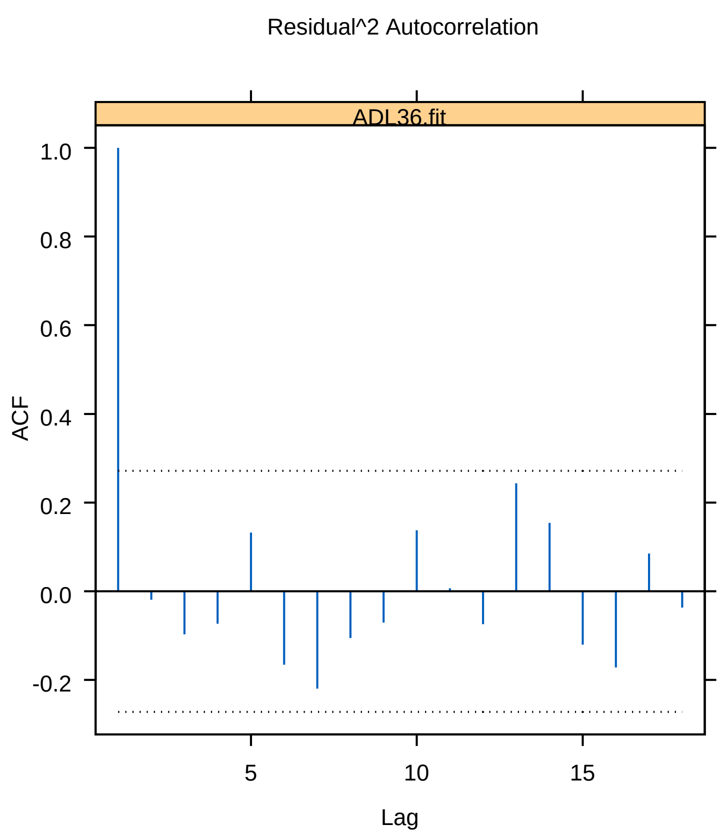
0.8
0.6
0.4
0.2
0.0
-0.2
5
10
15
Lag


Residual^2 Autocorrelation
ADL36.fit
ACF
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
5
10
15
Lag

Manuscript 2

The cost of autocorrelation in real estate returns

2.1 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) FINMA (2009). 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.

2.2 The RiskMetrics methodology

The first ingredients needed in the evaluation of risk are the risk factors (Mina and Yi Xiao (2001)). 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) (Cuthbertson and Nitzsche (2004)). Thus if P_t^i is the price of asset i at time t then

$$\frac{dP_t^i}{P_t^i} = \mu^i dt + \sigma^i dW_t \tag{2.1}$$

For horizons shorter than 3 months it makes sense to set $\mu = 0$ (Mina and Yi Xiao (2001)). 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:

$$\sigma = \frac{1-\lambda}{1-\lambda^{m+1}} \sum_{i=0}^{m} \lambda^i r_{t-i}^2 \tag{2.2}$$

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 (2.2) can be rewritten as

$$\sigma_t^2 = \lambda \sigma_{t-1}^2 + (1-\lambda) r_t^2 \tag{2.3}$$

In this form one can see why λ is called the decay factor. If n assets are present in the portfolio then equation (2.1) 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.

$$\Sigma_{i,j} = \sigma_i \sigma_j \rho_{i,j} = \frac{1-\lambda}{1-\lambda^{m+1}} \sum_{k=0}^{m} \lambda^k r_{t-k}^{(i)} r_{t-k}^{(j)} \tag{2.4}$$

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 (Cuthbertson and Nitzsche (2004)). Direct real estate markets on the other hand do not share the same degree of efficiency and liquidity as stock and bond markets(Geltner (1989b, 1991)). 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".

2.2.1 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

$$\sigma_{RBC} = (s_1\sigma_1 \dots s_{81}\sigma_{81}) \begin{pmatrix} 1 & \rho_{1,2} & \dots & \rho_{1,81} \\ \rho_{2,1} & 1 & \dots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \rho_{81,1} & \dots & \dots & 1 \end{pmatrix} \begin{pmatrix} s_1\sigma_1 \\ s_2\sigma_2 \\ \vdots \\ s_{81}\sigma_{81} \end{pmatrix} \tag{2.5}$$

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:

$$\widehat{\sigma_i^2} = \frac{1}{T-1}\sum_{t=1}^{T}(r_{it} - \overline{r_i})^2 \tag{2.6}$$

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

$$\widehat{\rho_{i,j}} = \frac{1}{T-1}\frac{\sum_{t=1}^{T}(r_{it} - \overline{r_i})(r_{jt} - \overline{r_j})}{\widehat{\sigma}_i\widehat{\sigma}_j} \tag{2.7}$$

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 (2.5) 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.

2.3 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 (Fama (1970)). 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 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 (Jegadeesh and Titman (1993); Shefrin and Statman (1985)). 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. Several authors (Diaz III (1999); Diaz and Hansz (1997)) 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 (Geltner (1989b, 1991)). Several studies have shown how these biases at the individual level impact the development of appraisal-based indices (Geltner (1989b)) 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. Blundell and Ward (Blundell and Ward (1987))develop 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. 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 3.6 for the smoothing process.

$$A_t = \alpha \overline{P}_t + \underbrace{(1-\alpha)}_{smoothing} A_{t-1} \tag{2.8}$$

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 (Fisher et al. (2003)). 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 2.1. The IAZI index is one of the 81 risk factors used

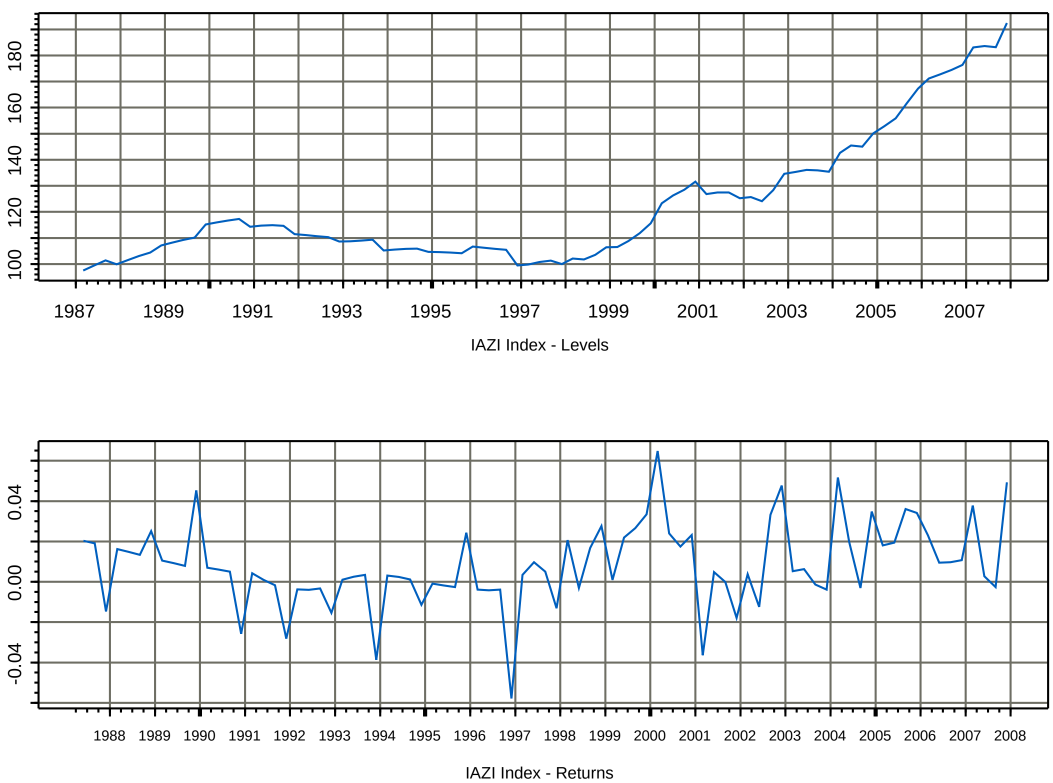


Figure 2.1: The IAZI Performance Index

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

in the correlation matrix needed to compute the RBC. This is equivalent to 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 2.2 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 lacks

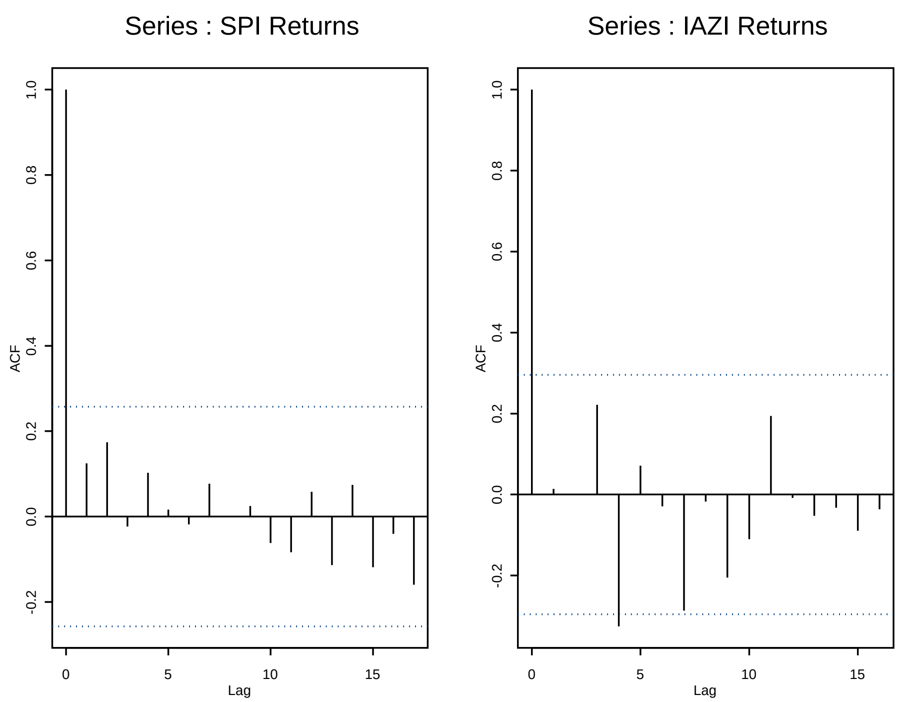


Figure 2.2: The autocorrelation of the IAZI Performance Index and of the SPI index

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

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

to be independent (Shreve (2004)). The correlogram shows that even the weaker assumption of linear independence is not satisfied.

2.3.1 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 2.7 is just.

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

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \epsilon_t^x, \alpha < 1 \tag{2.9}$$

$$y_t = \epsilon_t^y \tag{2.10}$$

$$\epsilon^x \sim WN(0, \sigma_x^2) \quad , \quad \epsilon^y \sim WN(0, \sigma_y^2) \tag{2.11}$$

One can solve the difference equation for x to obtain

$$x_t = \frac{\alpha_0}{1 - \alpha_1} + \sum_{i=0}^{\infty} \alpha_1^i \epsilon_{t-i}^x \tag{2.12}$$

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 (2.6) and (2.7). 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:

$$\sigma_x^2 = \frac{\sigma_\eta^2}{1 - \alpha_1^2} \tag{2.13}$$

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.

2.3.2 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 $x_t = 0.5 + 0.75x_{t-1} + \epsilon^x_t$. A sample of the two series (100 points) is graphed in figure (3). The population covariance,

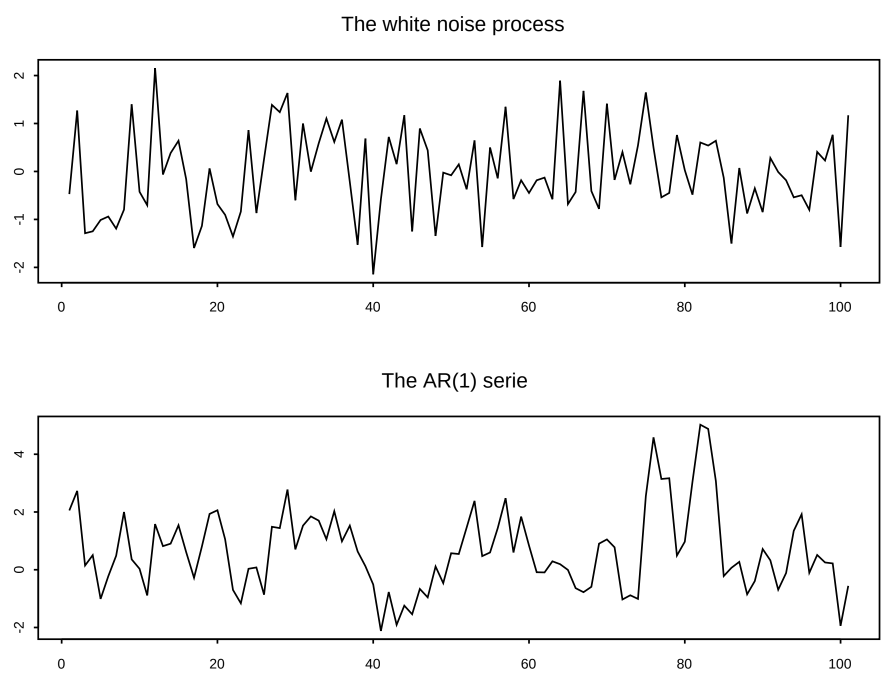


Figure 2.3: The two simulated time series

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 (2.7). The value of the 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 (2.13)) 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].

2.3.3 Estimation of the AR process

Using the Bok-Jenkins procedure several AR structures have been examined. 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 (2.14). The estimated model is:

$$r_t = \alpha + \beta_4 r_{t-4} + \epsilon_t \tag{2.14}$$

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

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 2.1: Parameter values and test statistics

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 (Brown et al. (1976)) the intercept and the fourth-lag coefficient are stable. The CUMSUM of both the residuals and of the squared residuals stay within the bands. The AR model is also estimated using a rolling

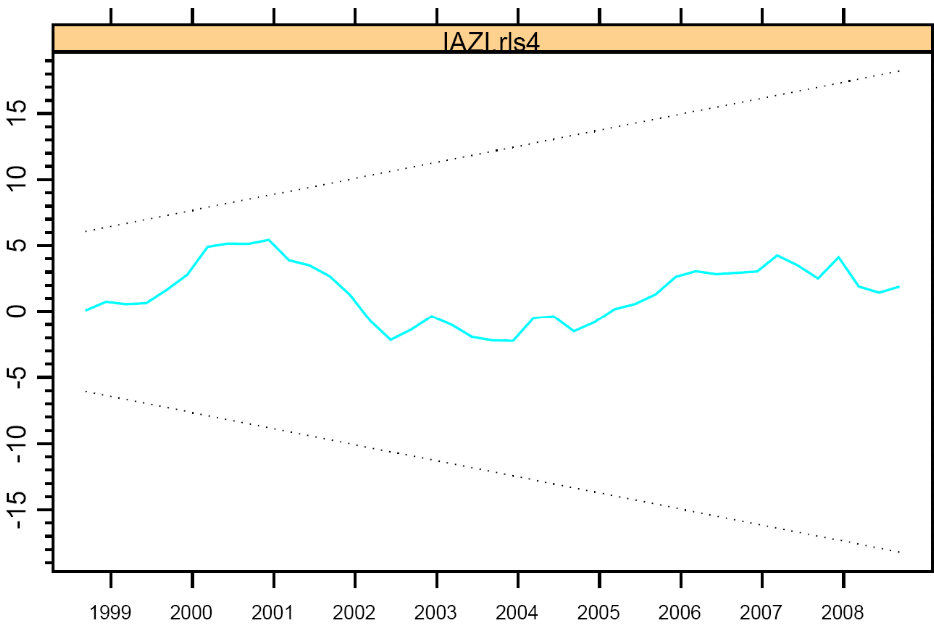


Figure 2.4: Results of the stability tests - the CUMSUM test

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.

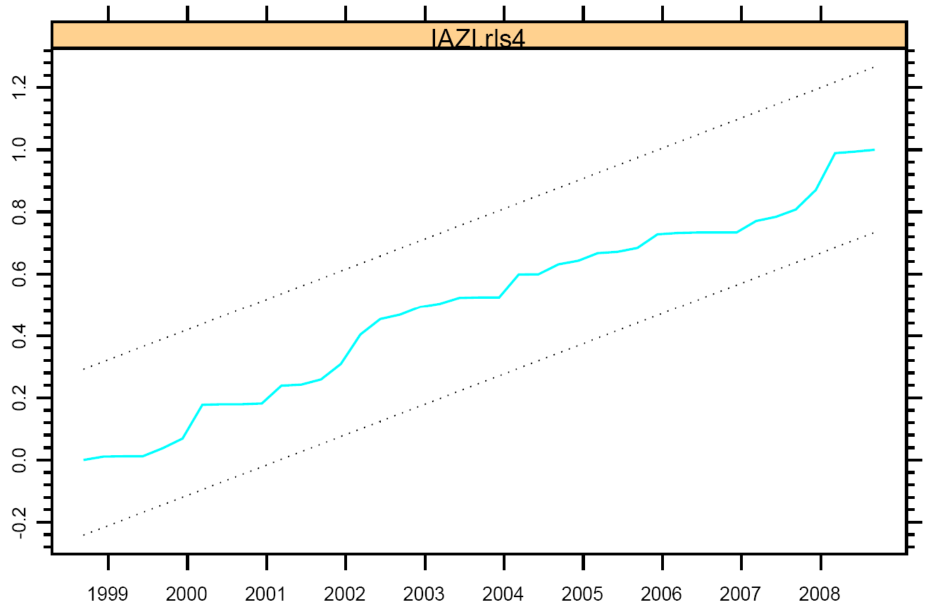
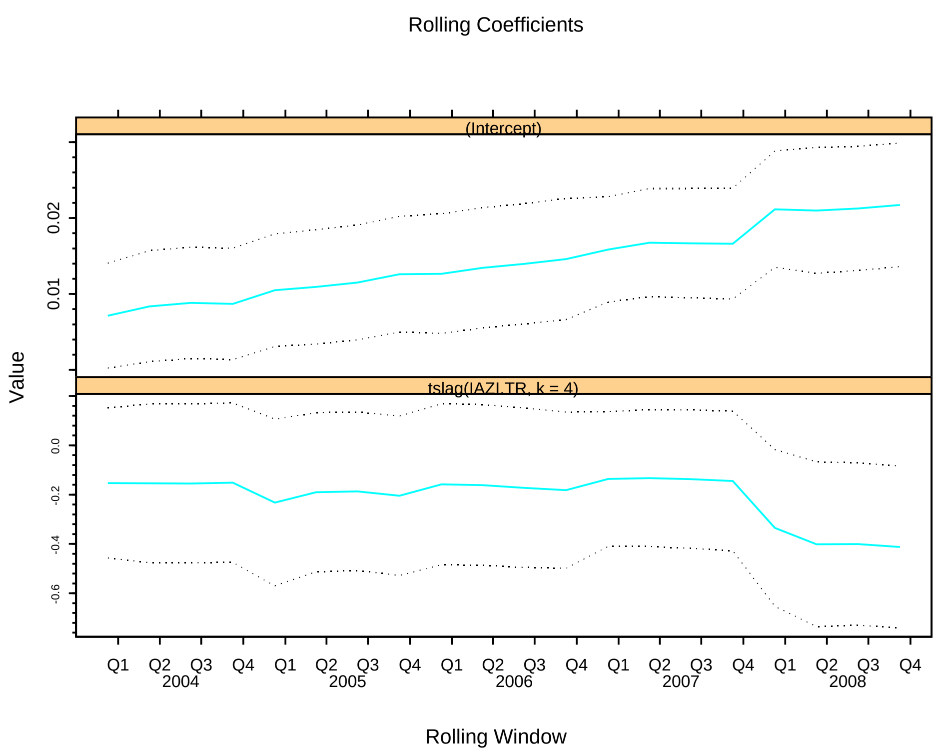


Figure 2.5: Results of the stability tests - the CUMSUMQ test



2.4 Results

The SST White Document states on page 19 (FINMA (2009)): "The asset model is conceptually similar to the well-know RiskMetrics approach ...." This means that asset prices are being modeled as a random walk (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 assumption 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.

2.5 Conclusion

In this paper we have shown 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 into consideration the presence of autocorrelation in the time series of returns.

Part II

Return

Manuscript 3

Measuring returns in the Swiss rental market - A new repeated measure index

3.1 Introduction

The development of real estate prices is closely monitored both by government agencies and investors alike. Their impact on the macroeconomic policy has been clearly shown in the past year and given the sheer size of this asset class it will most likely retain its importance in the future. The focus of this paper is on the development of the rental residential sector from the perspective of an institutional investor holding rental property as an asset. Values and returns are estimated in attempt to build both a price and a total return index reaching as far back in time as 1950. The motivation of this undertaking is the lack of an up to date multi-family housing and the existing exposure of Swiss institution investors to Swiss rental property.

Two indexes measure the development of this market sector. The first index is the IAZI Total Performance Index. This is an index composed of both residential and commercial property with residential making up roughly a half of the underlying pool used to estimate the index. This index is computed starting from 1988. Although mixing the types of properties increases the sample size and thus decreases the standard error of the index, mixing the various real estate sectors masks the actual development of the individual sectors. This occurs both in terms of development of the markets as well as in terms of volatility and correlation to other asset classes. Understanding risk is of utmost importance for investors trying to match the income and risk of real estate with that of its outstanding liabilities. The FINMA (Swiss Financial Market Supervisory Authority) requires any Swiss bank or insurance company investing in multi-family housing to set aside risk capital according to the risk of this investment (FINMA (2009)). The index used for the calculation of the risk based capital is the IAZI index. This is done basically through the computation of a correlation matrix in which the IAZI index captures the risk of residential property. Therefore this index is very important not only for the measurement of returns but also for computing the risk based capital needed to keep the investor running in a time of crisis. The second index is a multi-family housing index of the Zürcher Kantonal Bank (ZKB). It is computed from the beginning of 1980 but unfortunately is no longer estimated after 2000. Our intention is to build an index focused exclusively on multifamily housing starting in 1950 which through its sole focus on rental property will hopefully better indicate market trends and correlations to other asset classes.

3.2 Methods of index construction

The existing literature on real estate index construction has been developed initially around the hedonic (Rosen (1974)) and the repeated sale methodology (Bailey et al. (1963)). In the later years increasing attention has been paid to the hybrid approach and to special applications for thin markets (Schwann (1998)). The SPAR method is also presented as a less error-prone alternative to the existing methods (Bourassa et al. (2006)). This section gives a brief overview of the pervasive methodologies and their documented strengths and weaknesses.

3.2.1 The hedonic index

The hedonic method uses a system of equations to decompose the price of a property as the sum of prices of the individual characteristics of the house. A common hedonic specification usually relates a function of the price (usual is the log of the price) to the house characteristics as in equation (3.1)

$$ln(P_{i,t}) = \beta_{0,t} + \beta_{1,t}X_{1,i,t} + \cdots + \beta_{k,t}X_{k,i,t} + \epsilon_{i,t} \tag{3.1}$$

where $P_{i,t}$ is the price of property i at time t, $X_{k,i,t}$ is the characteristic k of property i at time t, $\beta_{k,t}$ is the marginal cost of characteristic k (such as the price of an extra bedroom or of a fireplace) and $\epsilon i, t$ is property's i random transaction price noise. In order to use the hedonic method in this form one needs to estimate the equation cross-sectionally at each point in time and then compute the values of non-transacting properties based on the results of the transacting properties. This offers a value for the portfolio at time t. At time $t+1$ the procedure is repeated thus leading to the value of the portfolio as of date $t+1$. This method controls for quality yet it requires tremendous amounts of data. In order to estimate the system of equations one needs a list of prices and the corresponding characteristics of those pieces of property transacting. This list contains both property-specific data (total surface area, number of bedrooms, presence of pool, etc.) as well as data pertaining to the geographical location (distance to the Central Business District or access to highway, etc.) and structure of the neighborhood (presence of a school, crime rate, etc.). One of the advantages of this specification is that it allows the prices of the characteristics to vary over time. Functional form and sample size rank among the top concerns regarding this hedonic method. One can assume fixed characteristic prices over time and then estimate the equations including also a time component. This method manages to divorce the cross-sectional effects from the temporal effects. This is realized by including in the regression specification a time-dummy for each period over which the index is estimated.

$$ln(P_{i,t}) = \sum_{j=1}^{k} \beta_j X_{i,j} + \sum_{t=1}^{T} c_\tau D_\tau + \epsilon_{i,t} \tag{3.2}$$

where the novelty comes from assuming a constant $\beta_{i,j}$ and the inclusion of the time dummy variables c_t. The dummy variable D_τ will be 1 if house i is sold in period t and 0 otherwise. The coefficients on the time dummies are the cumulated returns caused by the passage of time while controlling for any quality features. The $t+1$ periodic return is then computed as the difference between β_{t+1} and β_t. With this method one makes a more efficient use of the existing data yet constrains the characteristic prices to be fixed over time.

Numerous version have been developed of the hedonic methodology though all feature as main ideas the ones described in this section. For the purpose of our work the important feature is the need of a generous data base. Frequent applications use at least a few tens of thousand of transaction prices and the corresponding house characteristics. Given the size of our sample and the lack of house characteristics data this method was impossible to implement.

3.2.2 The repeat-sale index

The literature on index construction using the repeated-sales method has grown significantly since its first use by (Bailey et al. (1963)) in 1963. The idea of the RS method is that by registering the sales price of a property transacting more than one time, one can determine the increase in the value of that property without having to account for the individual characteristics of the property. This prevents all the problems related to functional form and coefficient stability present in the hedonic model yet introduces sample selection bias. The repeated-sale method is valid as long as no major transformations have been done to the property (such as increasing the surface area or adding a pool). If this exercise is performed across many properties one can then register the growth rate common to all properties in the sample. This common trend will be then the market influence on the properties in the sample. The procedure's aim is to estimate market growth rates and not actual levels. One way to derive the repeated-sale model is by considering equation (3.2) at two points in time for the same property and computing the difference in values

$$\begin{aligned} ln(P_{i,t}) - ln(P_{i,s}) &= \underbrace{\left(\sum_{j=1}^{k}\beta_j X_{i,j} - \sum_{j=1}^{k}\beta_j X_{i,j}\right)}_{\Delta} \\ &+ \left(\sum_{t=1}^{T} c_t D_t - \sum_{s=1}^{T} c_s D_s\right) + e_{i,t} \end{aligned} \tag{3.3}$$

The above equation reduces to

$$ln\left(\frac{P_{i,t}}{P_{i,s}}\right) = \sum_{i=1}^{T} c_t D_t + e_{it} \tag{3.4}$$

This is the econometric specification frequently found in the literature and the one which we will use in our analysis. The dummy variables are now -1 at the time of the first sale, 1 at the time of the second sale and 0 otherwise. The coefficient c_t is the logarithm of the cumulative price index at time t. Implicit in this derivation is of course the assumption that house characteristics do not change over time. If this assumption fails and the characteristics of the house do change then the term Δ will no longer be zero rendering the estimated $c_t's$ biased.

A notable improvement of the method is the weighed repeat sales methodology of Case and Shiller (Case and Shiller (1989)). The added value of this paper is the observation that heteroscedasticity is present in housing data. The sampling variability of registered changes is assumed to be larger the larger is the time span between the two transactions. Assuming that the underlying house value is a Gaussian diffusion, one can correct for the presence of the price heteroscedasticity after performing a three stage regression in which the time span between transactions is used as the weight in the GLS estimation.

Our index will be an alternative of the traditional repeat sale method as we shall not use two transaction prices but the purchase price and the latest valuation. Therefore our index will be a repeat measurement index. The econometric specification will be given as

$$ln\left(\frac{A_{i,t}}{P_{i,s}}\right) = \sum_{i=1}^{T} c_t D_t + e_{it} \tag{3.5}$$

where all variables have the same interpretation as in equation (3.4) with the exception of $A_{i,t}$ which is the appraised value of property i as of time t. The use of the appraised value instead of the actual transaction price does raise some questions. Given the documented biases present in the appraisal process Diaz III (1999) isn't this method going to bias the entire index? A bias might be present for properties which have been recently acquired and whose valuation occurs at less than one year. The results in the literature point out that the information present in an appraised value lags actual market developments by up to an year Geltner (1989b). This leads to several authors using some form of unsmoothing procedure to extract the market information out of the appraisal index with Blundell and Ward (1987) and Geltner (1991) among the first applications. The underlying assumption used in the unsmoothing filter is that appraisers form opinions about current values using some mix of current market information and past appraisal values. This leads to specifying an appraisal formation equation which puts some weight on actual market transactions and some on previous appraisals. The valuation is assumed to be formed according to the following equation

$$A_t = \alpha \overline{P}_t + \underbrace{(1-\alpha)}_{smoothing} A_{t-1} \tag{3.6}$$

Equation (3.6) can be used to back out the actual expected sales price given that one knows the smoothing coefficient and the previous period appraisal. The expected market price equals

$$\overline{P}_t = \frac{A_t - (1-\alpha)A_{t-1}}{\alpha} \tag{3.7}$$

The smoothing parameter can be obtained by regressing the returns of the appraised index on its past values (Blundell and Ward (1987)).

Even if the previous period appraised value could be obtained we unfortunately lack a long appraisal index from which to derive the α. This impedes us from actually replacing the appraised value with an indirect transaction value yet the procedure remains valid in those markets where reliable appraisal indexes are available (the IPD Switzerland is too short to yield a reliable estimate of the smoothing parameter).

In favor of this index speaks also the fact that the method has already been successfully used in the literature by Marcato (2005). Marcato shows that the repeat measurement method using appraisals yields good results when compared to either hedonic or backward looking indices.

3.2.3 The Sale Price Appraisal Ratio index

The Sale Price Appraisal Ratio Index (SPAR) is an arithmetic repeat measurement index which makes use of observations over time of the same property yet unlike the standard repeat sale method this method uses an appraised value as the first measure and a transaction price as the second measure . The method has been successfully implemented around the world by Bourassa et al. (2006) in New Zealand and De Vries et al. (2009) in the Netherlands. The method is promoted as a reliable index methodology for regulatory bodies wanting to properly measure the development of the property market Bourassa et al. (2006). The SPAR therefore has the same data requirement as the repeated measurement methodology of Marcato. The difference between the two methods is the actual index computation method. While the repeated-measure index makes use of a regression technique, the SPAR computes averages of the appraisal to price ratios. The equal-weighted SPAR index number is computed using the formula in equation (3.8)

$$Index_t^{EW} = \frac{(1/n_t) \cdot \sum_{i=1}^{n_t}(S_{it}/A_{i0})}{(1/n_{t-1}) \cdot \sum_{i=1}^{n_{t-1}}(S_{it-1}/A_{i0})} \cdot Index_{t-1}^{EW} \tag{3.8}$$

where $Index_t^{EW}$ is the value of the equal-weighted index at time t, S_{it} is the sale price of property i at time t, A_{i0} is the appraised value of property i at the base period and n_t is the number of transactions at time t. Equation (3.8) shows that in each period the aggregate value growth is averaged across the existing properties. This aggregate growth is then divided by the average aggregate growth of the previous period giving thus an average period growth rate. This rate is further multiplied with the previous index value to indicate the market development over the existing period. A value-weighted version of this index can also be computed using equation (3.9)

$$Index_t^{VW} = \frac{\sum_{i=1}^{n_t} S_{it}/\sum_{i=1}^{n_t} A_{i0}}{\sum_{i=1}^{n_{t-1}} S_{it-1}/\sum_{i=1}^{n_{t-1}A_{i0}}} \cdot Index_{t-1}^{VW} \tag{3.9}$$

3.2.4 Developing an alternative SPAR method

The standard SPAR makes use of the ratio of transaction price (second measurement) to appraised value (first measurement) where all properties in the index have an appraised value in the base period. In our case the data is composed of pairs of purchase prices (first measurement) and latest appraisals (second measurement). This data feature makes the original SPAR method impracticable. We nevertheless develop and alternative SPAR method which uses the same philosophy of the original SPAR yet can be used with the data set available to us. We denote this method the inverse SPAR (or ISPAR). The main change comes from recognizing that we can use as the base period the latest valuation and compute the index "going back" in time and not forward as the original SPAR is designed. This inversion has no major impact on the features of the model. It remains a constant-quality index which is easy to construct and is consistent when new data is added to the original sample. The main change is therefore that we set the index to 1 at the time of the last observation (in our case 2007) instead of the first observation as it is currently done. We therefore compute the development of the index decreasing from 1 towards its initial value which will correspond to the period of the first purchases. The equation describing the equal-weighted index will be now

$$Index_{t-1}^{EW} = \frac{(1/n_t) \cdot \sum_{i=1}^{n_t} (S_{it}/A_{i0})}{(1/n_{t-1}) \cdot \sum_{i=1}^{n_{t-1}} (S_{it-1}/A_{i0})} \cdot Index_t^{EW} \tag{3.10}$$

The same inversion also works for the value-weighted index. The value-weighted ISPAR index can be computed using equation (3.11).

$$Index_{t-1}^{VW} = \frac{\sum_{i=1}^{n_t} S_{it} / \sum_{i=1}^{n_t} A_{i0}}{\sum_{i=1}^{n_{t-1}} S_{it-1} / \sum_{i=1}^{n_{t-1} A_{i0}}} \cdot Index_t^{VW} \tag{3.11}$$

It can be seen from the formulas used to compute the ISPAR that no major changes have occurred in the actual computation of the index. The only notable modification is the "inversion" of the time with the index being computed from the present to the past. This convenient trick allows us to make use of this methodology praised by Bourassa et al. (2006) for its potential use by regulatory bodies.

3.3 Data

The sample size available to us is of 995 pairs of purchase prices and 2007 valuations with the corresponding purchase years. All properties are being held in the portfolio of either one of the institutional investors that contributed data to our pool. The sample selection bias is not as important for our sample as it is for repeated sales data. Samples containing only properties transacting at least two times are prone to sample selection bias as the registered transactions may be in most cases of "lemons" or buildings that were redeveloped. We do face another type of bias namely a kind of survival bias. This is because we do not have data on the properties that were sold from the portfolios. A histogram of the distribution of transactions over time is available in Figure 3.1. Several years have very few transactions such as 1937 to 1939, 1974, 1997 and 2003. We expect the accuracy of the index to be low around these years. Also of interest to us is the year 2005 in which a very large number of transactions was registered. We are trying to find extra-data for the years in which very few transactions have been registered as well as the cause for the large number of purchases in 2005. We suspect a large portfolio was acquired by one the companies supplying data to the data pool. For the time being only a part

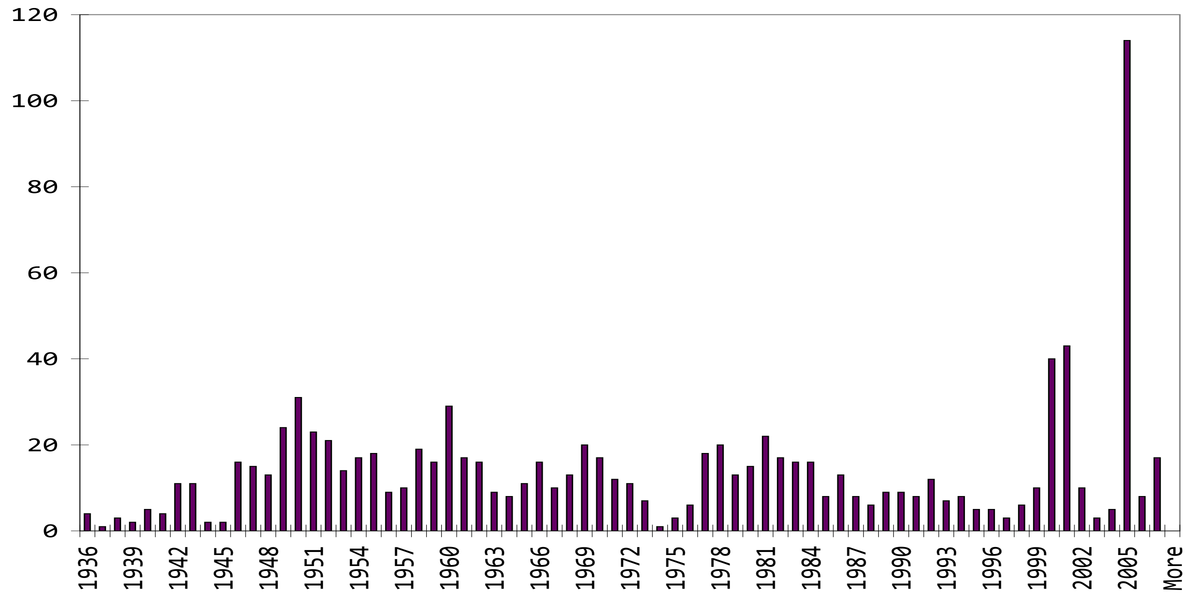


Figure 3.1: Distribution of transactions over time

of the sample has cash-flow data (either rents and/or maintenance or renovation data) meaning that only a price index can be computed going back to the 1930's. The lack of this data has a much larger impact on the results and efficiency of the repeated measurement index than on the ISPAR index. Bourasse et al. state that repeated appraisals will be a requirement for the index to quality adjusted. In our case we deal with the latest available appraisal implying that no splicing is needed for our index. Nevertheless cash-flow data is still important in understanding the impact of renovations on values and is a pre-requisite for computing a total return index. The data base contains a accounting measure for the book value of property investment [1]. This represents the initial purchase price plus the sum of all type of investments made in the property (maintenance and renovation are added together without having the time when these occurred).

3.4 Results

We compute an equally-weighted version of the index developed by Marcato as well as an equally-weighted and a value-weighted ISPAR. All indexes start in 1937. A portion of the equally weighted ISPAR is plotted against the Zürcher Kantonal Bank (ZKB) Mehrfamilienhuser during the period in which the ZKB index was available. The EW ISPAR is similar to the ZKB index both in term of levels and dynamics (see Figure 3.2). Although the ZKB is no longer computed from 2000 onwards it offers a very good benchmark against which to measure our index as this index targeted the same real estate submarket that we are trying to measure. Figure 3.3 shows the equal-weighted ISAPR price index starting in 1937. The bubble visible also in the IAZI and the

[1] Anschafungswert

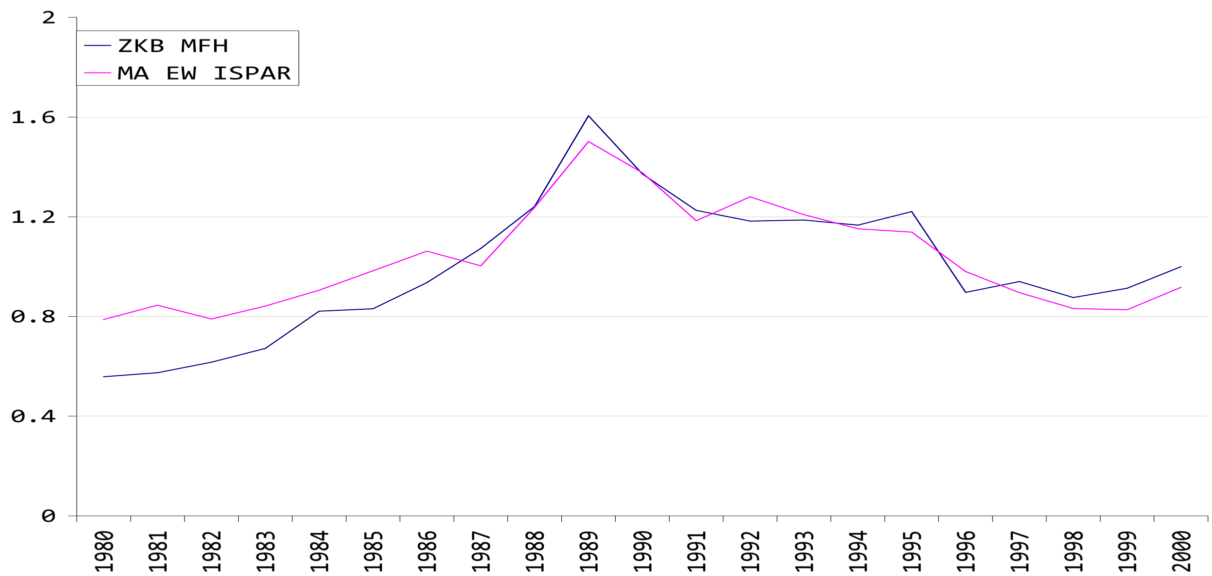


Figure 3.2: Comparing the EW ISPAR to the ZKB MFH index

W&P index is also depicted by our index. What is more interesting is the development of the market in the late 2000. A upward trend can be seen starting with the beginning of 2000. The dip that can seen in 2001 might be attributed to the 9/11 events though other factors might have been at work during that period as well. Summary statistics are computed for the simple period

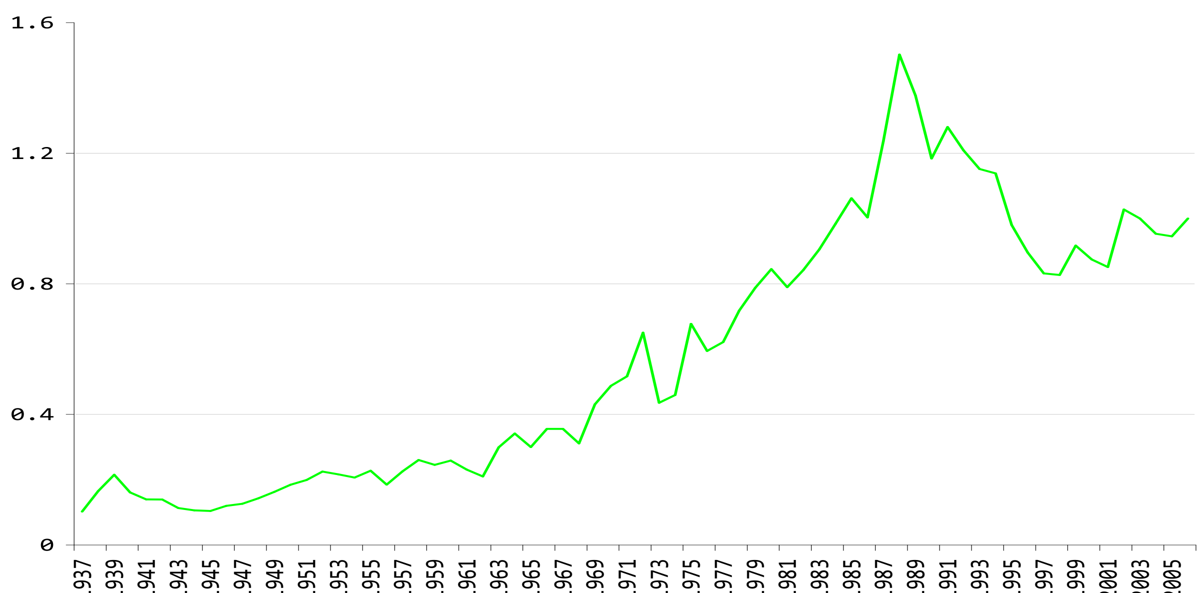


Figure 3.3: The equally weighted ISPAR index

returns of two indexes. The results may be seen in Table 3.1. Overall notable differences may be observed in both mean and volatility of the indexes. This may be because the underlying sample is structurally different or because the index construction methods are different. Both the ISPAR and the RMI compare well to the ZKB index both in term of index development and summary statistics. This can be seen as a point in favor of the ISPAR or RMI as the ZKB index measured the same market segment that we try to gauge. Substantial difference may be observed when comparing the ISPAR or RMI to the IAZI index. This can be attributed mainly to the difference in the underlying sample used for the index estimation. The IAZI index mixes data from residential and commercial while we focus exclusively on residential.

The kurtosis of the time series indicate the presence of either fat tails (in most cases) or thin tails (platykurtic). The only notable exception is the equal-weighted ISPAR for the period 1988-2007 which has a value of the kurtosis very close to 0. In all cases the return distributions are skewed with direction changing across the selected samples. The volatilities of the indexes varie considerably across the samples and indexes. Over the entire time span the highest volatility is registered by the repeated measurement index. When compared to the ZKB index the volatilities of all the computed indexes are lower as can be seen in the second group of statistics in Table 3.1. The correlation of the simple period returns from the EW and from the VW ISPAR indexes with

Index	Mean	Volatility	Skewness	Kurtosis
VW ISPAR 1937-2007	0.041	0.23	0.45	1.03
EW ISPAR 1937-2007	0.029	0.19	-0.21	3.06
RMI 1937-2007	0.053	0.25	0.98	2.5
VW ISPAR 1980-2000	0.004	0.12	1.11	1.61
EW ISPAR 1980-2000	0.012	0.10	0.39	-0.51
ZKB MHF 1980-2000	0.03	0.12	-0.32	0.84
RMI 1980-2000	0.006	0.12	0.67	-0.16
VW ISPAR 1988-2007	0.012	0.12	1.12	0.69
EW ISPAR 1988-2007	0.005	0.11	0.94	0.02
IAZI 1988-2007	-0.006	0.04	-0.06	-1.02
RMI 1988-2007	0.001	0.17	0.89	0.74

Table 3.1: Summary statistics of the simple yearly returns

the simple period returns from the ZKB and the IAZI are also computed for the periods in which the corresponding indexes have overlapping data (see Table 3.2). Even though in some cases the samples are pretty small the correlation numbers offer an idea about the joint linear dynamics of the indexes. As it was to be expected the EW ISPAR index has a fairly high correlation with the ZKB index (0.71). An intriguing figure is the low and negative correlation between the RMI and the EW ISPAR during the period 1980 to 2000.

’80-’00									’88-’07
	VW	EW	ZKB	RMI	RMI	IAZI	EW	VW	
VW	1	0.72	0.52	.41	0.02	0.22	0.81	1	VW
EW	0.72	1	0.71	-0.03	-0.21	0.39	1	0.81	EW
ZKB	0.52	0.71	1	0.17	0.02	1	0.39	0.22	IAZI
RMI	0.41	-0.03	0.17	1	1	0.02	-0.21	-0.09	RMI

Table 3.2: Correlations of the simple yearly returns

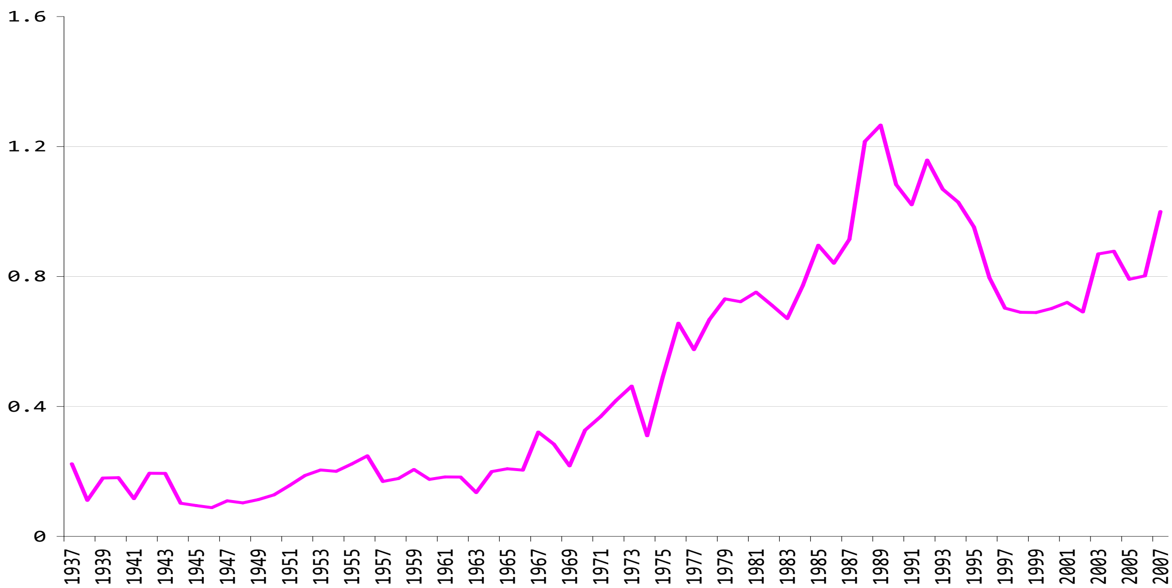


Figure 3.4: The value weighted ISPAR index

3.5 Conclusions

In this paper we compute two types of indexes describing the evolution of the rental housing market using pooled data coming from several Swiss institutional investors. We develop an alternative of the Sale Price Appraisal Ratio (SPAR) index which we call the Inverse Sale Price Appraisal Ratio (ISPAR). The methodological modification allows us to use this technique with a data sample consisting of roughly 1000 pairs of initial purchase prices and latest valuations (as of 2007). The returns of the ISPAR index show a strong correlation to the ZKB index over the period in which this index is available. This gives good support to our exercise and demonstrates the strength of the ISPAR method when small samples are used.

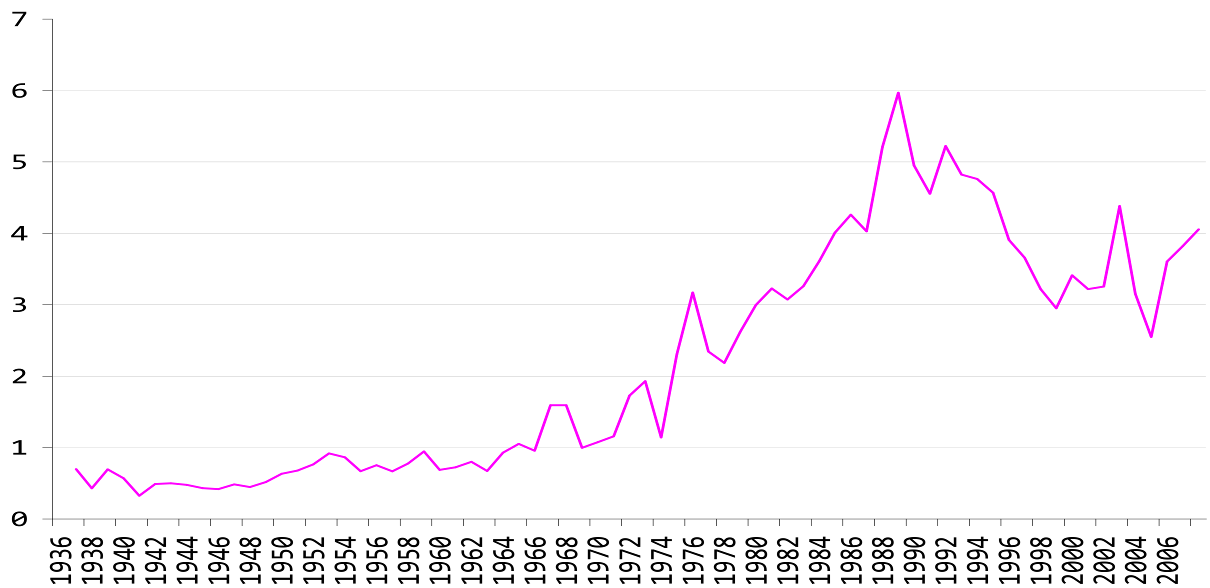


Figure 3.5: The repeated measure index

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