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Reference

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Multifamily Residential Asset and Space Markets and Linkages with the Economy

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Abstract

We show that a proper assessment of the linkages between real estate markets and the economy requires state of the art modelling techniques, which treat economic variables endogenously and allow for a number of long run relationships. We therefore use a long run structural modelling approach, which incorporates equilibrium relationships that are predicted by economic theory, in an otherwise unrestricted vector autoregressive model. The application of this approach to Swiss multifamily residential data shows that four long run equilibrium relations exist among inflation, long- and short-term interest rates, real M2, real GDP, real construction expenditures, real market rents, and capitalization rates. Disturbances to the equilibria last for approximately five years before they completely vanish. The analysis of the short run dynamics additionally suggests that the linkages between real estate and economic variables are bi-directional. Our findings should provide for a better understanding of the linkages and feedback mechanisms between a developed economy and its real estate markets and thereby help in the identification and quantification of both market interventions by policy makers and risks borne by investors.

Keywords: multifamily residential, macroeconomy, error correction models, cointegrated VAR, long run equilibrium modelling

JEL Codes: R13, R15, R32
1 Introduction

Real estate markets are influenced by macroeconomic factors through a variety of channels and these linkages have been documented both for housing (Cihák, Iossifov, & Shanghavi, 2008; Kennedy, 2005) and commercial real estate markets (Hoesli, Lizieri, & MacGregor, 2008; McCartney, 2012). For example, GDP growth is related to changes in employment, wealth and population and these factors are important drivers for the demand of space. Also, the capitalization rate (cap rate) is equal to the required rate of return minus the expected growth rate in net operating income. The former component is influenced by interest rates, while the latter is known to be determined by inflation and GDP. The linkages between real estate markets and the macroeconomy are likely to be bidirectional, as evidenced by the economic downturn that can follow a major real estate crisis (Case & Quigley, 2008; Iacoviello & Ner, 2010).

The studies that have investigated those linkages for the housing market have predominantly used vector autoregressive (VAR) models or some form of (vector) error correction models (ECM) as developed by Engle & Granger (1987), Johansen (1988, 1991), Johansen & Juselius (1990) and Phillips (1991). However, even the most recently applied models suffer from some drawbacks. First, the Engle & Granger approach to ECMs is limited to a single cointegrating vector, i.e. one unique long run equilibrium relation. Next, the popular Johansen methodology would allow for more than one long run relation, but these long run relations are statistically motivated identifying restrictions that have no clear economic interpretation (Garratt, Lee, Pesaran, & Shin, 2006, p. 37). Finally, to investigate the short run dynamic responses of the model to shocks, most studies still follow the approach proposed by Sims (1980), so their results are not unique as they depend on the ordering of the variables.

With respect to the linkages between the economy and the commercial real estate market, methods are generally less sophisticated, probably in part due to data limitations. It is only since Hendershott, MacGregor, & Tse (2002) and Hendershott, MacGregor, & White (2002) that long-term relationships and short-term disequilibria are considered simultaneously. Even the more recent studies (Clayton, Ling, & Naranjo, 2009; Hendershott & MacGregor, 2005; Hoesli et al., 2008) leave space for improvement. First, rents, cap rates and returns are
modelled separately, although the four quadrant model of DiPasquale & Wheaton (1992, 1996), hereafter D&W, demonstrates that they are connected. In addition, previous studies only explain real estate variables, leaving economic variables to be determined exogenously. This is in contradiction with the facts that construction impacts GDP and that rents are part of the consumer price basket and hence influence inflation. Next, with the exception of Kohlert (2010) and Schätz & Sebastian (2009), the methods applied are limited to one single long run equilibrium relation. Finally, even though Kohlert (2010) and Schätz & Sebastian (2009) use the Johansen (1988, 1991) approach, which can treat economic variables endogenously and which is not limited to a single long run relation, the resulting cointegrating vectors are statistically motivated and lack a clear economic interpretation. In addition, these two studies do not model the real estate market as a whole as suggested by D&W, nor do they provide a detailed analysis of the short run dynamics.

We contribute to the literature in the following ways. First, we introduce a new modelling approach from macroeconometrics to the commercial real estate literature. The approach is based on Garratt, Lee, Pesaran & Shin (2003; 2006) and allows to incorporate long run structural relationships, as suggested by economic theory, in an otherwise unrestricted VAR model. This allows for transparent models that have a theoretically coherent foundation and an economic interpretation of the cointegrating vectors. In addition, this approach provides several tools to analyse the short run dynamics of the system, which are independent of the ordering of the variables. Second, on the basis of the equilibrium framework provided by D&W, we model the commercial real estate market as a whole to account for the fact that construction, rents, and cap rates are interrelated. Third, we model all series including core economic variables endogenously, therefore allowing for various contemporaneous linkages as well as for several long run equilibrium relations. Forth, we analyse the length of time to equilibrium, the persistence of shocks and how deviations will be corrected.

Due to the availability and quality of the required data in general and of transaction-based cap rates in particular, we select the Swiss market to test empirically the validity of our approach. Given that the basic principles of macroeconomics and of real estate economics that underlie our empirical model are country-independent and that several ‘building blocks’ which constitute the basis for our study have been applied successfully to various markets, such as the U.S. (DiPasquale & Wheaton, 1996), the U.K. (Garratt et al., 2006), China (Chow, Yiu,
Leung, & Tam, 2008), Germany (Michelsen & Weiss, 2009), and Switzerland (Assenmacher-Wesche & Pesaran, 2009), our results should be generalizable. They show that four long run equilibrium relations exist among real estate and core economic variables. These equilibrium relations are (1) the slope of the term structure, which links short- and long-term interest rates, (2) the Fisher Parity that links interest rates to expected inflation, (3) the real estate market equilibrium that is based on the framework of D&W and Tobin's Q by relating construction to cap rates and rents, and (4) the real estate excess return linking cap rates with interest rates on the basis of asset pricing models. We also find that shocks are gradually reduced over approximately five years before the market fully returns to equilibrium. Our results show that complex short run dynamics between the economy and the real estate markets exist and that these linkages are bi-directional.

These findings provide for a better understanding of the various linkages, error correcting behaviour and feedback mechanisms between a developed economy and its real estate markets. As such, the findings should help policy makers be fully aware of the consequences of their monetary policy actions and guide them in properly quantifying their policy interventions. The results will also benefit investors, real estate developers, and even tenants as a better understanding of the linkages can help them to prepare themselves better for economic shocks and market disequilibria.

The remainder of this paper is organized as follows. The next section provides a review of the literature. The subsequent sections focus on the model, data and long run relations, respectively. We then discuss our results, before concluding in a final section.

2 Context and extant literature

The real estate market can be partitioned into two submarkets, i.e. the market for real estate space and the market for real estate assets. The D&W model, illustrated in a four-quadrant diagram, shows how these submarkets are connected (Figure 1). For a given stock of rentable space, the rent is determined on the space market as a function of the demand curve. The rent is then transformed into a price in the asset market through appropriate capitalization. On the basis of the Q ratio introduced by Tobin (1969), the construction sector, which also belongs to the asset market, will produce new space whenever property prices are
above construction costs. If construction equals depreciation, no additional space is added to the space market and the real estate market is in equilibrium. Otherwise, available space, rents, cap rates (and thus prices), and construction may adjust, which eventually will bring the market back to equilibrium.

[Figure 1 about here]
The asset market has extensively been researched by studies that investigate the determinants of the cap rate. A recent review of the relevant literature is provided in Chaney & Hoesli (forthcoming). The conclusions from cap rate studies are that the rates depend on capital markets, individual property characteristics and local market conditions. While individual property characteristics are independent from the economy, capital markets and local market conditions will be influenced by economic forces. One therefore would expect to find linkages between the real estate market and the macroeconomy through cap rates.

With respect to methods, cap rate research is dominated by single-equation econometric techniques with rather simple dynamics. Only a limited number of recent studies have applied more complex time series models to acknowledge that current cap rates can deviate from equilibrium values due to numerous asset market inefficiencies, such as high transaction costs, lengthy institutional decision-making processes, and informational inefficiencies. To allow cap rates to temporarily deviate from their long run equilibrium values, the more recent studies apply the error correction approach of Engle and Granger (Clayton et al., 2009; Dunse, Jones, White, Trevillion, & Wang, 2007; Hendershott & MacGregor, 2005).

The studies that focus on the space market are mainly concerned with estimation of the rental adjustment process. The early literature, dominated by U.S. studies, focuses on the adjustment of real rents to deviations of the current vacancy rate from the natural vacancy rate (Shilling, Sirmans, & Corgel, 1987; Wheaton & Torto, 1988). Later, the basic vacancy rate model was extended with real rents that are specified such that they adjust to gaps between the natural and actual vacancy rate as well as to gaps between equilibrium and actual rents (Hendershott, Lizieri, & Matysiak, 1999; Wheaton, Torto, & Evans, 1997). To explain the (equilibrium) rents, various demand drivers and – if available – supply variables have been considered. The most frequently applied explanatory variables are employment, economic activity, interest rates, space supply, the (natural) vacancy rate, construction costs, and lagged rental values (Tonelli, Cowley, & Boyd, 2004).
The latest significant improvement of this line of research has been the introduction of an ECM by Hendershott, MacGregor & Tse (2002) and Hendershott, MacGregor & White (2002). They relate short run changes in rents to short run changes in demand and supply variables as well as to deviations of rents from their long run equilibrium values. Their ECMs are based on the two-step procedure of Engle and Granger and their models have been used by several researchers to analyse the rental adjustment process for office markets in the U.S. (Brounen & Jennen, 2009a), Dublin (McCartney, 2012), Germany (Adams & Füss, 2012), and several other European cities (Brounen & Jennen, 2009b; Mouzakis & Richards, 2007). Englund, Gunnelin, Hendershott & Söderberg (2008) and Hendershott, Lizieri & MacGregor (2010) also follow the Engle and Granger strategy to ECMs. However, they use the deviation from the long run rental level as an error correcting term not only in the short run model for rental adjustments, but also in another two short run models, one for vacancy rates and another one for supply.

In contrast to the approach of Engle and Granger, which assumes a single unique cointegrating vector (i.e. one long run relationship), Johansen (1988, 1991) and Johansen & Juselius (1990) develop a systems-based approach to cointegration, which enables for more than one cointegrating vector. This approach has been applied to the commercial real estate market only recently. Schätz & Sebastian (2009) analyse the U.K. and German commercial real estate markets and find two cointegrating vectors between commercial real estate prices, consumer prices, industrial production, unemployment and short- and long-term interest rates for the German market, but only one vector for the U.K. market. Kohlert (2010) focuses on 27 regional office markets in the U.K. and concludes that there are two cointegrating vectors that relate total returns with the unemployment rate, GDP, and real estate investments.

Thus, previous research demonstrates that strong linkages between the real estate market and various economic variables exist. As a consequence, a shock to any of the economic variables has the potential to bring the real estate market out of equilibrium. Novel econometric methods that have recently been used in macroeconomics allow to model a dynamic system of equations that is based on the intuitive D&W framework and that enables to trace out the steps as the market moves back to its equilibrium. However, the models applied so far did usually focus only on some of the quadrants as defined by D&W, instead of modelling the market as a whole. Also, with a few exceptions, extant research did not use a
full systems approach and to the best of our knowledge no commercial real estate study exists that uses a full systems approach that allows for a multitude of cointegrating vectors that all have an economic interpretation. The purpose of this study is to fill this gap.

3 The structural cointegrated VAR model

The goal of the structural cointegrated VAR strategy of Garratt, Lee, Pesaran & Shin (2003, 2006) is to develop a macroeconometric model that has a transparent theoretical foundation and to provide insights on the behavioural relationships that underlie the functioning of the macroeconomy. The approach is based on the premise that economic theory is most informative about the long run relationships, while it is generally silent about the short run dynamics. Therefore, the structural cointegrated VAR approach begins with an explicit formulation of the long run relationships between the variables in the model, which are derived from macroeconomic theory. These long run relations are then embedded in an otherwise unrestricted VAR model. The approach allows for testing formally the validity of the restrictions that were imposed based on the theory-motivated long run structural relations and provides a statistically coherent framework for the analysis of the short run dynamics.

We follow Garratt et al. (2006, pp. 107-135) and start with a general structural VAR model for an \( m \times 1 \) vector of endogenous variables \( \mathbf{x}_t \), given by

\[
A\mathbf{x}_t = A_1\mathbf{x}_{t-1} + \ldots + A_p\mathbf{x}_{t-p} + Dd_t + \varepsilon_t, \quad (1)
\]

where \( d_t \) is a vector of deterministic variables (intercept and trend), \( \varepsilon_t \) is an \( m \times 1 \) vector of serially uncorrelated errors distributed independently of \( \mathbf{x}_t \) with zero mean and a constant positive definitive variance-covariance matrix \( \Omega = (\omega_{ij}) \), where \( \omega_{ij} \) is the \( (i, j) \)th element of \( \Omega \).

Multiplying equation (1) with \( A^{-1} \) leads to the reduced form VAR

\[
\mathbf{x}_t = \Phi_1\mathbf{x}_{t-1} + \ldots + \Phi_p\mathbf{x}_{t-p} + Yd_t + \mathbf{u}_t, \quad (2)
\]

where \( \Phi_1 = A^{-1}A_1, Y = A^{-1}D, \mathbf{u}_t = A^{-1}\varepsilon_t \) is i.i.d \( (0, \Sigma) \) with \( \Sigma = A^{-1}\Omega A^{-1} = (\sigma_{ij}) \).

The reduced form VAR can be re-parameterized as a vector error correction model

\[
\Delta \mathbf{x}_t = a_0 + a_1t - \Pi \mathbf{x}_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta \mathbf{x}_{t-i} + \mathbf{u}_t, \quad (3)
\]

where

\[
\Pi = I_m - \sum_{i=1}^{p} \Phi_i, \quad \Gamma_i = - \sum_{j=i+1}^{p} \Phi_i, \quad (4)
\]
and $\mathbf{a}_0$ represents a vector of constants and $\mathbf{a}_1$ is the vector of trend coefficients; the matrix $\mathbf{I}$ is a $m \times m$ matrix of long run multipliers and the matrices $\{\mathbf{G}_i\}_{i=1}^{n-1}$ summarise the short run responses.

If the elements of $\mathbf{x}_t$ are $I(1)$ integrated but not cointegrated, then $\mathbf{I} = 0$ and a VAR in first differences will be appropriate. If the elements of $\mathbf{x}_t$ are $I(1)$ and cointegrated with $\text{rank}(\mathbf{I}) = r$, then $\mathbf{I} = \mathbf{a}\mathbf{\beta}'$, with $\mathbf{a}$ and $\mathbf{\beta}$ both being $m \times r$ full column rank matrices and there will be $0 < r < m$ linear combinations of $\mathbf{x}_t$, i.e. $\xi_t = \mathbf{\beta}'\mathbf{x}_t$, which are $I(0)$. These are the cointegrating relations and the variables $\xi_t$ can be interpreted as the deviations from equilibrium, an interpretation that is at the heart of the modelling approach applied in this paper. In that case, $\mathbf{a}$ represents the matrix of adjustment or feedback coefficients, which measure how fast the deviations from equilibrium return back to their equilibrium. The fact that there are $0 < r < m$ cointegrating vectors implies that some of the elements of $\mathbf{a}$ must be non-zero and that there must be some Granger causality involving the levels of the variables in the system to keep the elements of $\mathbf{x}_t$ from diverging. Under these circumstances, i.e. when cointegration is present, equation (3) can be rewritten as

$$\Delta \mathbf{x}_t = \mathbf{a}_0 + \mathbf{a}_1 t - \mathbf{a}\mathbf{\beta}'\mathbf{x}_{t-1} + \sum_{i=1}^{n-1} \mathbf{G}_i \Delta \mathbf{x}_{t-i} + \mathbf{u}_t.$$  \hspace{1cm} (5)

An unrestricted estimate of $\mathbf{I}$ can be obtained from equation (3). In contrast, equation (5) requires estimation of two $m \times r$ coefficient matrices, because the matrix $\mathbf{I}$ is partitioned into two matrices $\mathbf{a}$ and $\mathbf{\beta}$. As these two matrices are not identifiable separately without some additional restrictions, exact identification requires a total of $r^2$ restrictions that need to be imposed on the cointegrating relations. A popular procedure to identify $\mathbf{a}$ and $\mathbf{\beta}$ has been suggested by Johansen (1988, 1991). The author computes the maximum likelihood estimates of $\mathbf{\beta}$ as the $r$ eigenvectors that correspond to the first $r$ largest eigenvalues of the canonical correlation matrix. While this provides $r^2$ restrictions, they are statistically motivated and have no economic meaning because there is no reason to expect economic cointegrating vectors to be orthogonal (Garratt et al., 2006, p. 124). In case of more than one cointegrating vector, economic interpretation of these vectors is almost impossible. An alternative is to obtain the required number of restrictions from economic theory, as proposed by Pesaran & Shin (2002). Given that economic theory is most informative about the long run relationships, this approach is appealing as the required restrictions are to be imposed on the cointegrating
vectors. The first step of the structural cointegrated VAR strategy therefore consists in using macroeconomic theory to derive an explicit formulation of the long run relationships between the variables in the model. These long run relationships are then embedded as cointegrating vectors in an otherwise unrestricted VAR model to describe the short run dynamics. After testing for the validity of the theory-imposed over-identifying restrictions, the model dynamics can be analysed with a number of econometric tools.

Probably the most frequently used tool to perform such analyses is the Impulse Response Function (IRF), which shows the effect that a shock exerts on the system through time. More precisely, IRFs measure the difference between two different realizations of the variable under consideration \( x_{t+n} \) that are identical up to \( t-1 \). At time \( t \), one realization assumes that the system is hit by a single shock of size \( \delta \), while the second realization, i.e. the benchmark or baseline value, assumes that the system is not hit by any shocks. Denoting the known history of the economy up to time \( t-1 \) by the information set \( \mathcal{I}_{t-1} \), the IRF of \( x_t \) at horizon \( n \) is defined as

\[
IRF(x_t | x_{t+n}, \mathcal{I}_{t-1}) = E(x_{t+n} | \epsilon_t = \delta, \mathcal{I}_{t-1}) - E(x_{t+n} | \mathcal{I}_{t-1}).
\]  

(6)

The hypothesized vector of shocks, \( \delta \), is central to the properties of the IRF. The traditional approach suggested by Sims (1980) is based on Cholesky’s decomposition of the variance-covariance matrix of the residuals \( \Sigma = PP' \), where \( P \) is a lower triangular matrix. A new sequence of orthogonalised errors, \( u_t^* = P^{-1}u_t \), is then used to determine the IRF. Given that the results based on this approach depend on the ordering of the variables in the system, Koop, Pesaran & Potter (1996) and Pesaran & Shin (1998) developed the Generalized Impulse Response Functions (GIRF). GIRFs do not use the Cholesky decomposition and are invariant to the ordering of the variables in the system. They measure the effect on the endogenous variables of a typical shock to the system based on variances and covariances of the reduced form shocks that are estimated with the available historical data and that are derived from the moving-average representation of equation (2).

Denote the generalized impulse responses of \( x_{t+n} \) to a unit change in the \( i \)th structural error, \( \epsilon_{it} \), measured by one standard deviation, \( \sqrt{\omega_{ii}} \), as \( g(n, x; \epsilon_i) \). At horizon \( n \) the GIRF is defined by the point forecast of \( x_{t+n} \) conditional on the information \( \mathcal{I}_{t-1} \) and the one standard error shock, relative to the baseline conditional forecast.
\[ g(n, x; \varepsilon_i) = E(x_{t+n} | \varepsilon_{it}) = \sqrt{\omega_{iit}} \mathcal{F}_{i-1} - E(x_{t+n} | \mathcal{F}_{i-1}). \quad (7) \]

While the \( \varepsilon_{it} \) are serially uncorrelated, they are contemporaneously correlated. Thus, a shock to the \( i \)th error, \( \varepsilon_{it} \), will also affect the other errors

\[ E(\varepsilon_i | \varepsilon_{it}) = \left( \frac{1}{\sqrt{\omega_{iit}}} \right) \mathbf{\Omega} e_i \quad (8) \]

where \( e_i \) is a \( m \times 1 \) selection vector of zeros except for its \( i \)th element which is set to unity.

This defines the shocks in each structural error given a shock to \( \varepsilon_{it} \), based on the correlation between the structural errors that were observed historically. The GIRF to a unit shock to the \( i \)th reduced form error \( u_{it} \) is then given by

\[ g(n, x; u_i) = \left( \frac{1}{\sqrt{\sigma_{ii}}} \right) \mathbf{C}_n \mathbf{\Sigma} e_i, \quad n = 0, 1, ..., i = 1, ..., m, \quad (9) \]

where \( \mathbf{C}_n \) is the cumulative effect matrix derived from the moving-average representation (Pesaran, Shin, & Smith, 2000).

Similar, GIRFs of the cointegrating relations to a shock in variable \( i \) are defined as

\[ g(n, \beta | x, u_i) = \left( \frac{1}{\sqrt{\sigma_{ii}}} \right) \beta^T \mathbf{C}_n \mathbf{\Sigma} e_i, \quad n = 0, 1, ..., i = 1, ..., m. \quad (10) \]

Persistent profiles, as developed by Lee & Pesaran (1993) and Pesaran & Shin (1996), are another important tool to analyse the dynamics of error-correction models. They are similar to GIRFs, but instead of showing the effect of a shock to a particular variable, persistent profiles illustrate the effects of system-wide shocks on the cointegrating relations. If cointegration is indeed present, such shocks will eventually disappear and the shape of the persistent profiles contains valuable information on the speed of convergence towards the equilibrium. Persistent profiles that are scaled to have a value of unity on impact are given by

\[ h(\beta_j | x, n) = \frac{\beta_j^T \mathbf{C}_n \mathbf{\Sigma} e_i}{\beta_j^T \mathbf{\Sigma} e_i}, \quad n = 0, 1, ..., j = 1, ..., r. \quad (11) \]

4 Data

The literature review and the D&W model reveal that the key variables required to describe the real estate market are rents, cap rates (which together define prices), and construction. Important economic variables that help to explain the variation in those series are the amount of money available, GDP, inflation, and interest rates. These economic variables are also found by macroeconomic researchers to be key variables in modelling the economy of the
U.S., the U.K., Switzerland and two dozen other countries (Assenmacher-Wesche & Pesaran, 2009; Dees, Mauro, Pesaran, & Smith, 2007; Pesaran, Schuermann, & Weiner, 2004).

We therefore use real M2, real GDP, three-month interest rates, 10-year government bond yields, inflation, real rents, real construction, and cap rates to calibrate equation (5). Due to the availability and quality of the required data in general and of transaction-based cap rates in particular, we use the Swiss market to test empirically the validity of our approach. Our data are for the period 1974Q1–2013Q2. Inflation is calculated as the one quarter log-change of the three-quarter averages of the monthly consumer price index (CPI). The CPI, obtained from the Swiss Statistical Office, requires an adjustment to be made because new data collection procedures at the Swiss Statistical Office were introduced in 2000.¹ Monthly values for nominal M2 were obtained from the Swiss National Bank (the central bank). We deflated them with the CPI and calculated quarterly averages of the real M2 series. Real construction and real GDP are also from the Swiss National Bank. For both series, the seasonally adjusted values are used, which are available back to 1980. For the 1970s, we perform the seasonal adjustment using the Tramo/Seats methodology that was originally developed by Gomez & Maravall (1996) and later promoted by Eurostat. Both short-term and long-term interest rates are from the OECD database and they are expressed as $0.25\ln(1+R/100)$ to be consistent with the quarterly inflation rate.

The cap rate index is based on 7,798 transactions of properties that are either pure multifamily residential properties (84% of the data used for the index) or mixed-use properties whose rental income from residential use represents at least 70% of the total rental income (16% of the data). The transaction data are from the IAZI database, which is arguably the largest real estate database in Switzerland. The data are collected both from banks that finance transactions of investment properties and from institutional investors. The properties are spread across the whole of Switzerland, but the majority of the transactions are from the cantons of Zurich, Geneva, and Vaud, which is where most of the population is concentrated.

¹ Since 2000, end-of-year sales for clothes and footwear have been included which introduces seasonality in the index, creating a need to smooth the series. The post 2000 series is smoothed by taking the twelve-month average of the clothing and footwear sub-index which is added to the CPI without clothing and footwear, using the appropriate weighting.
The cap rate index is calculated by first ordering the data according to the transaction date. Thereafter a centred rolling window of 50 transactions is constructed, whereof a trimmed average is calculated, i.e. to eliminate outliers, the lowest 15% and the highest 15% of the cap rate observations of each window are eliminated and the average is calculated using the remaining 35 transactions. Finally, and consistent with the M2 and inflation series, for each quarter, the arithmetic mean of the trimmed averages is calculated as the quarterly index value. This approach is preferred over a hedonic time dummy index because the hedonic approach would reduce the number of observations due to missing property characteristics and more importantly would also lead to heteroscedasticity because the number of observations increases with time. For consistency, the cap rate index is also expressed as $0.25 \ln(1+R/100)$.

A quarterly market rent index for apartments was obtained from the Swiss National Bank. It is based on advertisements that were published either online or in newspapers. The index uses a sample of about 25,000 advertisements per quarter until the 1990s and about 88,000 advertisements per quarter thereafter, which corresponds to a market coverage of above 90%. The index is calculated on the basis of a weighted median rent of homogeneous groups which are formed on the basis of the location of the properties, the number of rooms, and two dummies for old and for new buildings. The index shows significant seasonal patterns before the sampling procedure was changed in the 1990s. The Tramo/Seats methodology was therefore applied to the pre-1990 time period to eliminate these seasonal patterns.

5 Theory-predicted long run relationships

Economic theory predicts several long run equilibrium relations among the aforementioned economic series. The first equilibrium relation that we consider is the slope of the term structure, which links short-term to long-term interest rates:

$$r_{10_f} = b_{10} + \beta_{11} r_{3m_f} + \xi_{1,t},$$

(12)

where $r_{10}$ represents the 10-year interest rate, $r_{3m}$ is the 3-month interest rate, $b_{10}$ and $\beta_{11}$ are coefficients to be estimated and $\xi_{1,t}$ is the deviation in time $t$ from the long run equilibrium value. The extent to which this long run equilibrium condition has held historically is
presented in Figure 2a, which shows that long-term rates are less volatile and usually higher than short-term rates, hence suggesting a value of \( \beta_{11} < 1 \) and of \( b_{10} > 0 \).

The second equilibrium condition is motivated by the Fisher Parity, Money Demand and the classic Taylor rule. Fisher Parity relates nominal interest rates to real interest rates and expected inflation, while the Money Demand relates the real amount of money demanded to real GDP and nominal interest rates.\(^2\) The variables that are expected to enter the Money Demand long run relation are depicted in parts b) and c) of Figure 2. The former shows the evolution of real GDP and of real M2, while the latter plots the difference between the two, i.e. money velocity, together with short-term interest rates. It seems that real M2 and GDP indeed follow a similar trend and that the movements in the differences between the two coincide well with the evolution of short-term interest rates. Part d) of Figure 2 depicts the quarterly rate of inflation and the three-month interest rate. It shows that with the exception of a limited number of observations, interest rates are slightly higher than inflation. As shown by part e) the difference between the short-term interest rates and inflation indeed is usually positive and in addition seems to be related to money velocity, as depicted by its four quarter moving average. We make use of these observations by substituting expected inflation in Fisher Parity by a function of current inflation and of money velocity:

\[
Fisher \ Parity: \quad r^{3m_t} = b_{20} + \beta_{21}\pi_t + \beta_{22}(y_t - m2_t) + \xi_{2t}, \tag{13}
\]

Where \( \pi_t \) is the quarterly rate of inflation, \( \pi^e = \beta_{21}\pi_t + \beta_{22}(y_t - m2_t) \) is expected inflation, \( m2 \) is \( \ln(\text{real M2}) \), \( y \) is \( \ln(\text{real GDP}) \), \( b_{20} \) is the real interest rate and \( \xi_{2t} \) is the deviation from the long run equilibrium. Note that if we substitute money velocity by the output gap (which is another proxy for the overheating of the economy) and replace \( \beta_{21} \) with \( (1 + \theta_1) - \theta_1\pi^*/\pi_t \), we have the classic Taylor rule, which states that the short-term interest rate is a function of the equilibrium real interest rate, \( b_{20} \), current inflation, target inflation \( \pi^* \), and the output gap \( (y_t - y^*) \) (Taylor, 1993):

\[
\text{Classic Taylor Rule:} \quad r^{3m_t} = b_{20} + \pi_t + \theta_1(\pi_t - \pi^*) + \theta_2(y_t - y^*) + \epsilon_t, \tag{14}
\]

where \( \theta_1 \) and \( \theta_2 \) are two parameters that specify how much interest rates adjust to inflation and output gap, respectively, and \( \epsilon_t \) is the residual.

Another long run equilibrium condition is suggested by the D&W framework, which shows that the real estate market is in equilibrium only if rents, cap rates, construction, and depreciation are well aligned. This long run condition goes back to Tobin's Q and it implies that we expect to observe a high level of construction whenever the market value strongly exceeds replacement costs and less construction otherwise. Approximating the market value by the ratio of market rents to cap rates, Tobin's Q can be replaced by

\[ Q = \frac{\text{market rent}}{\text{cap rates}}. \]  

(15)

Acknowledging that the amount of newly constructed space is a function of Tobin's Q and multiplying both sides with replacement costs and taking logs thereafter yields

\[ \ln(\text{construction spending}) = f(\ln(\text{market rent}) - \ln(\text{cap rates})), \]  

(16)

where construction spending includes replacement costs, hence is measured in terms of money instead of space. Equation (16) forms the basis of our third long run equilibrium equation. Assuming for simplicity that changes in the depreciation rate can be neglected, the real estate market equilibrium is:

**Real Estate Market Equilibrium:**

\[ \text{con}_t = b_{30} + \beta_{31} \text{rent}_t + \beta_{32} \text{cr}_t + \xi_{3t}, \]

(17)

where \(\text{con}_t\) is \(\ln(\text{real construction})\), \(\text{rent}_t\) is \(\ln(\text{real rent})\), \(\text{cr}_t\) is the cap rate and \(\xi_{3t}\) is the deviation from long run equilibrium. In order to proxy for the price, the coefficients of rent and \(\text{cr}\) need to be restricted to be equal and of opposite sign. However, given that \(\text{rent}_t\) is specified as \(\ln(\text{real rent})\) while \(\text{cr}_t\) is \(0.25\ln(1+\text{cap rate})\) as opposed to \(\ln(\text{cap rate})\), the appropriate restriction for an average cap rate of 7.12% is \(\beta_{32} = -154\beta_{31}\). This is because \(\ln(7.21\%) = -154\times0.25\ln(1+7.21\%).\) The resulting price proxy has a correlation of 0.84 with the SWX IAZI Investment Price index, which is a hedonic multifamily transaction-based price index. As depicted in Figure 2f, construction spending and prices indeed follow a similar path.

Finally, a forth long run equilibrium condition is predicted by asset pricing models, such as the capital asset pricing model of Lintner (1965) Mossin (1966), and Sharpe (1964) or the arbitrage pricing theory of Ross (1976). These models link the expected return of an asset to
the risk free rate, plus one or several potentially time-varying risk premium(s).\footnote{Ling & Naranjo (1997) and Liow (2004) apply these pricing models to commercial real estate in the U.S. and Singapore, respectively. They find that the return above the risk free rate is time varying and that economic variables such as the per capita consumption, GDP growth, interest rates, the term structure of interest rates, and unexpected inflation help to explain the time-varying behaviour.} Figure 2g shows that cap rates follow a similar long-term trend as the ten-year interest rate, although with a lag of about six quarters. An obvious exception is a decade around 1990 where cap rates were too low compared to the long-term interest rates. In addition to the cap rate spread, we therefore also consider the evolution of other cap rate components. These are the evolution of the risk premium and of the growth rate of cash flows, which we both proxy by an indicator of the boom of the construction sector, measured as the ratio of construction spending to GDP. The idea behind this proxy is that whenever the property market is optimistic, we expect to observe a booming construction sector, i.e. high construction compared to GDP, and low risk premiums and/or high growth expectations. This implies a negative relationship between the cap rate spread and the construction-to-GDP measure. Figure 2h depicts that the cap rate spread indeed swings together with the boom of the construction sector, although the two series have a different trend. This could happen if in the long run GDP growth were higher than the growth in the construction sector. It could also be due to a potential compression over time in the risk premium that is required for real estate investments if the real estate market became increasingly transparent and more efficient over time. Acknowledging that, depending on the current state of economic variables, the excess return may deviate from its long-term equilibrium value, our forth long run equilibrium condition is:

\[
\text{Real Estate Excess Return: } \quad cr_t - r_{10,t} = b_{40} + b_{41}t + \beta_{41}(con_t - y_t) + \xi_{4,t},
\]  

(18)

where \(b_{40}\) is the average cap rate spread, \(b_{41}t\) represents the time trend and \(\xi_{4,t}\) is the deviation from the long run equilibrium.

Note that the goal is not to empirically find the best model to explain the four deviations, \(\xi_{4,t}\). Instead, the idea of the structural cointegrated VAR model is to embed these theory predicted equilibrium equations in the \(\beta\)-matrix of equation (5) and to use their deviations to help explain the short-run dynamics of the endogenous variables. The four long run relations, i.e. equations (12), (13), (17) and (18) in matrix form, are
\[ \xi_t = \beta' x_t - b_0 - b_1 t, \]  
\[ (19) \]

where \( b_0 = (b_{10}, b_{20}, b_{30}, b_{40}) \) and \( b_1 = (0,0,0,b_{41}) \). With the vector of endogenous variables \( x_t \) being

\[ x_t = \{r3m_t, \pi_t, m2_t, y_t, con_t, cr_t, rent_t, r10\}, \]

the over-identified \( \beta' \)-matrix that contains the aforementioned four long run relations is given by

\[ \beta' = \begin{pmatrix} \beta_{12} & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ \beta_{22} & \beta_{23} & \beta_{24} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & \beta_{36} & \beta_{37} & 0 \\ 0 & 0 & 0 & \beta_{44} & \beta_{45} & 1 & 0 & -1 \end{pmatrix} \]

with the linear restrictions \( \beta_{23} = -\beta_{24} \) for the money velocity in the Fisher Parity equation, \( \beta_{36} = -154\beta_{37} \) for the price in the real estate market equilibrium equation and \( \beta_{44} = -\beta_{45} \) for the construction boom measure in the real estate excess return equation.

6 Empirical results

The discussion of the empirical results is organized as follows. First, we present results for the long run structural relations before discussing the full error correction equations by analysing the impact of the deviations from equilibrium and the length of time to reach equilibrium. Next, we focus on the short run dynamics by assessing the impact of monetary policy, analysing the reactions of the real estate variables in response to various economic shocks and finally discussing the impact that real estate shocks exert on economic variables.

6.1 Long run structural relations

The first stage in the systems approach is the determination of the number of lags for the unrestricted VAR. The Schwarz Bayesian Criterion suggests an order of one while the Akaike Information Criterion suggests two lags. As overestimation of the order of a VAR is less serious than underestimation (Kilian, 2001), we use a lag length of two. As a second step, the number of cointegrating relations \( r \) has to be determined. The maximum eigenvalue (\( \lambda \)-max) test and the trace test indicate the presence of three cointegrating relations for a VAR(2) specification and would indicate four cointegrating relations in case of a VAR(4) specification. Given that the VAR(2) specification leads to serial correlation in some of the error correction equations and that theory predicts four long run equilibrium relations, we
proceed with the VAR(2) specification and four cointegrating relations while making use of heteroscedasticity and autocorrelation adjusted standard errors.

The estimated coefficients of the $\beta$-matrix are presented in Table 1. The likelihood ratio test of the over-identifying restrictions that are imposed on the $\beta$-matrix produces a test statistic of 49.49. The bootstrapped critical values based on 1,000 replications at the 5% and 1% significance level are 42.86 and 51.17, respectively. Thus, the theory-based restrictions that we impose are rejected at the 1% but not at the 5% significance level. Because this specification of the cointegrating vectors is in line with long run theory and results from the univariate autoregressive distributed lag (ARDL) cointegration approach of Pesaran & Shin (1999) (Table 2), and because it meets a number of other statistical requirements, we proceed with these restricted estimates.

[Table 1 and Table 2 about here]

The estimate of the Libor coefficient in the slope of the term structure equation is 0.76. With a standard error of 0.07 this demonstrates that short- and long-term interest rates indeed are strongly related and that short-term rates are more volatile than long-term rates.

Results of the Fisher Parity parameters show that expected inflation is well proxied by current inflation (its parameter estimate of 1.07 is not significantly different from unity), adjusted for money velocity. Stated in terms of the Taylor rule, the central bank tends to reduce the short term interest rate almost one by one with inflation and some more when money velocity is low, i.e. if GDP growth is low (compared to M2). This is exactly what happened after the financial crisis: As there were no inflationary pressures, central banks reduced interest rates and increased money supply in order to stimulate GDP growth and to avoid deflation.

The highly significant estimates of the cap rate elasticity, $\beta_{36}$, and of the rent elasticity, $\beta_{37}$, in the real estate market equilibrium equation demonstrate the empirical validity of the analytical framework of D&W, because it shows that construction, cap rates, and rents are indeed strongly linked in the long run. This is especially true as these parameter estimates would

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4 Exact identification of equation (5) would require 16 restrictions. The $\beta$-matrix contains 32 parameters and the intercept and trend vectors together another eight. Out of these 40 parameters 30 are restricted, hence 14 restrictions are over-identifying.

5 For example, persistent profiles of all four cointegrating relations tend toward zero reasonably fast and the effects of shocks on the cointegrating relations eventually vanish.
remain largely unchanged if they were completely unrestricted. The results also imply that the real estate market is only in equilibrium if all of its quadrants are well aligned. Finally, the estimates of the excess return equation show that the cap rate spread indeed evolves with the ratio of construction to GDP.

6.2 Error-correction equations

6.2.1 The impact of deviations from long run equilibriums, $\xi_{i,t-1}$

Estimates of the error correction equations are presented in Table 3. The adjusted $R^2$ lie in the range 0.17-0.68, indicating that the error correction models track the main movements of the dependent variables sufficiently well.\(^6\) We additionally calculated the adjusted $R^2$ of benchmark models, which are VAR models with the same variables and lag orders as the error-correction models, i.e. where the only difference with the error correction models is the absence of the long run equilibrium relations. The use of the long run structural modelling approach greatly increases the adjusted $R^2$ for most equations. In line with this observation, the coefficients of the error correction terms make a significant contribution in many equations. This shows that the error correction mechanisms provide for a complex and statistically significant set of interactions and feedbacks across the whole economy, including all real estate quadrants. It also demonstrates that the benefits of our approach are not limited to the structural interpretation based on economic theory but rather also lead to an improvement in the explanatory power of the short run dynamics.

The deviations of the first long run equilibrium equation, $\xi_{1,t-1}$, represent the slope of the term structure. The higher the values the steeper the term structure. As expected and as depicted by the significant coefficients of $\xi_{1,t-1}$ in Table 3 for the equations for the short- and long-term interest rates, a steep term structure will reduce long-term rates and increase short-term rates in order to return back towards equilibrium. In addition, whenever the term structure is strongly upward sloping, we also observe that M2, inflation and cap rates tend to increase.

\(^6\) The eight plots that visually compare for each of the error-correction equation the actual and fitted values also confirm this observation. These plots are available upon request.
Deviations from Fisher Parity, $\xi_{2,t-1}$, can be interpreted as the short-term real interest rate. Consistent with economic theory, short-term real interest rates are negative for the 3-month interest rate equation (although only with a p-value of 14%) and significantly positive for the inflation equation. The deviations from Fisher Parity have also a negative influence on rents and to some degree a negative impact on construction.

If the real estate market is out of equilibrium, e.g. because there is too much construction ($\xi_{3,t-1}$ would be positive), then we observe two differing behaviours. On the one hand, a short-term increase in construction raises cap rates due to higher risk perceptions and reduced growth expectations, which is shown by the positive construction beta in the cap rate equation. On the other hand, for the market finally to return to equilibrium, either a justification for the initial increase in construction is required (which according to the D&W framework could be provided either by an increase in rents or by a reduction in cap rates), otherwise construction needs to fall again. Our findings are in line with the theory predicted error-correcting behaviour as $\xi_{3,t-1}$ is negative for the construction and the cap rate equations. Rents do not adjust in a significant way to fluctuations in $\xi_{3,t-1}$. This suggests that prices correct back to equilibrium mainly through an adjustment in cap rates, which is in line with the fact that investors can adjust cap rates more easily than landlords can adjust rents.

Deviations from the real estate equilibrium have also a significant effect on M2 and on short-term interest rates, indicating that central banks also react to disequilibria in the real estate market.

Finally, if the real estate excess return is above its equilibrium value, i.e. when $\xi_{4,t-1}$ is positive, the correction back towards the equilibrium value takes place through both cap rates and interest rates. This is shown by the fact that the error correction term is significant for cap rates, and long- and short-term interest rates (at the 10% level only for the latter). Results additionally show that disequilibria also affect inflation, economic growth and rents.

6.2.2 **Length of time to equilibrium**

The deviations from the long run equilibrium relations are plotted against time in Figure 3. These suggest that Fisher Parity is strongly error-correcting. The other three equilibrium equations are also error-correcting but it takes longer for their deviations to be corrected. This is consistent with the persistent profiles of system wide shocks (Figure 4). For the Fisher
Parity, deviations are corrected by as much as 97% already after four quarters and completely vanish after another four quarters. Deviations from the other three long run equilibrium relations are corrected only by 82% to 95% after three years and need roughly five years to completely vanish. This reflects the standard view that arbitrage in asset markets works faster than in the goods markets in restoring equilibrium and above all the sluggishness of the real estate market.

[Figure 3 and Figure 4 about here]

A direct comparison of the length of time to equilibrium with previous studies is difficult, because the only indication provided by earlier studies is usually the coefficient estimate of the error correcting term, i.e. of the deviations, $\xi_{i,t-1}$. In addition, caution is required in comparing studies which use different datasets and methods, which is especially important as our approach strongly differs from those used in previous studies in terms of both the methods applied and the specifications of the long run equilibriums.

Bearing these caveats in mind, the error correction terms in the cap rate models of Clayton, Ling & Naranjo (2009), Dunse et al. (2007) and Hendershott & MacGregor (2005) may be compared with our deviations in the excess return equation, $\xi_{h,t-1}$. The coefficient of $\xi_{h,t-1}$ in the cap rate equation in Table 3 suggests that these deviations are corrected by about 13.9% per quarter. This finding is similar to the evidence reported by Hendershott & MacGregor (2005) who find the adjustment speed for the U.K. retail and office market to be 15.3% and 14.7%, respectively. Clayton, Ling & Naranjo (2009) find a faster convergence (between 40% and 100%) for various U.S. commercial categories, while Dunse et al. (2007) find a slower convergence of 31.7% p.a., i.e. about 8% per quarter, for the U.K. office market.

The adjustment speed of rents to deviations from their long run equilibrium values is in the range of 30% to 45% for most studies (McCartney, 2012). Unfortunately, these values cannot be directly compared with our findings, because our real estate market equilibrium equation represents the deviation of the whole market and not only of the equilibrium rent. The estimates of $\xi_{3,t-1}$ in the construction, cap rates and rent equations suggest that the deviations are corrected by about 12.3% per quarter via adjustments in construction and that prices also adjust to disequilibria, mainly through adjustments in the cap rates rather than through changes in rents (as depicted by the p-values).
The GIRFs for the cointegrating vectors enable to analyse the error correction behaviour in more detail by disentangling the effects of each individual shock on the long run equilibrium over time. The results of the GIRFs of the cointegrating vectors are presented in Figure 5a for the real estate excess return and in Figure 5b for the real estate market equilibrium. The results show that all 16 shocks have only temporary effects on the long run equations. This is also true for shocks to the Fisher Parity and to the slope of the term structure equilibrium equations, which again confirms the cointegrating properties of all four long run relations.

[Figure 5 about here]

Figure 5 indicates that the length of time to equilibrium varies from 10 to 30 quarters depending on the shock. The smallest influence on the real estate excess return equation is exerted by a change in inflation and its effect vanishes after 10 quarters. The biggest changes are caused by short- and long-term interest rates, M2 and GDP. The real estate market equilibrium is again not much affected by a change in inflation, while a one standard deviation change in either cap rates, long-term interest rates or rents does affect the equilibrium substantially more. Finally, Figure 5 also reveals that some shocks eventually simply vanish while others, such as a shock in construction, M2, or GDP lead to oscillation and that the length of time to equilibrium is almost seven years for most shocks in the real estate equilibrium equation and roughly five years for the excess return equilibrium.

6.3 Short run dynamics

As a discussion of all 64 GIRFs of the model would go beyond the scope of this paper, we focus on three important topics. First, we briefly discuss results that are related to the monetary policy of central banks, which use the short-term interest rate as their main monetary policy instrument. Next, we look at the reactions of the real estate variables in response to various economic shocks before the section closes with a discussion of the impact that real estate shocks exert on economic variables.

6.3.1 Monetary policy of central banks

In Figure 6 the reaction of all endogenous variables to a one standard deviation increase in short-term interest rates is illustrated. If the central bank increases short-term interest rates by 15 basis points, bps, they also tend to decrease M2 by 1.2%. As intended, inflationary pressure is reduced over the course of the next 10 quarters, but the intervention comes at the
cost of a reduction in GDP by 65 bps. In addition, over the next four years, on the real estate market, rents decrease by 1% due to reduced demand while cap rates increase by 1.7 bps, hence prices fall and so does construction by 1.1%. This demonstrates the effectiveness of monetary policy in controlling inflationary pressures and economic growth. It additionally highlights that consequences are potentially far reaching as they are not limited to the core economy and instead also affect the real estate market. As we show below, the real estate market will feed back to the core economy and hence could intensify the initial effects. Ultimately, this can lead to a recession and a real estate crisis, unless the interventions were well tempered and their entire consequences fully anticipated.

[Figure 6 about here]

6.3.2 Dependence of the real estate market to economic shocks

Figure 7 shows that on top of the short-term interest rates many other economic variables influence the short-term dynamics of the real estate market. For example, a positive shock in short- or long-term interest rates make investments more expensive and therefore reduce construction. As suggested by D&W and Tobin's Q, construction is also reduced when cap rates increase and increased when market rents rise. If more money is made available (increase in M2) construction is increased, as part of the money flows to the real estate market.

Cap rates rise (and real estate prices therefore decrease) following increases in short- and long-term interest rates, which is in line with the fact that opportunity costs are part of cap rates. The effect, however, is not immediate but rather builds up over the first three years when it reaches its maximum and stabilizes at a slightly lower level thereafter. A decrease in cap rates on the other hand is observed after positive shocks in construction or M2. The latter is because an increase in M2 leads to more cash being invested in the real estate market. More money will render the real estate market more competitive, which leads to a compression in the real estate risk premium (Chaney & Hoesli, forthcoming). The decrease in cap rates after the positive shock in construction might seem counter-intuitive. More construction will lead to more available space, which reduces rents and hence could increase cap rates if growth expectations were reduced. However, as explained in section 6.2.1, another way for the real estate market to react and to return to equilibrium is for cap rates to
decline, which is what the GIRF show. This implies that the equilibrium generating process overrules the former effect and that growth expectations and the risk premium are not fully adjusted due to optimistic market sentiment (that is likely present when the construction sector is booming).

Finally, real rents are primarily affected by construction, M2 and short- and long-term interest rates, which all affect real rents by about 1%. An increase in inflation reduces real rents by about 0.8%. This is probably due to the reaction of central banks, which as discussed earlier, aim to reduce inflationary pressure through an increase in interest rates and/or a decrease in M2, which both reduce GDP and hence real market rents.

[Figure 7 about here]

6.3.3 Dependence of the economy to shocks in the real estate market

The GIRFs also show that the linkages between the economy and the commercial real estate market are not just via the previously discussed long-term relationships and also not just through the influence that economic variables exert on real estate variables. Indeed, we also observe that the real estate market variables themselves have an influence on the short run dynamics of core economic variables (Figure 8). This is important because contrary to our approach, most previous studies did model these core economic variables exogenously. Construction is part of GDP and our results show that a shock in construction increases GDP over a period of three years. This translates into inflationary pressures, which finally leads to both a decrease in M2 and an increase in the short- and long-term interest rates (Figure 8a). If real rents increase, we also observe inflationary pressures because rents are part of the CPI basket, hence M2 will be reduced and interest rates increased (Figure 8b). An increase in cap rates influences the economy to a lesser extent as depicted by the less ample swings in the GIRFs in Figure 8c.

[Figure 8 about here]

7 Conclusions

Theory predicts various linkages between the economy and commercial real estate markets. Previous studies usually have focused on a limited subset of these linkages, while more advanced time series techniques to analyse these linkages have only appeared recently in
the literature. We therefore revisit this important topic and introduce a new modelling technique that was developed by Garratt et al. (2003, 2006). We use this approach to model the whole economy (including several real estate quadrants) by incorporating equilibrium relations that are predicted by theory in an otherwise unrestricted VAR model.

We find four long run equilibrium relations across various macroeconomic and real estate market variables. These have a clear economic interpretation, hence they do not just improve the explanatory power of the models’ short run dynamics, but they additionally help in the interpretation of economic conditions and of the persistent profiles of shocks to any of the equilibrium conditions.

As observed in the 1990s in many European markets, major real estate crises are often associated with increases in interest rates. If one aims at avoiding or at least dampening the impacts of future crises, there is a need to fully understand the linkages between the economy and the real estate market and take these linkages more strongly into consideration when deciding upon monetary policy interventions. This becomes all the more important as our findings also reveal various short run linkages and because those are bi-directional, i.e. economic variables influence the short run dynamics of the real estate market while at the same time real estate variables influence the short run dynamics of the economic variables.

For example, if the monetary authority increases interest rates to reduce inflationary pressures, this will directly reduce GDP growth and inflation, but on top will also impact the real estate market through a reduction in construction and rents and through an increase in cap rates. Our results show that this will feed back to the core economy, as lower construction and lower rents both reduce GDP. The ultimate outcome may be a recession and falling real estate prices.

The results contained in this paper should prove useful to investors, real estate developers, and tenants because a better understanding of the linkages can help them to prepare themselves better for economic shocks and market disequilibria. They should also benefit researchers as the presence of bi-directional links and of a variety of long run equilibrium relations implies that it is likely that several previous studies did not fully capture the whole error-correcting behaviour.

Three areas seem fruitful for future research endeavours. First, the focus of this paper is on multifamily residential properties and a comparison between different commercial property
categories could lead to interesting findings with respect to their short run dynamics or the length of time to restore equilibrium. A priori one might for example expect that the longer lease lengths of office contracts could lead to larger deviations from equilibrium and a longer length of time to restore equilibrium than is the case for multifamily residential properties. Second, one could try to incorporate other variables, such as vacancy rates or a proxy for the rate of depreciation, which is assumed to be constant in this paper.

Finally, extensive research starting with Meen (1999) in the area of spatial cointegration analyses exists that documents that shocks to regional house prices ‘ripple out’ to other regional house markets and that the speed of adjustment can vary by geographic distances, spatial arbitrage, availability of mortgage financing or labour mobility conditions (see e.g. Apergis & Payne, 2012; Holmes, Otero, & Panagiotidis, 2011). Switzerland is a small and stable economy with a high population density and rather homogeneous mortgage financing availability. In addition, according to the 2012 global transparency index of Jones Lang LaSalle, Switzerland is ranked among the ten most transparent real estate markets worldwide. Consequently, disturbances to long run equilibrium are likely to vanish fast and the short run dynamics across Swiss submarkets are likely quite homogeneous. However, the findings in relation to the ripple effect as well as the previously discussed differences in the adjustment speeds of equilibrium cap rates and rents suggest that some differences in the length of time to equilibrium might exist depending on country characteristics. How much and what factors would help explain potential differences in the adjustment speeds, if these were indeed to exist, ultimately remains an empirical issue. To answer such questions a transparent framework is needed where the long run equations are not purely statistically motivated, but instead can be interpreted on the grounds of economic theory. It also requires tools to analyse the short run dynamics and the length of time to equilibrium. We hope to motivate other researchers to analyse such questions in more detail with the methods and tools that are introduced to commercial real estate market analysis in this paper.

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8 References


Table 1 Estimated cointegrating vectors

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<thead>
<tr>
<th>Coefficient</th>
<th>Point estimate</th>
<th>Std Error</th>
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<tbody>
<tr>
<td>$\beta_{12}$</td>
<td>-0.7630</td>
<td>0.0730</td>
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<tr>
<td>$\beta_{22}$</td>
<td>-1.0663</td>
<td>0.2169</td>
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<td>$\beta_{23}$</td>
<td>0.0170</td>
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<td>$\beta_{24}$</td>
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<td>$\beta_{36}$</td>
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<tr>
<td>$\beta_{37}$</td>
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<td>$\beta_{44}$</td>
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<td>$\beta_{45}$</td>
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<td>$b_{41}$</td>
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Table 2 ARDL model

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<th>F-stat</th>
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<td>STS</td>
<td>-0.086</td>
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<td>4.1; 4.8</td>
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<td>-2.8; -3.5</td>
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<td>5.0; 5.9</td>
<td>4.0; 4.9</td>
<td>ARDL(1,0) C</td>
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<tr>
<td>RER</td>
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<td>-4.23</td>
<td>-3.4; -3.4</td>
<td>9.2</td>
<td>6.7; 7.5</td>
<td>5.7; 6.4</td>
<td>ARDL(2,0) T</td>
</tr>
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</table>

Note: STS is the slope of the term structure, estimated as $r10 = 0.568 \times r3m + 0.004$, FP is Fisher Parity estimated as $r3m = 0.011 \times (Y - M2) + 0.017$, RME is the real estate market equilibrium, estimated as $con = 0.241 \times (rent-157^*cr) + 8.476$, and RER, estimated as $cr - r10 = -0.042 \times (con - y) - 0.00005$, is the real estate excess return equation. Critical values for the F-test of the joint significance of the lagged levels and for the t-test for the significance of the coefficient of the error-correction term are based on Pesaran, Shin & Smith (2001). In case the test statistic is below the lower bound, the null cannot be rejected. If it is above the upper bound, the null is rejected and cointegration is assumed to be present. Whenever the test statistic lies between the two bounds, results depend on whether the variables are I(0) or I(1). Finally, the critical values depend on whether a trend or a constant is included, i.e. on the characteristics of the deterministic terms, indicated in the last column.
Table 3 Estimated error correction equations

<table>
<thead>
<tr>
<th>Equation</th>
<th>Δ3m_t</th>
<th>Δm_t</th>
<th>Δm2_t</th>
<th>Δν_t</th>
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Diagnostic Tests

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Note: the error correction terms, Δν, are defined in equation 19 and Table 1. Benchm. R² represents the adjusted R² of an equivalent VAR that does not include long-term equilibrium relations. Values in brackets represent p-values that are based on Newey & West (1987) autocorrelation and heteroskedasticity consistent standard errors because some equations show some evidence of serial correlation or heteroskedasticity. The assumption of normally distributed errors is rejected in four error correction equations. This is mainly due to some large outliers, which is not surprising considering the events that have strongly influenced the Swiss economy during the period of study, such as the oil crisis in 1974, or the strong appreciation of the Swiss franc in conjunction with a ‘fixing’ of the exchange rates in 1978 and in 2011, to mention just a few. While these departures from normality should not have a significant impact on our main findings, they indicate that it may be problematic to use the models for forecasting purposes in times of highly volatile market periods and that absolute p-values should be interpreted with caution as the significance of the estimated coefficients will likely be underestimated.
Figure 1 The real estate markets and its submarkets (DiPasquale & Wheaton, 1992, 1996)
Figure 2 Long run relationships

a) Short- and long-term interest rates

b) Real GDP and real M2

c) Three-month interest rate and M2 velocity

d) Inflation and three-month interest rates

e) Real interest rates and money velocity

f) Real prices and real construction

g) Ten-year interest rate and cap rate

h) Cap rate spread and construction to GDP
Figure 3 Deviations from long run equilibrium relations

a) Slope of the term structure

b) Fisher Parity

c) Real estate market equilibrium

d) Real estate excess return

Figure 4 Persistent profiles of a system-wide shock to the cointegrating relations
Figure 5 Generalized impulse responses of the cointegrating vectors

a) Real estate excess return

b) Real estate market equilibrium

Figure 6 Generalized impulse responses related to monetary policy

Note: The graphs show the estimated GIRFs for the various variables over 40 quarters. The shock used to calculate the GIRFs corresponds to a one standard deviation increase (15 basis points) of the short-term interest rate.
Figure 7 Generalized impulse responses of real estate variables to economic shocks

a) GIRF of construction

b) GIRF of cap rates

c) GIRF of market rents

Figure 8 Generalized impulse responses of the core economic variables to shocks in the real estate market

a) Shock in construction (2%)

b) Shock in rents (1%)

c) Shock in cap rates (7.5 Bps)