

**A Simplified Constant-Liquidity Price Index for U.S. Commercial Property Based on the
RCA Database**

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Abstract

This thesis builds on the endogenous relationship between transaction price and volume in commercial real estate markets in order to construct a simple “constant-liquidity price index” (SCLI) applicable to general transaction databases such as that of Real Capital Analytics Inc (a MIT/CRE member firm). By recognizing the fact that current commercial property indices do not capture the demand-side of the market (potential property buyers), which is the source of liquidity in the market, the type of index developed in this thesis fills a gap in the need for commercial property investment information.

The ease of selling a property at the price indicated by an index of average realized prices (in closed deals) is variable and highly correlated with market cycles. And investors care not only for the price but also want to know how easy it is to sell property at those prices. This thesis is an extension of the formal study of constant-liquidity indexing (Transaction based supply and demand index) developed by Fisher, Gatzlaff, Geltner and Haurin (2003) based on the NCREIF (National Council of Real Estate Investment Fiduciaries) Property Index (NPI) transaction data base (hereafter referred to as “FGGH”). Compared with the underlying more rigorous econometric model of FGGH, this thesis presents a simplified approach to construct a constant liquidity price index (hereafter referred to as “Simplified Constant-Liquidity Price Index/ SCLI”) suitable for a more typical type of commercial property transaction database, one that contains data only on sold properties (the NCREIF database used by FGGH contains data on both sold and unsold properties).

In this thesis, monthly SCLIs are compared with the corresponding realized price indices and the results suggest that the SCLIs tend to lead the price indices and display a greater volatility. The SCLI developed here behaves similarly to the more econometrically rigorous FGGH-based demand-side indexes, therefore tends to validate the construction method of the SCLI, suggesting that this could be a useful information product and possibly a valuable tool for investment allocation and derivatives trading.

Thesis Advisor: David M. Geltner
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Introduction

It is fundamentally important for investors to understand any investment asset class by tracking the changes in investment values. In the US, commercial real estate has evolved into a major asset class that plays a significant role in many institutional portfolios. The total US investable commercial real estate assets are estimated at \$5 trillion, approximately 15% of the nation's investible universe which also includes stocks and bonds. However, there is no single commercial property index in the US that captures the relevant commercial property market completely and timely. Despite the market downturn, which is largely related to subprime credit crunch starting in the third quarter of 2007, the NCREIF (National Council of Real Estate Investment Fiduciaries) Property Index (NPI) continued to show capital appreciation for at least two or three quarters beyond the turning point, and then only began to turn very slowly with a very small (less than 1%) drop even up till the second quarter of 2008. The Moody's/REAL Commercial Property Price Indices (CPPI) showed an increase of 2.1% in February over the previous month. Even though Moody's/REAL Index measures 181.23 in April¹, a decline of 3.0% from the previous month, and 2.8% below the same period of the previous year, the CPPI still logs an increase of 9.1% over a two-year horizon. The fact that both indices failed to show much of a clear downturn has highlighted several different structural issues in the current commercial property indices.

There are three major challenges to measure and monitor changes in the private property market as a whole. First of all, the biggest difference between real estate and other securitized

¹ See "CPPI: Report Release Cycle, 2008-2009 in the Moody's/REAL Commercial Property Price Indices, June 2008 report." at website: http://www.rcanalytics.com/derivatives_index.aspx

financial assets is that whole heterogeneous assets are traded in the real estate private markets. No two properties are exactly the same with. The value of a property depends on the location, type, size, architectural quality, occupancy and many other factors. Moreover, investors see value differently because of their investment objectives, risk tolerances, tax motivations and the amount of information they can get for a specific property. This implies that real estate market information in general can be inefficient. Secondly, even though transaction based property indexes are a better alternative to track and record market changes compared to the appraisal based ones, transaction based property indexes face the challenge of sample selection bias, because only a small fraction of all the assets in the market transact during any given period and those that are sold may not represent the whole market in empirical analysis. Real estate is a relatively expensive asset class with high transaction costs, thus real estate investors typically hold properties for a longer time period and this results in infrequent trading activities, which are irregular over time compared to other financial assets. The last major challenge to measure real estate market as a whole is that, unlike highly liquid stock and bond markets where investors are always able to buy and sell easily in both up and down markets, real estate markets generally demonstrate highly variable liquidity over time. In general, it is easier to sell a property in an up market than in a down market (even though the prices in the first are higher). The “heterogeneous” character and “sample selection” bias have been extensively addressed in the real estate and financial economics literature. However, this is not the case with variable liquidity characteristics. This thesis focuses on variable liquidity characteristics to develop a “tool” that can use the association between price and volume to track the movement on the demand side of the market.

The purpose of this thesis is to provide information about the movement in the demand side of the market which is the source of liquidity by recognizing the endogenous relationship between observable transaction prices and transaction volume in private property market. This thesis employs the “constant liquidity value” concept first proposed by Fisher, Gatzlaff, Geltner and Haurin (2003) (hereafter referred to as “FGGH”), and adds to this earlier methodology by developing and presenting a simplified constant-liquidity price index of commercial real estate (SCLI). This development process will be based on the transaction database recorded by Real Capital Analytics Inc (RCA, a MIT/CRE member firm), as the RCA database is one of the most comprehensive and widely-used databases of commercial property transactions in the U.S., and has been made available to the author for the purpose of this thesis. Compared to the supply and demand indexes developed by the MIT Commercial Real Estate Data Laboratory (CREDL) based on NCREIF data (using the FGGH methodology), the proposed index will be based on a simplified model. The methodology is first tested on the same data base that is used to construct the TBI demand-side index, to compare the empirical difference between the more rigorous, complete econometric method of FGGH and the simplified approach developed here. The test proves the viability of a simplified method because based on the same data the simplified index behaves comparable to the FGGH-based TBI demand-side index, with similar volatility, an identical trend and a very high quarterly return correlation (+80%) between the two ways of constructing the demand-side index. Next, the simple method is applied to the database recorded by Real Capital Analytics to construct monthly, quarterly and annually simple constant liquidity price indices.² In this study, the constructed indices are compared with the Moody’s/Real Commercial Property Price Indices.

² Only the monthly aggregate index will be presented in the thesis. Other indices will be included in the white paper “A Simplified Constant Liquidity Price Index (CLPI) Based on the RCA Database”, Geltner and Wang (2008).

There are two major motivations for the development of a constant-liquidity price index. The first important reason is for the strategic planning of commercial real estate allocation in mixed-asset portfolios. Prior to the market crunch in 2007, commercial real estate as an asset class was generally considered to have extremely low volatility and extremely high risk-adjusted returns. However, the volatility seen in commercial real estate indices is very different than the volatility observed in stock exchange indices. The change in asset transaction prices fully captures the change in the market conditions and completely reflects the investors' risk in the stock exchange. This is because, classical models of asset equilibrium prices in the stock market (such as the CAPM) assume pure "price-taking", with demand and supply functions completely elastic (flat horizontal lines at the market price). In other words, the trading volume does not affect price. In the stock exchange, the asset prices can fall or rise as far as they need to go in order to enable investors to buy or sell quickly at any time. Investors' risk is reflected in the price. In the private real estate market, on the contrary, investors are also subject to the liquidity risk which is buried in the price recorded in real estate indices. The up-market prices reflect an ability to sell more assets quicker and easier, than in the down-side market. The constant liquidity price index adjusts for this difference and aims to track private real estate market conditions more completely. The liquidity adjusted price reflects a market based valuation which holds the transaction volume in the market constant over time compared to the highly variable liquidity in the true market.

Another important contribution of the constant liquidity price index to the real estate investment industry is its potential use in the property derivative market. Derivatives are financial instruments whose value is derived from an underlying asset or index. Assets with

traded derivatives include commodities, equities, bonds, and currencies. Although real estate represents over one third of the value of all the investable asset class in the US, almost no derivatives exist in this sector of the capital market. The development of real estate derivatives can greatly increase the real estate market efficiency which is currently hindered by high transaction costs, lack of liquidity, etc. Historically, derivative markets have been built on hedgers who use these products to manage risk. In the real estate sector, potential derivative traders such as real estate developers, property owners, investors, fund managers and mortgage lenders, may seek protection from a significant market downturn that would lead to a surge in defaults. Thus, the hedgers will be most concerned with the effectiveness of underlying trading indices tracking the property market movement. To the real estate hedgers who generally take the short side in the derivatives market, it's the demand side of the market movement that matters most (or most immediately) because it is to that side of the market that they must sell their property. Existing property price indices may not be viewed as fully hedging the investors' risk in a down market, because they only reflect the price risk and not the liquidity risk in the real estate market. Constant liquidity price indexes will be able to address this concern by capturing the liquidity risk in the market.

This thesis is organized as follows. The first chapter is a brief historical background introduction and literature review. The second chapter describes the data provided by Real Capital Analytics and introduces the 29 indices included in the Moody's/REAL Commercial Property Price Indices (CPPI). The third chapter develops the theory of the simplified approach to quantifying the difference between empirically observable transaction prices and constant liquidity price value. The fourth chapter describes the construction method. The generic model is

then applied to the NCREIF database and the resulting Simplified Constant-Liquidity Price Index (SCLI) is compared to the MIT-Published TBI demand side of the index. It shows that the SCLI displays very similar characteristics to the “econometric” model based TBI demand index. Thus, this validates the effectiveness of the simplified model developed in this thesis. The fifth chapter specifies how to apply the simplified model to the RCA database. A volume index based on the transaction frequencies of properties tracked by Real Capital Analytics is first developed. The choice of the magnitude of price elasticity of demand is then discussed and determined. Last, the underlying model of Simple Constant-Liquidity Price Indices based on RCA database is specified by combining the information of the Moody’s/REAL Commercial Property Price Indices with the volume index, using the estimated price demand elasticity magnitude. The sixth chapter discusses the empirical results when the simplified model is applied to the RCA database. The national aggregate monthly constant liquidity price index is presented here. The last section concludes with a summary of observations and recommendations for further study. The supporting information and materials are summarized in the appendix and bibliography sections.

Chapter One: Historical Background and Literature Review

The purpose of this thesis is to provide information about the movement in the demand side of the market which is the source of liquidity by developing and presenting a simplified constant-liquidity price index of commercial real estate (SCLI). In this chapter, major existing commercial price indices and their construction methods will be briefly introduced and discussed. In addition, previous academic literature relating to the concept of “constant-liquidity value” will also be studied and reviewed here.

1.1 Major Existing Commercial Property Price Indices

NCREIF (National Council of Real Estate Investment Fiduciaries) Property Index (NPI), MIT-Published TBI based on NCREIF database and the Moody’s/Real Commercial Property Price Indices (CPPI) represent major commercial property price indices in the U.S. NPI is appraisal based index, while TBI and CPPI are transaction based indexes.

The NPI tracks properties that are owned and operated by tax-exempt institutional investors. The total estimated market value of properties in the NPI is around \$328 billion compared to more than \$3 trillion of commercial investment properties in the US. Traditionally, the properties in an appraisal based index are appraised regularly and the index periodic returns are based on a simple aggregation of those appraised values over each period. Although NPI has become an industry standard performance bench mark for the institutional grade commercial real estate assets, its appraisal based nature has caused the index to lag behind true market changes in the value of commercial properties. This is mainly because most properties tracked in the index are not fully or independently reappraised every quarter. This can create difficulties when

investors need to benchmark the NPI to analyze the performance of their properties, to rebalance their multi-asset portfolio for the optimal risk adjusted returns, or when using real estate derivatives to hedge effectively at various market turning points as Geltner and Pollakowski (2007) have stated: “A lagged index, that therefore does not represent the going-forward expected returns implied by current equilibrium values in the property market, could also be more difficult to correctly price in the futures market as the effect of the lag in the index must be forecasted by traders and factored in their pricing”.³ Although techniques have been developed to adjust for the “smoothing” and “lagging” effect of the appraisal index, these techniques are somewhat ad hoc and the mathematical model employed is too complex for general real estate investors to understand.⁴

A transaction based index is a logical alternative to avoid the appraisal smoothing bias in the appraisal based index. In principle, all commercial properties can be included into a transaction based index because all of them can potentially transact. There are different techniques to construct a transaction based index and the most applicable ones are the “hedonic-price” method, the “repeat-sales” method, and the “hybrid” method. Each of these methods uses the econometric regressing method to record the price levels or changes of a “typical” property in the market and to create an index to track such levels or changes. The “Hedonic-price” method uses estimations between the asset transaction price and the asset characters such as location, land area, structure, and quality of the construction. The required data include transaction prices, characteristics of the property, and transaction dates. The MIT/CRE Transactions Based Index

³ Quote: “A Set of Indexes for Trading Commercial Real Estate Based on the Real Capital Analytics Transaction Prices Database”, Geltner and Pollakowski (2007)

⁴ See Brown (1985), Blundell & Ward (1987), Quan & Quigley (1989,1991); Giacotto & Clapp (1992); Geltner (1993); Fisher, Geltner & Webb (1994); Lai & Wang (1998); Fisher & Geltner (2000); Fu (2003)

(TBI) is a hedonic, regression based transaction price index for the NCREIF property population. However, this is a special circumstance which is not easily applicable to broader commercial property transaction databases and the TBI is not available below the national level.⁵

The “repeat-sales” method is an alternative to the “hedonic-price” method. The “repeat-sales” method does not require data such as characteristics of the property which are quite complex to identify in the commercial real estate market. This method records the transaction price change for the same properties from two periods based on the assumption that the properties do not change over time. An index based on the repeat sales method can be described as “same-property price-change index” and thus can be compared to other financial securities’ indexes such as stocks and bonds indexes which are based on the price change of the same stock from time to time⁶. The “repeat-sales” regression method was first applied to residential property indexes such as the Fannie Mae and Freddie Mac based “Conventional Mortgage Home Price Index” (CMHPI) published by the Office of Federal Housing Enterprise Oversight (OFHEO) and the privately produced Case-Shiller-Weiss (CSW) housing price indexes, which CME housing futures contracts are based on (as the S&P/Case-Shiller Home Price Indices). The Moody’s/Real Commercial Property Price Indices is a transaction based commercial property index using the “repeat-sales” method. It is based on the Real Capital Analytics database which attempts to capture, on a timely basis, price information for every commercial property transaction over \$2.5M in value in the U.S. Although an improvement when compared to the appraisal based index, the transaction based index generally suffers from two major measurement biases: the

^{5,6} See “A Quarterly Transactions-Based Index (TBI) of Institutional Real Estate Investment Performance and Movements in Supply and Demand”, J.Fisher, D.Geltner & H.Pollakowski (2007)

sample selection bias and the liquidity bias. These biases reflect the fundamental differences between the real estate asset class and other financial asset classes such as stocks and bonds.

Sample selection bias refers to the fact that typically only a small fraction of all the assets in the market transact during any given period and those that are sold may not represent the whole market in empirical analysis. Thus, the price index may be biased if the properties that transact are not representative of the entire stock market. This bias is affecting the commercial property price index much more than the residential property price index because there are much less commercial property transactions than residential property transactions. The sample selection bias has been addressed frequently in the real estate and financial economics literature. Heckman (1979) developed a two-step correction procedure which is specifically applied to real estate markets by many researchers including Gatzlaff & Haurin (1997, 1998) and Munneke & Slade (2000, 2001). The two-step correction procedure starts with the development of a model in which properties sale in a particular time period. Then, a variable is created to correct for the sample selection bias. Lastly, the “hedonic-price” method is employed to include this bias variable to estimate the relationship between transaction prices and property characteristics. Although much attention has been paid to correct the sample selection bias in the transaction based index, studies that relate to liquidity bias remain scarce in both the academic and industrial world.

Liquidity bias refers to the phenomenon that transaction volume typically varies dramatically over time in the private real estate market. During a “down” market, capital flows out of the sector, the demand for real estate falls, there is much less transaction volume, and it’s

much more difficult to sell assets at price levels that are observed from index records. In the Moody's/REAL Commercial Property Price Indices report of April 2008, the repeat-sells transaction volume in February was down 38.6% from December 2007 while the price index still showed a 2.1% appreciation in February. Just the opposite typically occurs in “up” markets. As a result, the price levels from transaction based index do not fully capture the actual liquidity risk in the market. Thus, real estate investors bear not only the price risk of the properties but also the liquidity risk.

1.2 Literature Review

The first breakthrough study on this subject is conducted by Fisher, Gatzlaff, Geltner and Haurin (2003). The paper defines a concept of “constant-liquidity value” in the context that the real estate market is characterized by a variable volume of trading over time. Given the long recognized correlation between price and transaction volume, the up market price would have been higher if the seller had waited longer and the down market price would have been lower if the same number of properties of a normal market condition had transacted. Moreover, the variation in transaction volume is “highly pro-cyclical”. Liquidity is “positively correlated with”⁷ the private property market cycle. During an up market, there is greater liquidity while the liquidity is less during a down market. The availability of both sold and unsold assets in the indexed asset population based on the NCREIF database enabled the authors to develop an econometric model that estimates the constant-liquidity value indices of market capital returns or value changes over time. By applying the model to the institutional commercial real estate

⁷ Quote: “Controlling for the Impact of Variable Liquidity in Commercial Real Estate Price Indices”, Fisher, Gatzlaff, Geltner and Haurin (2003).

market represented by the NCREIF database, the authors developed transaction based constant liquidity price indices both on the demand and supply side. The indices are published quarterly by MIT/CRE CREDL (Commercial Real Estate Digital Lab, MIT Center for Real Estate). Figure 1 depicts the cumulative log value levels of NCREIF Property Indices, Transaction Based Indices with variable liquidity, and Transaction Based Indices with constant liquidity on both the supply and demand side. Their research reveals that constant liquidity values tend to lead appraisal and transaction based indices in time and it also shows greater volatility and cycle amplitude. Other studies have been conducted by Lin and Vandell (2007) who integrate modern portfolio theory to address the dynamics of liquidity risk and price risk and Cheng, Lin and Liu (2007) who make attempts to integrate the Fisher, Gatzlaff, Geltner and Haurin (2003) constant liquidity methodology with the Lin-Vandell (2007) “ex ante” model.

Figure 1: TBI Price Index and Demand and Supply Indexes



FGGH's constant liquidity model is a major contribution to the real estate industry. However, the econometric constant liquidity index has not gained enough market attention because the underlying econometric model displays great complexities for its rigorous academic approach, and thus prevents the constant liquidity price indices from further engagement with real estate derivatives. Moreover, TBI and the demand and the supply indexes are not tradable at the time because NCREIF has already chosen NPI as the underlying index to trade real estate derivatives.⁸ In this thesis, I will show that the development of alternative commercial property price indices to underline the real estate derivatives products can provide opportunities for profit trading at different indexes, and thus will help to promote price discovery and market efficiency in the real estate investment community. In addition, it can stimulate further development of the real estate derivatives market and increase market transparency and liquidity.

The primary focus of this work is to take the study by FGGH to develop a simplified constant-liquidity price index (SCLI) based on RCA data which is a much broader commercial properties database compared to that of NCREIF. This simplified constant-liquidity price index will be built upon several key indices of the Moody's/REAL commercial property price indices. The model underlines the simple liquidity index is an extension and a simplified version of the econometric model discussed in FGGH's 2003 paper. It uses easy-to-understand mathematic models and data-filling rules to derive the relationship between constant liquidity value and market liquidity defined as transaction volume during any specified market period. This thesis hopes to promote the use of constant liquidity price indices in the general real estate investment community.

⁸NCREIF has issued the licenses to trade NPI to several dealers in early 2007.

Chapter Two: Review and Description of the RCA Data Sets and the Moody's/REAL CPPI

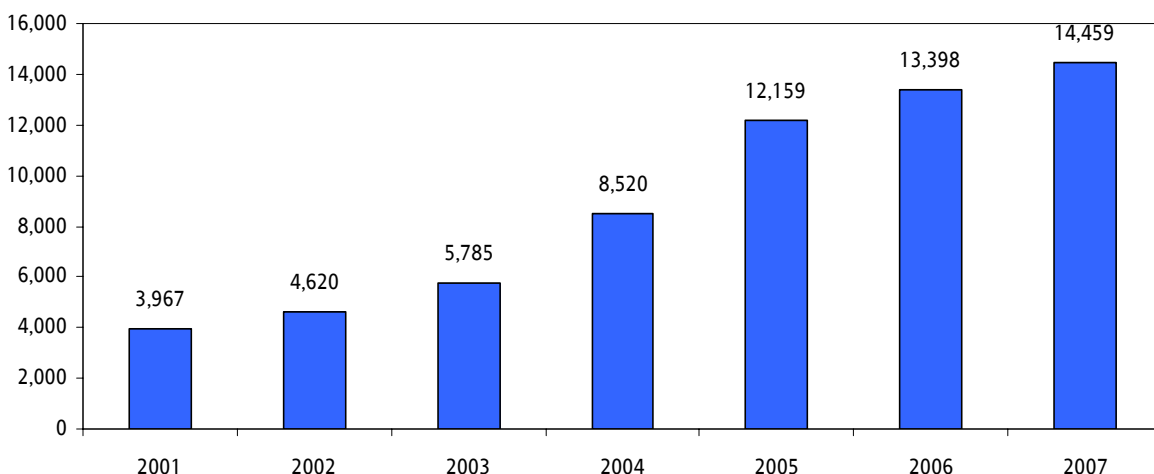
In this chapter, the underlying data and employed major indices will be introduced and discussed. The first section presents the database and the second section presents the information of the indices.

2.1 RCA Data Sets

This thesis is based on data collected by RCA which underlines the Moody's/REAL CPPI. In 2000, RCA started tracking commercial property transactions in the US and the data coverage was expanded to the global market in 2007. RCA captures sales of properties or portfolios \$2.5 million and greater in U.S. and \$10 million and greater globally. RCA focuses primarily on income producing properties which are categorized into six major sections: office, industrial, retail, apartment, hotel, and commercial developable land sites. RCA has collected transaction price data for a total of 61,168 commercial properties in the U.S. since 2000. The total aggregate value of these transactions through 2007 is estimated to be just under \$1.7 trillion. Figure 2 provides a detailed overview of U.S. commercial property transactions recorded by RCA from 2001 to 2007. The analysis data base of Moody's/REAL CPPI starts in January 2001 and covers U.S. commercial property transactions with a value of \$5 million or greater. The transactions with property or portfolio values of \$2.5 million or more started to be included in the database to construct CPPI from January 2005. Transactions are assumed to be fee simple, and leaseholds and commercial condominium interests are noted, if known. Transactions include asset sales and entity level transactions. The sale of controlling partial interests is grossed up to reflect a full valuation of the property. RCA takes great care to check and ascertain the accuracy of the transaction data by qualifying the price, cap rate and deal source. For example, each price

is categorized by one of the qualifiers such as “confirmed”, “approximate”, “street talk”, “allocated”, “estimated” or “appraised”. If conflicting information is coming from different reliable sources, prices are averaged. For the purpose of this thesis, the overall database for transactions with a value of \$5 million or greater is analyzed because it is a more matured database than that of transactions with a value of \$2.5 million or greater.

Figure 2: U.S. Commercial Property Transactions Recorded by RCA 2001-2007 ⁹



2.2 The Moody's/REAL CPPI

In total there have been 29 indices developed that are based on RCA transaction data. A list of the 29 indices is presented in figure 3 with published frequencies. These 29 indices are organized at three geographical levels: national, regional, and MSA (Metropolitan Statistical Areas)-level. The national level is the only level at which an “All-Property” index aggregating all property usage type sectors is published, and this is the only index which at present is

⁹ Reproduced graph based on information from Real Capital Analytics Website: <http://www.rcanalytics.com/coverage.aspx>

published monthly. All other indexes contain the four major commercial (income producing) property usage type sectors: apartments,

Figure 3: Moody's/ REAL CPPI¹⁰

Index:	Frequency:*
National Indexes:	
All Property	Monthly
Apartments	Quarterly
Industrial	Quarterly
Office	Quarterly
Retail	Quarterly
Regional Indexes:	
East Apartments	Annual
East Industrial	Annual
East Office	Annual
East Retail	Annual
South Apartments	Annual
South Industrial	Annual
South Office	Annual
South Retail	Annual
West Apartments	Quarterly
West Industrial	Quarterly
West Office	Quarterly
West Retail	Quarterly
Top10 MSAs Indexes:	
Apartments	Quarterly
Industrial	Quarterly
Office	Quarterly
Retail	Quarterly
MSA-level Indexes:	
Florida Apartments	Annual
New York Office	Annual
Washington DC Office	Annual
San Francisco Office	Annual
Southern California Office	Annual
Southern California Apartments	Annual
Southern California Industrial	Annual
Southern California Retail	Annual

¹⁰ See: "A Set of Indexes for Trading Commercial Real Estate Based on the Real Capital Analytics Transaction Prices Database" Geltner and Pollakowski (2007)

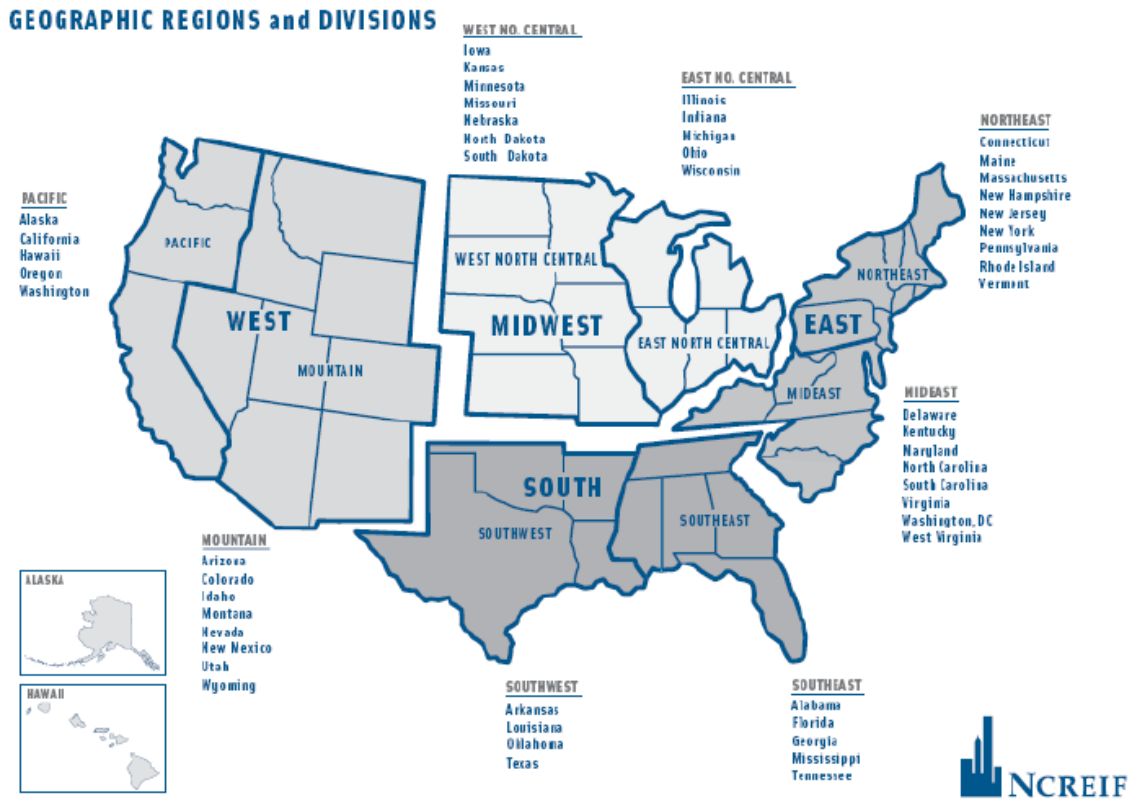
industrial, office, and retail, as defined by RCA.¹¹ Annual frequency indexes are published four times per year in four seasonal versions in January, April, July, and October, respectively, in order to facilitate trades that may occur at various times throughout the year. Only the January index will correspond exactly to the calendar years. Within each index, periods are non-overlapping consecutive 12-month periods. The multistate regions for which the regional indexes are defined are the NCREIF regions, indicated in the figure 4. The MSA-level indexes on which the “Top-10” indexes are based are defined separately for each property sector, based on the RCA dollar volume of trading during a recent two year period. There is no sufficient data to publish any Midwest regional indexes at the moment. In addition, a unique definition of the top 10 MSAs by grouping recent trading volume together has been established to represent “primary markets” in which most large-scale or institutional real estate investments likely occur. There are eight MSA-level indices in total, some of which refer to geographical clusters of nearby MSAs that have markets tend to behave similarly. These include a Southern California cluster (the LA region combined with San Diego) and a Florida cluster (South Florida combined with Tampa and Orlando).

In this study, the simple constant liquidity method will be applied to the national monthly and quarterly indices, and four MSA-level annually indices: Florida apartments, New York offices, South California retail, and San Francisco offices.¹²

¹¹ See the separate white papers available from RCA and Moody’s for detailed descriptions of property type sector and MSA level geographic regional definitions.

¹² Only the monthly national aggregate index will be presented in the thesis. Other indices will be included in the white paper “A Simplified Constant Liquidity Price Index(CLPI) Based on the RCA Database”, Geltner and Wang (2008)

Figure 4: Moody's/REAL CPPI Regions¹³



¹³ See: “A Set of Indexes for Trading Commercial Real Estate Based on the Real Capital Analytics Transaction Prices Database” Geltner and Pollakowski (2007).

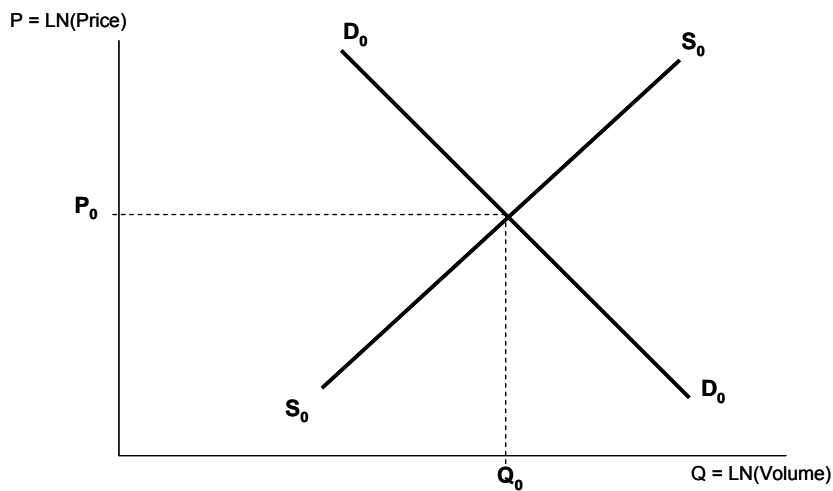
Chapter Three: Theory Model of Simplified Constant-Liquidity Price Index (SCLI)

To see what is meant by the SCLI and how it can be constructed from a combination of realized price and observed trading volume data, let us step back and consider the nature of the private property market.

3.1 Pro-Cyclical Variable Liquidity in the Real Estate Market

It's generally recognized that the real estate trading market is characterized by a downward-sloping demand function and upward-sloping supply function. Other things being equal, potential buyers will want to buy more properties if the property prices are cheaper and potential sellers will want to sell more properties if the property prices are more expensive to achieve a higher expected return. Figure 5 depicts these two function lines in the real estate market. As noted in figure 5, at time period 0 ($t=0$), S_0 is the market supply function line, D_0 is the market demand function line, Q_0 ¹⁴ is the transaction volume and P_0 reflects the market

Figure 5: Demand and Supply Function in the Real Estate Market

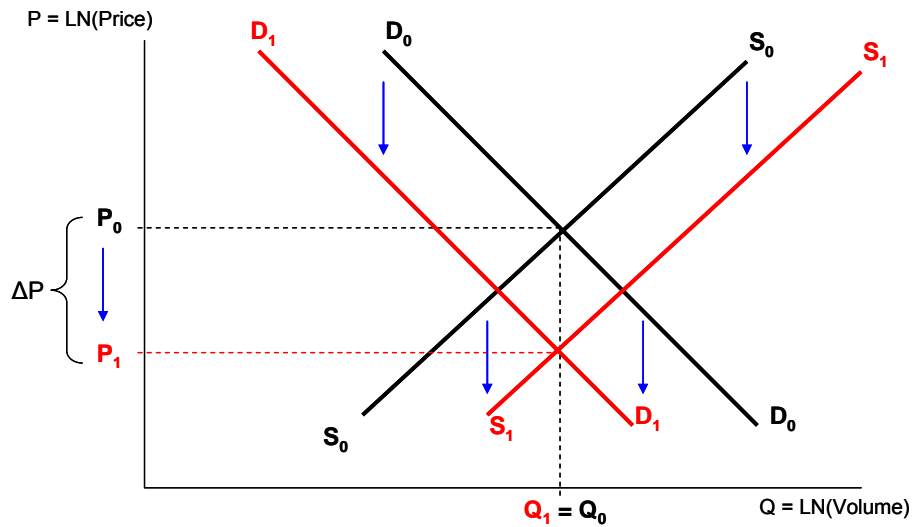


¹⁴ Both price and volume are in natural log values for mathematical convenience.

“equilibrium price” as reflected by the average transaction prices of deals closed at time zero. The average transaction price at time 0 reflects the result of negotiations between numerous pairs of buyers (from the D_0 function) and sellers (from the S_0 function). Individual transaction prices may differ from this average, but they will mostly be similar to it (controlling for quality differences across properties), because traders are aware of the market values, and the average price does reflect the ex ante expectation of the “most likely” sale price.

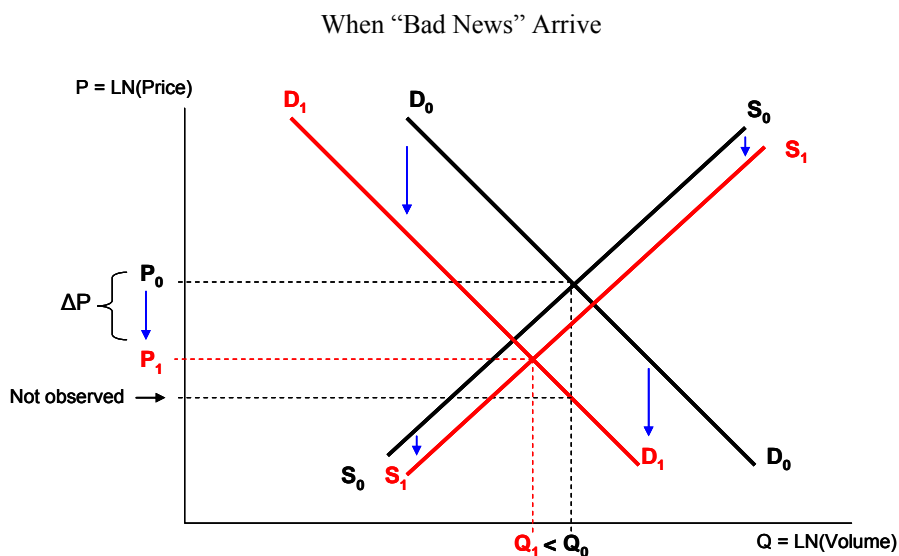
Changes in the general market conditions will shift the demand and supply function line to reflect buyers’ and sellers’ expectation of the market. For example, when “bad news”, such as an unexpected credit crunch, hits the market at time one and the demand for property investments falls. If the supply side of the market (property owners) and the demand side (potential buyers) agree about the magnitude of the property value impact of the bad news, then

Figure 6: Movements of Demand and Supply Functions with Constant Liquidity in the Market When “Bad News” Arrives



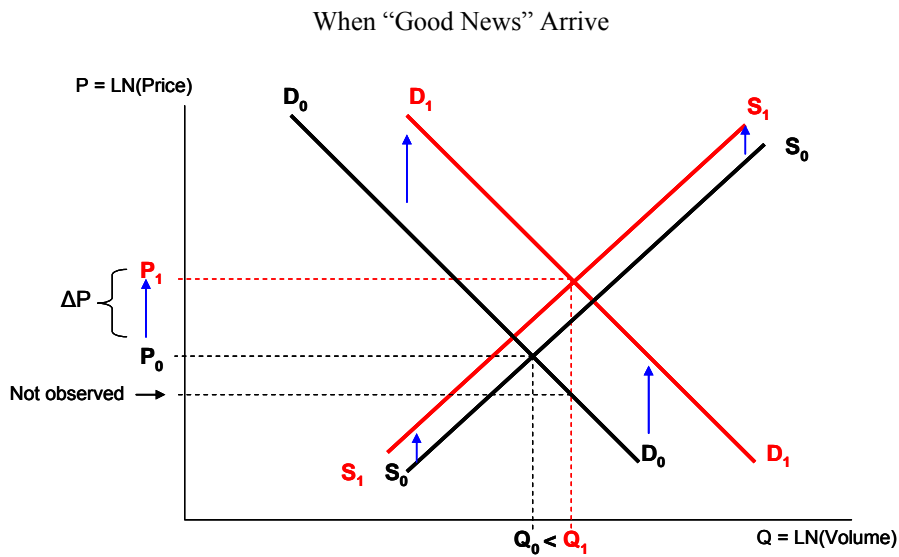
the observed average transaction price will fall to fully reflect that shared perception, and the trading volume will remain unaffected: $Q_1 = Q_0$; ΔP = agreed loss in value (as is shown in figure 6). However, this is rarely what happens in the real estate market. More likely is that the property owners on the supply side will be reluctant to reduce the price to the same level of what is perceived on the demand side of the market. Depending on the degree of uncertainty in certain market situations, property owners may not agree with the expectations of the demand side. They may only be willing to reduce the price partly or even pull back the properties from the market to avoid selling the properties at prices lower than what they expected. This is known as “loss-aversion” or “sticky price” behavior. The new supply function S_1 may drop only partly as far as the demand function D_1 , may not drop at all at the beginning of the market shock, or may even move up due to a quickly reduced supply. Figure 7 shows the situation for when the supply function drops partly as far as the demand function. This so called “loss-aversion” behavior causes trading volume drops ($Q_1 < Q_0$), thus a reduction in “liquidity” in the market. However,

Figure 7: Movements of Demand and Supply Functions with Variable Liquidity in the Market



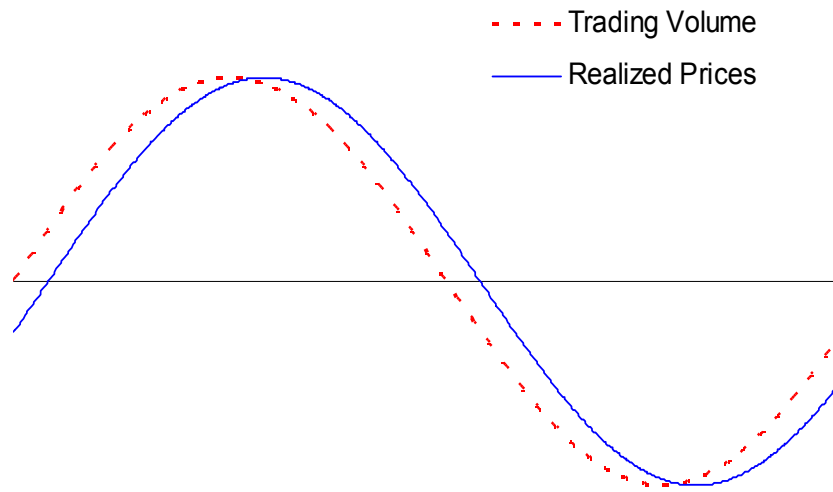
the realized prices do not drop as far as the fall in demand: $P_0 - P_1 < D_0 - D_1$. The same thing can happen in a sudden market upturn when investors decide to allocate more capital to the private property market. The increase in demand causes some increase in price ($P_1 > P_0$), but also an increase in volume: $Q_1 > Q_0$, reflecting increased “liquidity” in the market, but realized prices do not rise as far (or as fast) as the rise in demand: $P_1 - P_0 < D_1 - D_0$ (Shown in Figure 8).

Figure 8: Movements of Demand and Supply Functions with Variable Liquidity in the Market



As described above, the property prices and trading volume are jointly determined by the two opposite-sloped functions: the underlying demand and supply functions in the market. The particular “loss-aversion” behavior in the real estate market causes the phenomenon that transaction prices are positively correlated with trading volume, which is defined as “pro-cyclical variable liquidity” in FGGH’s 2003 paper. Transaction price (P) and volume (Q) tend to move together: volume is high when prices are high (and vice versa). Often the volume changes may tend to slightly lead the realized price changes observable in closed transactions (Figure 9).

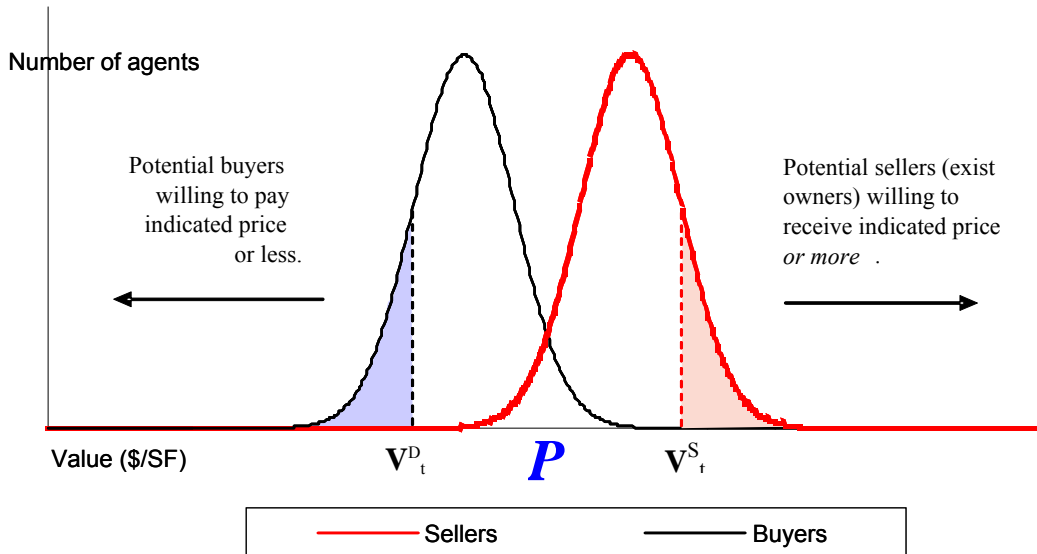
Figure 9: Pro-Cyclical Variable Liquidity



3.2 Buyers and Sellers Frequency Distribution in the Real Estate Market

According to Fisher, Gatzlaff, Geltner and Haurin (2003), the model of the constant-liquidity price index assumes that there is a large heterogeneous pool of potential buyers and sellers of heterogeneous properties. The range of the reservation price of both buyers and sellers follows a normal distribution curve as is shown in Figure 10. The reservation price refers to the maximum price a buyer is willing to pay for a property or conversely, the minimum price at which a seller is willing to sell a property. The horizontal axis represents the reservation price level and the vertical axis represents the number of buyers or sellers at the specific reservation price level. The reservation price for a single property will be different, because the investors see different inherent value in the property based on their investment objectives, cost base, and knowledge about the property.

Figure 10: Buyers and Sellers Reservation Price Distributions
(as of a single point in time)



The center of the buyer's reservation price distribution is to the left of that of the seller's reservation price distribution. This is because the sellers represent current owners of the property and typically value the property more than the buyers who don't own the property. At any given time period t , the shaded area to the left of the reservation price V_t^D on the buyers' side is the number of potential buyers willing to pay indicated price or less and the shaded area to the right of the reservation price V_t^S on the sellers' side is the number of potential sellers willing to sell for the indicated price or more. A transaction between buyers and sellers can only happen when there is a price match between buyers and sellers. If we denote the transaction price at time t as P_t , a possible transaction occurs when $V_t^S < P_t < V_t^D$. That is the transaction price at time t lies in between the minimum price for which the sellers are willing to sell and the maximum price that the buyers are willing to pay. The region of overlap between the buyer and seller reservation price distributions indicates the potential number of transactions in the asset market. The size of

this overlap region is proportional to the transaction volume for a given number of total properties in the asset market. The mean price of transactions will be around the middle of the overlap region which reflects the market equilibrium price.¹⁵ This value can be expressed as:

$$\bar{P}_t = \frac{1}{2} * (\bar{V}_t^S + \bar{V}_t^D) \quad (1)$$

This is the value that an index based on transaction prices tends to capture as well. (\bar{V}_t^S is the mean seller reservation price; \bar{V}_t^D is the mean buyer reservation price.)

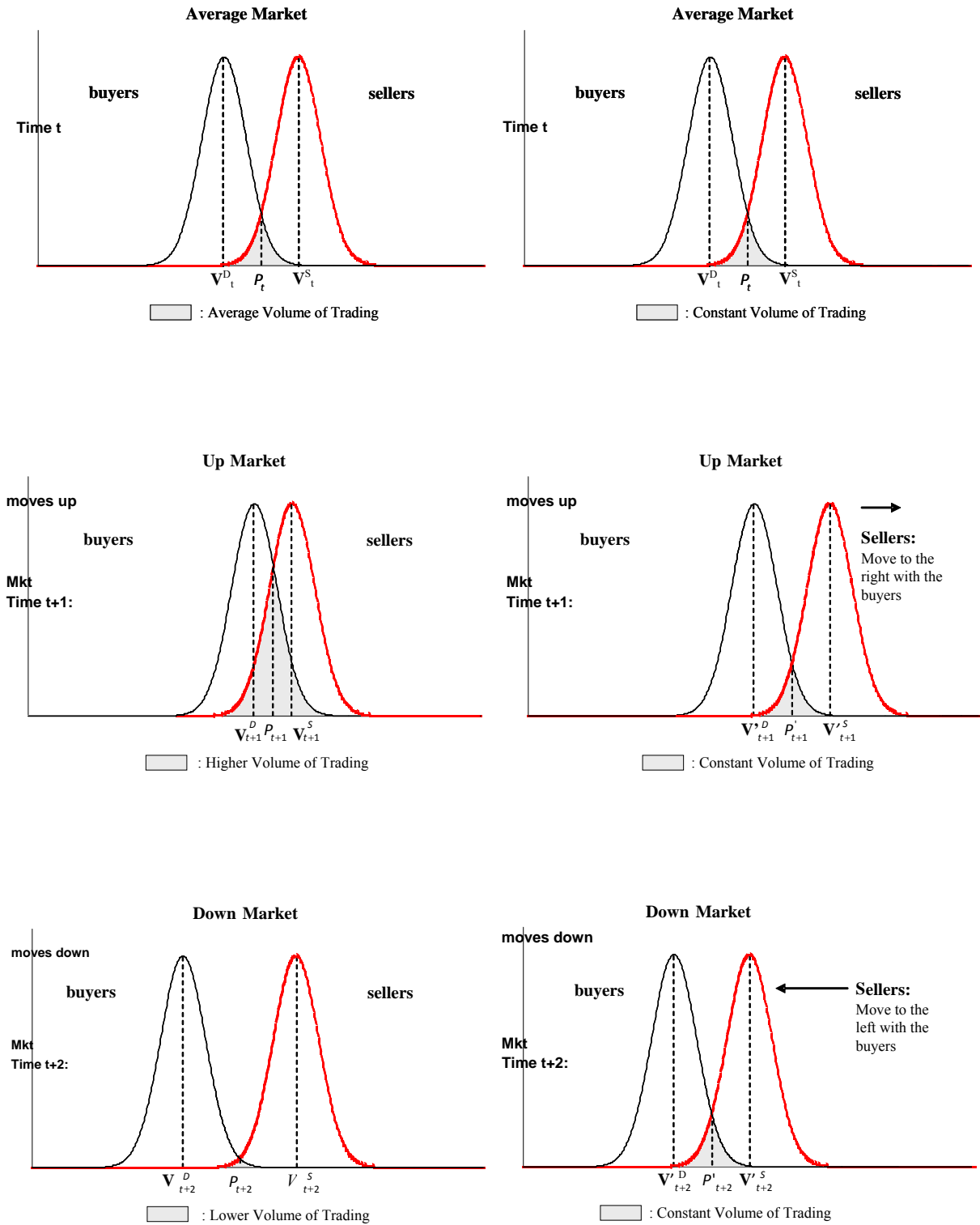
The relative movement between buyer and seller reservation price distributions in various market conditions directly influences the size of the overlap region, thus the liquidity in the market. In an up market, cash flows into the real estate market and investors are willing to pay a higher price and push both the buyer and seller reservation price distribution curves to the right. However, the buyer reservation distribution curve moves further than the seller reservation distribution curve because of the “pro-cyclical liquidity” in the real estate market. Therefore, the overlap region increases and the market exhibits greater liquidity than a normal market. Concurrently, when the market trend is downward, the macroeconomic forces pull the two distribution curves away from each other, resulting in a decreased overlap region, and the degree of liquidity will be less than in a normal market.

In figure 11, the characters and movements of the variable liquidity market are compared with those of the constant liquidity market which holds transaction volumes at the normal market level at all market conditions. The top panel is the base period of average liquidity at time t. The

¹⁵ See Chapter Four for further discussion.

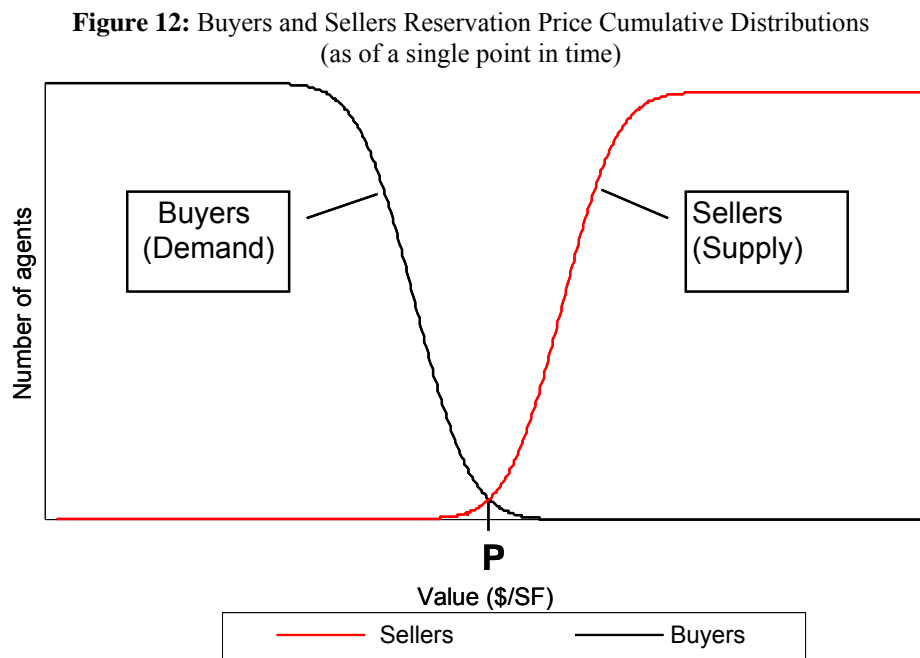
mean buyer reservation price at time t is V_t^D , the mean seller reservation price at time t is V_t^S and the mean transaction price at time t is P_t . The transaction volume in the average market is Q_t at time t which will be held constant in the constant liquidity market. The middle panel depicts a subsequent period of time $t+1$ when the market is up, characterized by above average liquidity (Q_{t+1} , and $Q_{t+1} > Q_t$) in the variable liquidity market. The average transaction price in the variable liquidity market is $P_{t+1} = \frac{1}{2} * (V_{t+1}^D + V_{t+1}^S)$. Yet, in the constant liquidity market, the seller distributions curve needs to move further to the right at V_{t+1}^S in order to keep the liquidity constant at Q_t . The hypothetical constant-liquidity average transaction price is $P'_{t+1} = \frac{1}{2} * (V_{t+1}^D + V_{t+1}^S)$. Clearly, $P'_{t+1} > P_{t+1}$; the mean transaction price in the constant liquidity market is higher than in the variable liquidity market. The bottom panel depicts a third period of time ($t+2$) when the market is down, characterized by below average liquidity (Q_{t+2} , and $Q_{t+2} < Q_t$) in the variable liquidity market. Compared to the movements in the variable liquidity market, the seller distributions curve moves further to the right at V_{t+2}^S to hold liquidity constant at Q_t . As a result, $P_{t+2} = \frac{1}{2} * (V_{t+2}^D + V_{t+2}^S) > P'_{t+2} = \frac{1}{2} * (V_{t+2}^D + V_{t+2}^S)$; the mean transaction price in the constant liquidity market is lower than in the variable liquidity market.

Figure 11: Variable Liquidity Market vs. Constant Liquidity Market



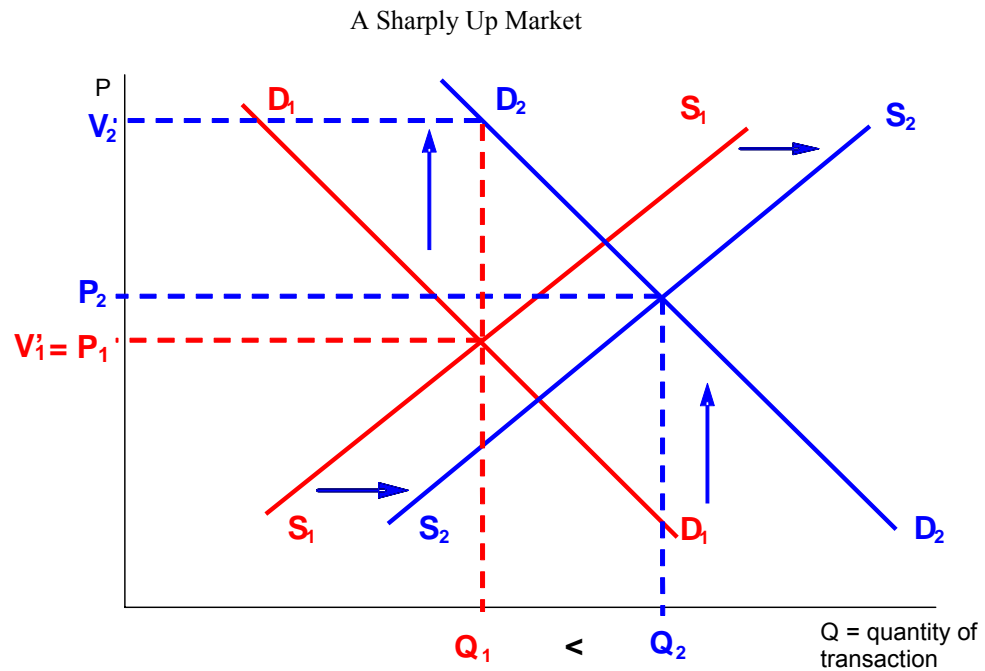
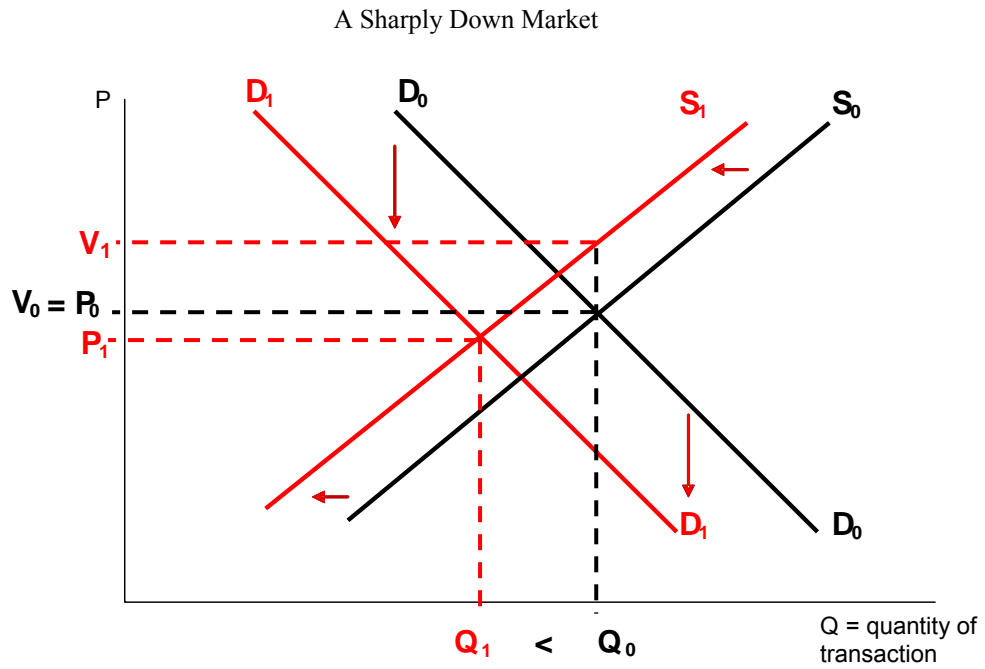
3.3 Cumulative Reservation Price Demand and Supply Model

Figure 12 is based on the cumulative reservation price distributions, the summation under the frequency distributions of figure 10. The horizontal axis represents the reservation price level and the vertical axis represents the total number of buyers (sellers) willing to pay (sell) at this specific price or lower (greater) on the buyers' (sellers') cumulative reservation price distribution curve.



When switching the vertical and horizontal axis, the cumulative reservation price distribution curves follow the classical supply (seller distribution) and demand (buyer distribution) model exactly as is shown in figure 5 in the first section of this chapter. And the comparison between the variable liquidity market and the constant liquidity market displayed in figure 11 can be re-explained in this classical supply and demand model as shown in figure 13.

Figure 13: Real estate market equilibrium: Demand moves further than supply



In market equilibrium,¹⁶ the intersection of the market demand (D_0) and supply (S_0) lines represents the cumulative reservation price (P_0) of the buyers' side and the sellers' side at the transaction volume (Q_0) at time 0. In a sharply down market, the demand falls sharply from D_0 to D_1 and the supply also falls from S_0 to S_1 . The empirically observable mean transaction price will typically only move a lesser fraction, indicated in the figure from P_0 to P_1 , but also reflecting (and causing) the substantial drop in the transaction volume from Q_0 to Q_1 . In a sharp upturn in the market, the demand rises quickly from D_1 to D_2 , but typically the supply may move less far at first, say, from S_1 to S_2 . The empirically observable mean transaction price only moves from P_1 to P_2 but also accompanied by a substantial increase in the transaction volume from Q_1 to Q_2 . The reservation price movement of the buyers' side in the down market is reflected by the movement from V_0 to V_1 , and V_1 to V_2 in the up market respectively.¹⁷

There are several key points illustrated in figure 13. First of all, asset price and transaction volume are determined by these two opposite sloped functions: the underlying demand and supply functions in the market. These two functions are derived from and reflect the cumulative distributions of the buyer and seller populations. Secondly, the movements in the two sides of the market can be estimated and tracked separately if the data of average transaction price and volume of transaction is available. The observed transaction prices reflect the average valuation between buyers and sellers. The recorded transaction volume reflects the difference of

¹⁶ "Market equilibrium" is defined as the market situation that the number of buyers wanting to buy exactly *equals* the number of sellers wanting to sell, at the given ("equilibrium") price. Hence, by definition, equilibrium is where the two cumulative RP curves cross.

¹⁷ The constant-liquidity index (like any index) only represents and quantifies relative changes in values from one period to the next, that is, only one period at a time. Thus, the constant-liquidity index effectively represents price movements that would hold trading volume constant only from each period only to the very next period.

the valuation between buyers and sellers. Lastly, relating the movements in the buyer and seller side of the market to the actual changes in transaction volume suggests a measure of price elasticity of demand and supply in the market.

3.4 Constant Liquidity Price Value Vs. Demand Function Value

As described in the previous sections, real estate market movements are characterized by two important statistics: the average transaction price and the transaction volume. These two statistics are jointly determined by the demand and supply function in the market. Hence, investors should care not only about the average transaction price of a property, but also about how long it would take to sell the property or how easy is it to sell the property at the average transaction price level at the time. The constant liquidity value is an interesting benchmark for investors to follow because this value measures the price level of the real estate market by holding the transaction volume constant in various market conditions. A constant liquidity price distribution simply traces the movement of the reservation price distribution on the buyers' side (demand side). It is to the buyers to whom the sellers must sell their properties and the demand function reflects the perceptions, preferences, needs, objectives, and sentiment among potential buyers (investors in the property market). The demand side of the market controls the money that must be used to pay for properties that are to be sold. Therefore, the demand side is the source of liquidity in the market. Holding price constant, a movement in this demand function (over time) will be reflected in a change in the volume of trading. To keep trading volume constant over time, sellers must move the prices at which they close deals in lock-step with movements in this demand function. Thus, movements measured in this demand function while holding trading volume (Q) constant reflect "constant-liquidity" price changes in the property market.

Tracking the demand side of the property market is particularly of interest to certain types of hedgers, such as those looking for “market value insurance” against a potential down turn or a freeze of liquidity in the market. Even though constant liquidity price movements may not be able to demonstrate the long term overall trend as well as the movements of average transaction prices between the buyers and the sellers in the market, they represent more liquidity valuations in the short run in a down market which is exactly when the hedgers are seeking protection from.

To summarize, a constant-liquidity price index intends to combine the information from both the observable realized transaction prices and the observable trading volume in the market to provide a single metric that integrates the price and volume information in order to track movements in the demand side of the market. It measures how far the price would have to fall in order to sell the same volume of properties in the down market as in a normal market or how far the price would have to rise to keep the transaction volume in the up market the same as in a normal market. Because it is to the buyers to whom the sellers must sell their properties, price changes that match movements in the demand side’s reservation price will reflect changes that keep the ease of selling constant on the market. The demand side of the index may also tend to lead the average transaction price index and be more volatile. It is valuable for the real estate investment community to understand the movements of the demand side of the index, thus the constant liquidity price index.

Chapter Four: The Construction Method of Simplified Constant-Liquidity Price Index

In this section, the method of constructing a simplified constant liquidity price index will be explained step by step. Both the geometric model and the algebra model will be discussed here. The fundamental construction method intends to be simple to create a transparent metric which is easy for the investment community to understand, and thus supports and promotes the trading of real estate derivatives (either by direct trading on the constant-liquidity index itself either separately or in combination with the price index, or indirectly by providing valuable information about the property market which can have implications for where property prices and hence other tradable indexes may be headed). At the end of this chapter, the model will be applied to the NCREIF database to demonstrate the effectiveness of the simplified index by comparing its performance to the more econometrically complete and rigorous FGGH-based TBI demand-side index based on the same (NCREIF) database. We shall see that the simplified approach described in this thesis produces a NCREIF-based demand-side index very similar to the more rigorous FGGH-based TBI demand index.

4.1 The Structure of the Simplified Constant-Liquidity Price Index

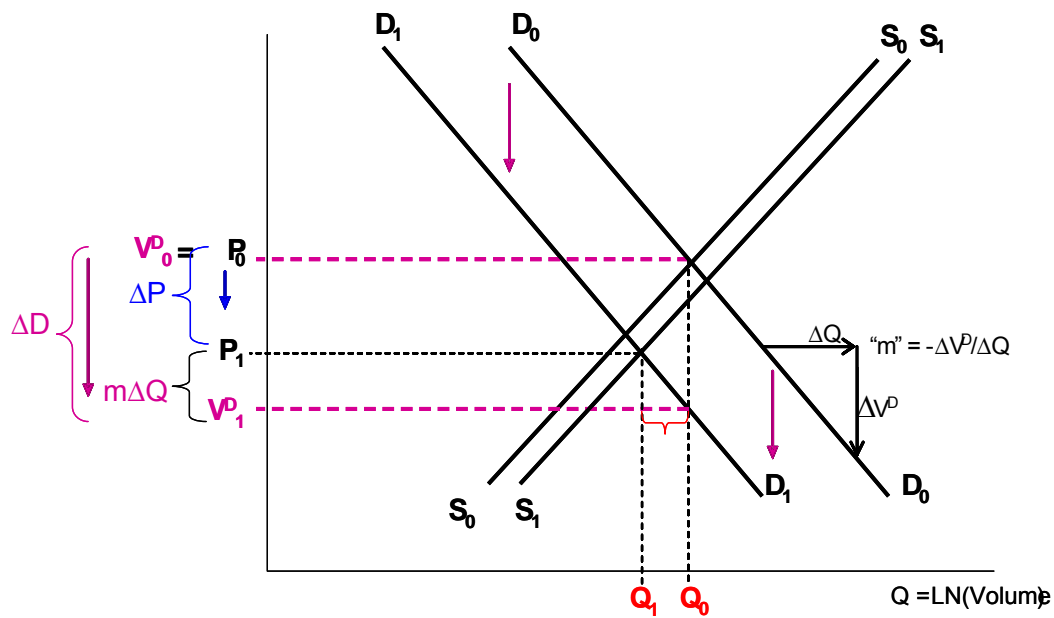
4.1.1 The Geometric Model of the Constant Liquidity Price Index

As stated in the previous chapter, a constant liquidity price index combines the information of average transaction price movements and observed transaction volume change at any market period. Therefore, there are three components to derive the constant liquidity price index: the observable transaction price index which tracks the changes of average transaction price in the market, the observable volume index which tracks the changes of transaction volume

in the market, and the demand price elasticity parameter which will transform the volume units to price units. This is shown in figure 14.

In the situation shown in figure 14, there is a drop in demand caused by any pessimistic expectations in the market. Demand function falls sharply from D_0 to D_1 from time 0 to time 1. The D_1 function is to the left and below the D_0 function. It means that potential property buyers will only continue to buy the same number of properties if the price falls to a certain level. They will buy fewer properties if the price maintains at the level same to that of time 0. In other words,

Figure 14: Combining Price-Change & Volume-Change to Create a Demand-Change (constant-liquidity) Index¹⁸



¹⁸ All number is expressed in natural logs (LN(Price), LN(Volume)) for mathematical convenience and because it allows a more realistic representation of the relationships. The log-changes are essentially the same as percentage changes: $\Delta VD/\Delta Q \approx \% \Delta VD / \% \Delta Q$.

potential buyers have reduced their “reservation prices” when the market is in a down turn. The supply also falls from S_0 to S_1 from time 0 to time 1 in this situation. Potential sellers are willing to sell the same number of the properties at a slightly lower price level. However, the reduction of “reservation price” on the sellers’ side is only minimal compared to the reduction of “reservation price” on the buyers’ side because of the “loss-aversion” behavior in the market discussed in Chapter Three. Thus the empirically observable mean transaction price only moves from P_0 to P_1 , although (importantly) that is accompanied by a substantial drop in the transaction volume from Q_0 to Q_1 .

Let us estimate the demand side movements from time 0 to time 1. At time 0, the reservation price of the marginal buyers is V^D_0 reflecting Q_0 volume of properties being traded. The average transaction price between the buyers and sellers at time 0, P_0 is equal to V^D_0 because Q_0 reflects the transaction volume at time 0.¹⁹ At time 1, the new demand function D_1 intersects with the new supply function S_1 and the new transaction volume is Q_1 at time 1. However, in order to maintain the potential buyer population to be willing to purchase the same previous Q_0 transaction volume of properties given their new reservation prices, we would have to move to the new marginal reservation price on the demand function of V^D_1 , where the new demand function (D_1) intersects with the previous volume of trading (Q_0). The movements of

¹⁹ Setting $V^D_0 = P_0$ is just a convenient temporary benchmark or reference point. As the constant-liquidity index (like any index) only measures *changes* in values from one period to the next, and as by definition the equilibrium transaction price must lie on the buyers’ aggregate demand function, we can always effectively define the previous period’s transaction price as the starting point from which we measure the change in both transaction price and in the demand-side reservation price (in the latter case labeled V^D_0). Technically, since we assume constant price-elasticity of demand, the movement over time in the demand function (the schedule of reservation prices) consists purely of vertical (or equivalently, horizontal) displacements in the same-sloped “ D_i ” function, i.e., it is only the intercept of the demand function that changes over time. We want to measure that change in the intercept along the vertical (price) axis dimension.

the buyers' side marginal reservation price (V^D_0 to V^D_1) can be divided into two parts: first from V^D_0 (P_0) to P_1 and then from P_1 to V^D_1 . The first part of the move represents the transaction price change ΔP which can be observed from a transaction price index. The second part is the vertical side of the right triangle whose base has length ΔQ and whose hypotenuse is the sloped D_1 demand function. This vertical side of the triangle equals the change in the demand function intercept on the vertical (price) axis (due to our constant-elasticity assumption). Thus, even though the movements of the demand side of the reservation price ($V^D_1 - V^D_0$) is not itself directly observable in the property marketplace at time 1, this value can be derived by adding ΔP to the length of the vertical side of the previously-specified right triangle.

Let us label the absolute value of the slope of the demand function as “**m**”, quantified as the (unsigned) change in the vertical dimension along the demand function per unit change in the demand side's willingness-to-buy volume along the horizontal dimension. Thus, “**m**” is the absolute value of the “price-elasticity” of demand. A key assumption of the “simplified” constant-liquidity index construction methodology is that “**m**” is assumed to be constant.²⁰ Therefore, “**m**” multiplied by ΔQ (with the latter being the *signed* difference in log-volume) gives the implied change in demand-side willingness-to-pay price beyond any observed change

²⁰ The assumption that “**m**” is constant over time is not technically necessary. Constant-elasticity means that the percentage change in trading volume associated with a given percentage change in price (holding everything else equal) remains the same when prices are high or low, and the same over time. In principle we could allow this to be re-estimated or re-calibrated every period. But in practice with the type of information available in the RCA database we have no good way to perform such reestimation. The more “complete” or “rigorous” econometric-based approach to constant-liquidity index estimation contained in FGGH and the TBI does allow for time-varying price-elasticity. However, as we shall see later in this chapter, the simplified approach allows a very accurate approximation of the FGGH econometric method within the NCREIF database. (See subsequent sections of Chapter 4 and 5 for further explanation.)

in actual transaction price ΔP , sufficient to account for the observed change in the trading volume:

$$\text{ABS}(V_1^D - P_1) = m * \text{ABS}(Q_1 - Q_0) \quad (2a)$$

$$\Delta Q = Q_1 - Q_0 \quad (2b)$$

$$\rightarrow m = \text{ABS}(\Delta V^D / \Delta Q)^{21} \quad (2)$$

The key analytical geometry implication of figure 14 is that the percentage movement in the constant liquidity value equals the percentage movement in the observable transaction price (ΔP) combined with the percentage of movement in the transaction volume multiplied by our “m” parameter which is a simple assumed (calibrated) constant equaling the absolute value of the inverse of the price-elasticity of demand. With this simple construction, the constant liquidity index is given by:

$$\Delta V = V_1^D - V_0^D = (P_1 - P_0) + m * (Q_1 - Q_0) = \Delta P + m * \Delta Q^{22}$$

When rewriting the formula in general terms, the constant liquidity value is:

$$\Delta V_t = \Delta P_t + m * \Delta Q_t \quad (3)$$

Where $\Delta V_t = V_t - V_{t-1}$, $\Delta P_t = P_t - P_{t-1}$, $\Delta Q_t = Q_t - Q_{t-1}$, and

V_t = Constant liquidity index value in natural logs at period t.²³

ΔV_t = The log-difference in the constant liquidity value index from time t-1 to time t.

P_t = Observable transaction price index value in natural logs at period t.

²¹ ΔV^D reflects the reservation price change along a single function line such as D_1 .

²² ΔV reflects the movements of volume change in between different function lines, such as D_0 to D_1 .

²³ As the index only measures *changes* in relative values over time, the starting value of the index (or its absolute level at any time) is arbitrary. Hence, the *level* of V_t is arbitrary as such. What is meaningful is the level of V_t *relative to* any other value of the index at another point in time (that is, the *difference* in values of the (log) index across time).

ΔP_t = The log-difference in the observable transaction price index from time t-1 to time t.

Q_t = Volume index value in natural logs at period t.

ΔQ_t = The log-difference in the trading volume from time t-1 to time t.²⁴

m = Absolute value of the demand slope parameter (inVs. of the price elasticity of demand).

4.1.2 *The Algebra Model of Constant Liquidity Price Index*

In this section, the simplified model is developed again only now relying more on an algebraic presentation rather than the geometric focus of the preceding section. While the two presentations are consistent and essentially the same, some additional perspective can be most easily gained through the algebraic analysis. The efforts in this section are aiming for a better understanding of the underlying fundamental theory underlying the previously-described simple constant liquidity model.

Let us go back to the classic demand and supply function space depicted in figure 15. D_0 represents the buyers' valuation function and S_0 represents the sellers' valuation function at time 0. The buyers' reservation price V^D can be expressed as:

$$V^D(i) = D_0 - m * Q(i) \quad (4)$$

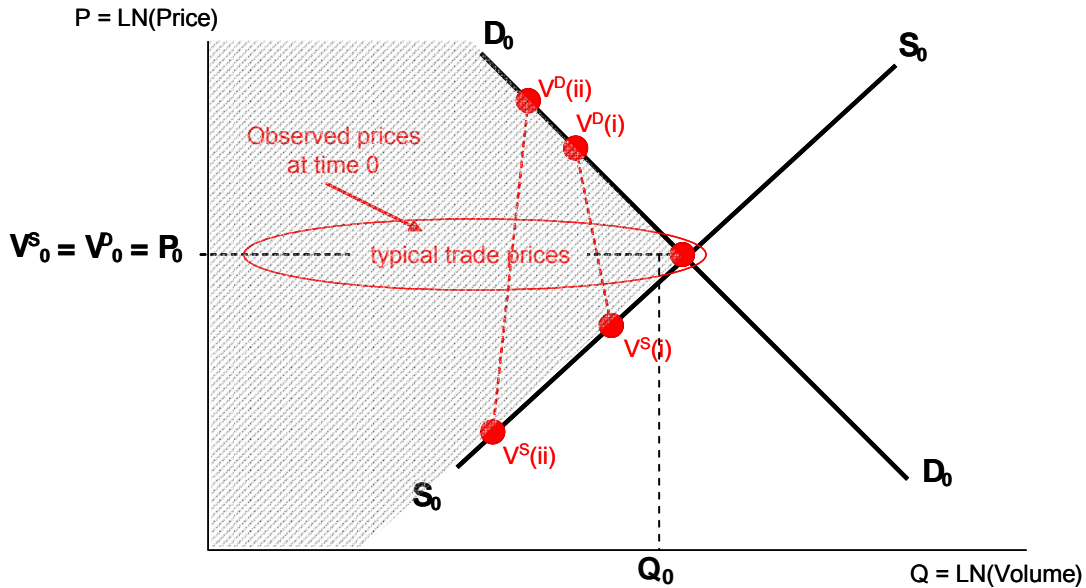
The sellers' reservation price V^S can be expressed as:

$$V^S(i) = S_0 + m * Q(i) \quad (5)$$

²⁴ As noted, we're working log values for mathematical convenience. Ultimately a published version of the index would probably convert from logs to straight levels and geometric differences (simple returns), but this has no substantive impact on our development and analysis of the indexes in this thesis.

²⁵ The assumption that the slope parameter of the sellers' function is the same as that of the buyers' function is further explained in the white paper "A Simplified Constant Liquidity Price Index (CLPI) Based on the RCA Database", Geltner and Wang (2008).

Figure 15: The “Price Model” Defined by the Demand and Supply Function



Where, D_0 represents the vertical (price) axis intercept of the buyers’ reservation price function (i.e., the demand function) and S_0 represents the vertical axis intercept of the sellers’ reservation price function (the supply function). Potential buyers with reservation prices, V^D , drawn from the part of the D_0 demand function to the left of Q_0 , will trade with potential sellers with reservation prices, V^S , drawn from the part of the S_0 supply function to the left of Q_0 , such that $V^D \geq V^S$ in any successfully-consummated transaction (i.e., parties do not make negative-NPV trades). The observed transaction price in any individual deal “i” will therefore lie between the two reservation prices:

$$V^S(i) \leq P(i) \leq V^D(i)$$

A transaction can only occur within the shaded area in figure 15. Intra-marginal buyers like Mr.(i) and Mrs.(ii) with reservation prices of $V^D(i)$ and $V^D(ii)$ respectively, might trade with intra-marginal sellers like Mrs.(i) and Mr.(ii) with reservation prices of $V^S(i)$ and $V^S(ii)$ respectively, at agreed-upon (observable) transaction prices of $P(i)$ and $P(ii)$ respectively. The

average price of all the trades at time 0 is P_0 . An exactly marginal buyer like Mr.(iii) trading with an exactly marginal seller like Mrs.(iii) must trade exactly at P_0 (which exactly equals both $V^D(\text{iii})$ and $V^S(\text{iii})$ and both V^D_0 and V^S_0 in the Figure). In general, we can be confident that the average price observed at time 0 will lie approximately halfway between the average V^S reservation price drawn from the supply function at time 0 and the average V^D reservation price drawn from the demand function at time 0:

$$\begin{aligned} P_0 \equiv P_{(\text{Avg})} &= (\frac{1}{2})V^D_{(\text{Avg})} + (\frac{1}{2})V^S_{(\text{Avg})} \equiv (\frac{1}{2})(D_0 - mQ_{(\text{Avg})}) + (\frac{1}{2})(S_0 + mQ_{(\text{Avg})}) \\ &= (\frac{1}{2})(D_0 + S_0) \end{aligned}$$

Note that this “price model” applies to any time t:

$$P_t = (\frac{1}{2})(D_t + S_t) \quad (6)$$

Now, let us consider what determines the volume of trading. Q_0 represents the number of properties traded at time 0 in the graph. Since trades occur only when there is a buyer with V^D greater than the V^S of a seller, the trading volume will be greater the more such reservation price “overlaps” are available, that is, the more potential intra-marginal trading partners there are. This will occur when the demand function is higher and/or the supply function is lower relative to each other (in the graph). Since, the vertical position of the demand & supply functions is purely determined by the values of D_0 and S_0 respectively. A simple model of trading volume at time 0 is therefore the following:

$$\begin{aligned} Q_0 &= c + a(V^D_{(\text{avg})} - V^S_{(\text{avg})}) \equiv c + a((D_0 - mQ_{(\text{avg})}) - (S_0 + mQ_{(\text{avg})})) \\ &= c + a(D_0 - S_0) - 2amQ_{(\text{avg})} \end{aligned}$$

where “c” and “a” are scaling parameters that “locate” and “shape” the lines in the graph, that is, they quantitatively relate price to volume (and vice versa). The $-2amQ_{(avg)}$ term at the end is effectively a constant, and so may be subsumed into a redefined initial constant:

$$C = c - 2amQ_{(avg)}$$

Thus, apart from this constant, trading volume is purely a function of the excess of D_0 over S_0 (as modified by the scaling parameter “a”). Of course this “volume model” applies at any time t:

$$Q_t = C + a(D_t - S_t) \quad (7)$$

If observed volume at time t is: $Q_t = C + a(D_t - S_t)$, and movement in demand or supply is purely a function of movement in the intercept: $\Delta V_t^D = \Delta D_t$ (See figure 16), then at any given time t :

$$\Delta Q/\Delta D = a = \Delta Q/\Delta V_D = (1/2)(\text{Negative Price Elasticity of Demand}) = 1/(2m).$$

where $\Delta Q/\Delta D$ is the partial derivative (demand elasticity) holding S constant.

Similarly for the supply elasticity:

$$\Delta Q/\Delta S = -a = \Delta Q/\Delta V_S = (1/2)(\text{Negative Price Elasticity of Supply}) = -1/(2m).$$

where “m” is the magnitude of the slope parameter as defined previously. Thus, the volume model is:

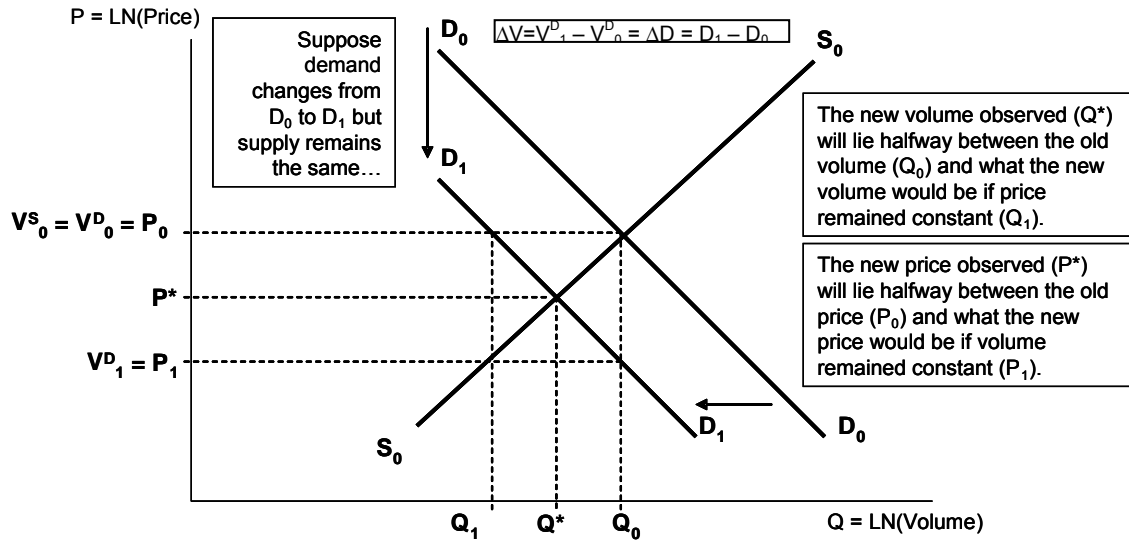
$$Q_t = C + a(D_t - S_t),$$

Where,

$$a = 1/(2m). \quad (8)$$

²⁶ As the index only measures changes over time, any constant term will drop out, and therefore we can ignore “C”.

Figure 16: The “Volume” Model



Therefore, combining formula (6) and formula (7), we have two equations, of price and volume, that are linear in the two underlying unknowns, the buyers’ and sellers’ reservation prices (V^D , V^S). Solving the two equations for the two unknowns we arrive at the un-observable buyers’ and sellers’ reservation prices as functions of the observable average transaction price and transaction volume (and the elasticity parameter) as shown below:

$$P_t = (1/2)(D_t + S_t), Q_t = C + a(D_t - S_t), a = 1/(2m) \rightarrow$$

$$D_t = P_t + mQ_t - mC \quad (9)$$

$$S_t = P_t - mQ_t + mC \quad (10)$$

As the last term (mC) is a constant from the perspective of changes in the system (changes in P_t and Q_t caused by changes in D_t and S_t), it can be ignored in indexes that track only changes over time.

If, Observed Average Price Index: $\Delta P_t = P_t - P_{t-1}$

Observed Volume Index: $\Delta Q_t = Q_t - Q_{t-1}$

Demand-side Index = “Constant-Liquidity Index” = $\Delta V_t^D = V_t^D - V_{t-1}^D = D_t - D_{t-1} = \Delta D_t$

Then,

$$\Delta V_t^D = \Delta P_t + m\Delta Q_t ; \quad (11)$$

$$\Delta V_t^S = \Delta P_t - m\Delta Q_t^{27} \quad (12)$$

with “m” as defined in (2).

Thus, the “constant-liquidity” price-change equals the observable price index change plus the volume index change times the inverse of the absolute price elasticity of demand . To construct a simple, transparent constant liquidity price index, a volume index based on a recorded transaction volume data needs to be established, and the value of “m” which represents the demand slope parameter needs to be calibrated. In the next section, such a simplified model will be applied to the NCRIF database that underlies the FGGH-based TBI to construct a simple constant liquidity price index that can be directly compared to the more econometrically rigorous and complete TBI demand-side index.

4.2 The Simplified Constant Liquidity Price Index Using MIT-Published TBI Results

One important assumption in both the geometric and the algebraic analysis in the previous sections is that the demand and supply slope parameter “m” is constant over time. Constant-elasticity means that the percentage change in trading volume associated with a given percentage change in price (keeping everything else equal) remains the same when prices are high or low, and the same over time. In principle, “m” could have different values at different times and could be different from one market to another. However, in the interest of simplicity and transparency and because within the RCA database we lack the data necessary to effectively apply a more flexible model, a single constant value for “m” will be specified for the

²⁷ For the construction of the supply side of the index, see white paper “A Simplified Constant Liquidity Price Index (CLPI) Based on the RCA Database”, Geltner and Wang (2008).

construction of the simplified constant liquidity price index. In order to test the validity of this simplification and the effectiveness of the developed simplified constant liquidity price model, a simplified constant liquidity price index is established in this section using the MIT-published TBI results. The demand side of the index of TBI is developed based on the econometric model presented in the “FGGH 2003” paper, which effectively allows “m” to be flexible each quarter. Comparing the simplified constant liquidity index governed by the constant elasticity assumption with the econometric-based TBI demand-side index which allows “variable elasticity” over time will enable us to examine the effectiveness of the simplified model.

First of all, let us briefly review the NCREIF database here. This database includes property-specific information on investment grade properties that have been held for tax-exempt members of the NCREIF. These data have been used to construct the NPI since the fourth quarter of 1977. The NCREIF portfolio of properties currently (2008:Q1) consists of 5,976 properties, with an aggregate appraised value of just over \$328 billion. NCREIF properties are well diversified across the East, Midwest, West and South which represent 4%, 14%, 32% and 30% of the number of properties in the database, respectively. There are currently five property types included in the current database: office (25%), industrial (35%), apartment (24%), retail (15%) and hotel (1%). The data set examined in this thesis includes all properties in the historic NCREIF database from period 1984:2Q to 2008:1Q. During this period, there were 7,155 properties that were sold and 251,986 properties that remained unsold. The number of observations in the data set totals 259,141.²⁸

²⁸ See NCREIF website: <http://www.ncreif.com/>

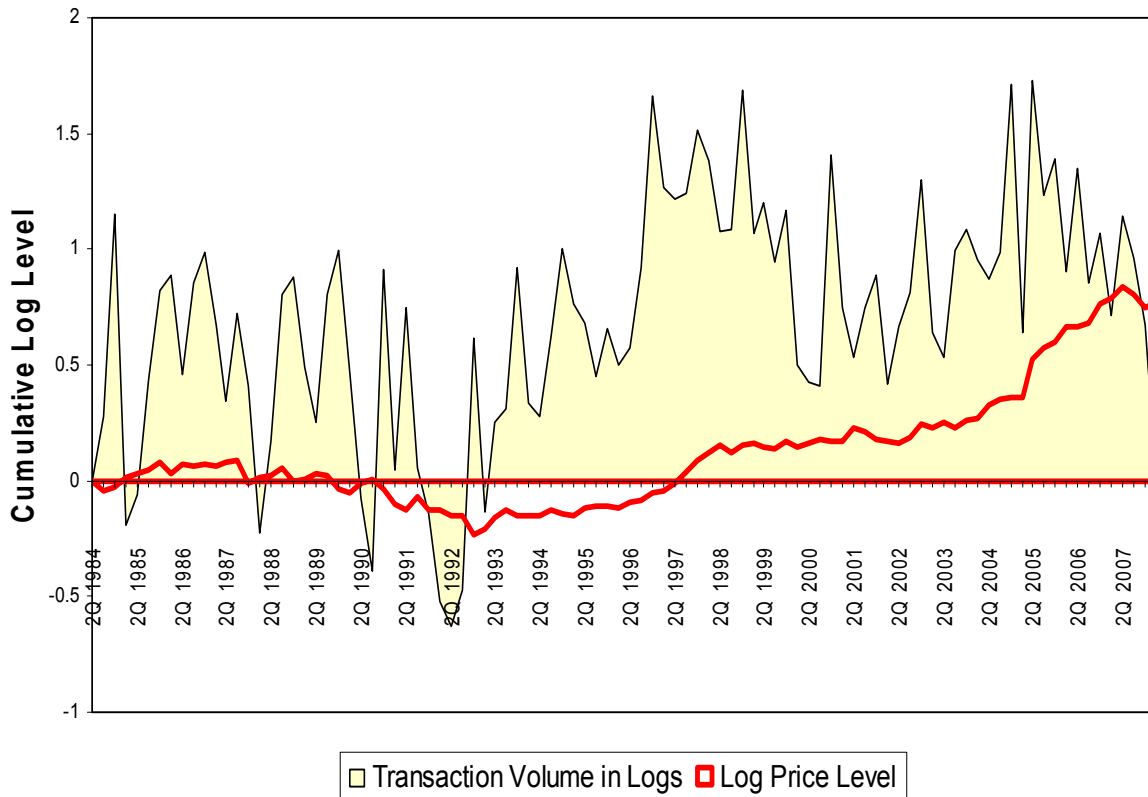
The first step to construct a simplified constant liquidity index is to construct the volume index. The transaction volume is defined by the ratio between the number of sold properties and the total number of properties in the market at any given time period.²⁹ The volume index is the percentage change in trading volume in the market.

$$\Delta Q_t = Q_t - Q_{t-1} \text{ }^{30}, \text{ where}$$

$$Q_t = \frac{\text{number of transactions at period } t}{\text{total number of properties in the market at period } t}$$

Figure 17 superimposes the volume index and the observable price index based on the database described above. Figure 17 reveals that the volume index reflects greater volatility than the price

Figure 17: NCREIF Volume/Price Index (1984.3Q – 2008.1Q)



²⁹ See Chapter Five Section 1 for detailed volume index discussion.

³⁰ As always, all values are in natural logs for mathematical convenience (but could be converted to levels in a published index).

index. The volume index leads the price index in most periods and it sharply decreased from the second quarter of 2007 to the first quarter of 2008 even though the price index showed a slightly upward trend for the first quarter of 2008. The graph shows as well that the 1984-2001 period was characterized by a very pronounced cycle in the commercial property market. Also evident (though somewhat obscured by the noise in the volume) is the strong pro-cyclical variation in the volume index, which is characteristic of real estate asset markets.

The second step to construct a constant liquidity price index is to estimate the magnitude of price elasticity on the demand side. The change of constant liquidity value estimated by the “FGGH” model based TBI demand side of the index is combined with the change of the observable average transaction price level recorded by TBI and the volume index constructed above to calculate the average magnitude of price elasticity of supply and demand. From formula (3) and (11):

$$\Delta V_t = \Delta P_t + m * \Delta Q_t \quad \rightarrow$$

$$m = \frac{\Delta V_t - \Delta P_t}{\Delta Q_t} \quad (13)$$

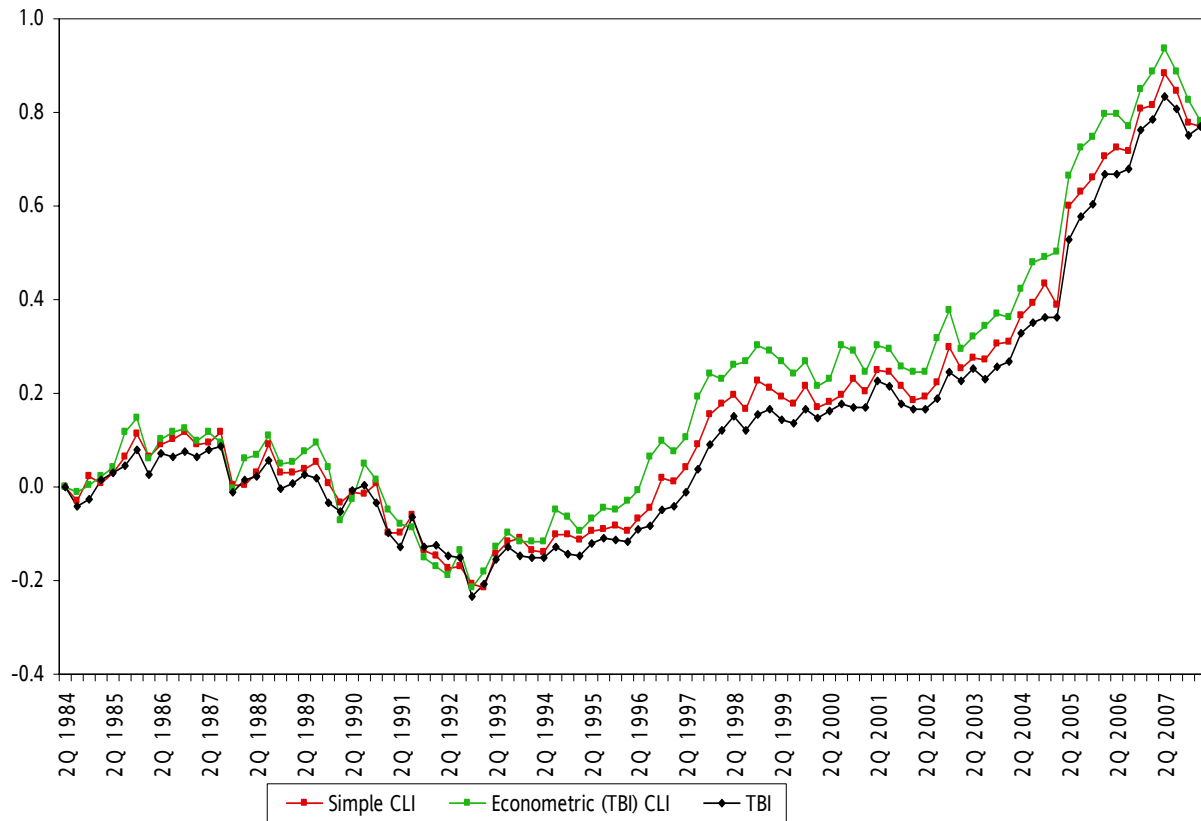
So, the average value of m equals the average difference between the constant liquidity index level and the observable transaction price index level divided by the average value of the volume index level. The estimated absolute value of m is 0.042.

Finally, the Simplified constant-liquidity price index is constructed by combining the volume index and price index by using as a constant the average magnitude of price elasticity estimated above. Figure 18 depicts this simplified constant liquidity price index together with the econometric-based TBI demand index and price index. Note how parallel and similar the two

constant liquidity indexes are, even in the specific quarterly movements. The quarterly correlation between the two index's returns is +80%.

From the above comparison, it is clear that the simplified constant-liquidity price index tracks very closely to the econometric constant-liquidity price index and genuinely represents the major attributes reflected in the more complete and rigorous index. The assumption that the demand slope parameter “m” is constant over time in the simplified model helps to simplify the underlying method and make it more understandable by potential users, and nevertheless appears to not significantly diminish the effectiveness of the model.

Figure 18: NCREIF Simple vs. Econometric Demand Index and Price Index (1984.3Q – 2008.1Q)



Chapter Five: The Construction of Volume Index and the Calibration of “m” Based on the RCA Database

In the last chapter, the underlying method of a simplified constant liquidity price index (SCLI) was applied to construct an SCLI based on the NCREIF database. This chapter will start to apply the method to construct SCLI using the RCA database. This part of the thesis will treat the construction of the volume index and the calibration of the demand slope parameter based on the RCA database.

5.1 The Construction of the Volume Index Based on the RCA Transaction Volume Database

In this section, a volume index will be developed to track the transactions in the underlying property population recorded by the RCA database.

The first thing to consider is the minimum size of transactions to be included in the volume index. For the purpose of a volume index, it is important to maintain a consistent and reliable population of the underlying properties to avoid noise over time. However, for the purpose of a price index based on repeat sales method such as the Moody's/REAL CPPI, it's more important to try to capture as many repeat-sales price observations as possible to reflect the market movements of realized transaction price accurately overtime. Even though RCA is now tracking all sales of over \$2.5 million which are used in the Moody's/REAL CPPI since 2005, the property population of \$5 million or greater is considered more complete and reliable compared to that of \$2.5 million. Accordingly, the volume index will be based on transactions \$5 million or greater in the RCA data base.

The next thing to consider is whether this index will be an equally weighted index or a dollar weighted index. An equally weighted index tracks the number of properties sold in every specific period and a dollar weighted index tracks the value of the transactions in every specific period. The fact that the Moody's/REAL CPPI is an equally weighted index makes it logical to construct the volume index based on the number of properties sold in every period. This forms a relationship of comparing “apples to apples” rather than “apples to oranges”. In addition, tracking volume change by the number of transactions helps avoid the influence of periodic large dollar valued transactions.

The third thing to determine is what the volume index tracks over time. The index could track either the change of percentage of number of transactions over the entire underlying property population or the change of the number of transactions per period. The first method requires consistent information of both sold and unsold underlying property, while the second method only requires information of the number of properties sold over time. In order to compare these two methods, let us first take a look at the two volume indexes based on the NCREIF data base since NCREIF offers information on both sold and unsold underlying property populations.³¹ Figure 19 depicts these two cumulative volume indexes based on the

³¹ RCA only offers consistent information on the number of transactions over time. Therefore, it is not possible to construct a simple percentage based volume index based on RCA data. However, we can some idea of the differences between the two construction methods by quantifying them both on the NCREIF database. Of course, there are also other differences between the RCA and NCREIF databases and populations. For example, the NCREIF population is relatively “fixed” by virtue of it being based on NCREIF’s data-contributing membership (which is dominated by pension funds and their investment managers), whereas the RCA population mirrors the actual population of U.S. commercial properties (which reflects growth and structural change in the real GDP). Also, RCA is a relatively new company that was still “maturing” in its effectiveness at data collection at least during the early years of the RCA database history. Finally, RCA has a lower-limit threshold in the price magnitude of transactions that it collects. To the extent that the average nominal value of commercial properties in the U.S. is growing (either due to price appreciation and/or to physical size growth of the average property), this lower-limit cutoff will be breached by a larger percentage of all properties over time, and this too will cause additional incremental growth in the RCA number of transactions, an increment which would not have a counterpart in the NCREIF database population of properties.

Figure 19: Cumulative Percentage-Based Volume Index Vs. Number-Based Volume Indexes
Based on NCREIF database: 1984: Q2 – 2008: Q1

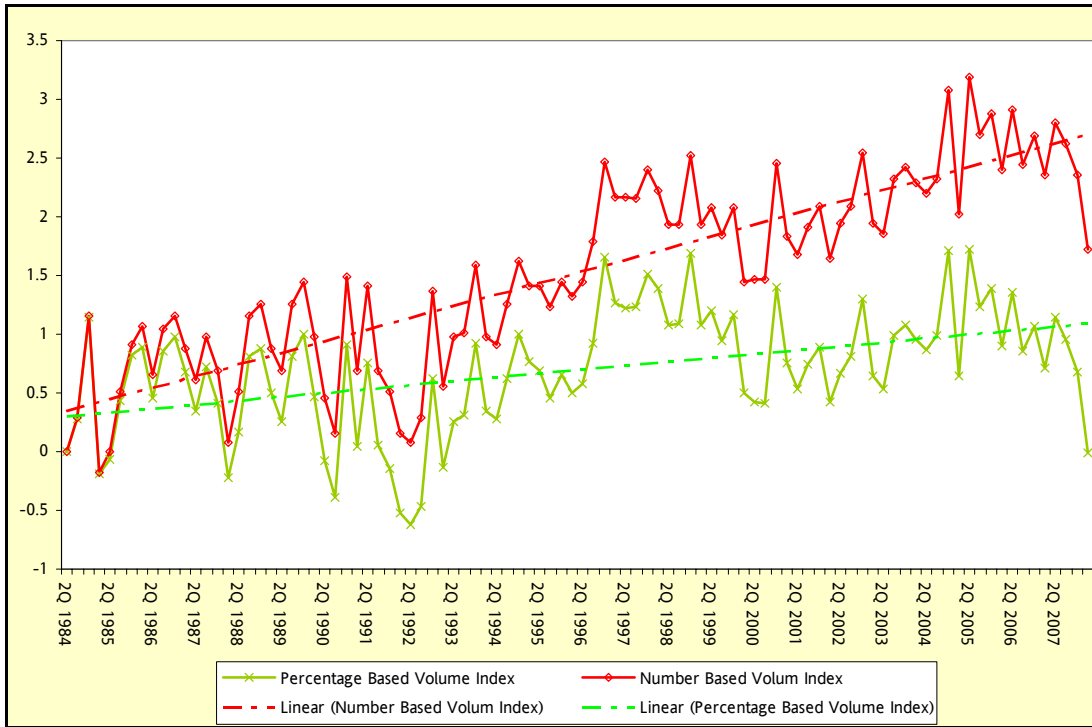
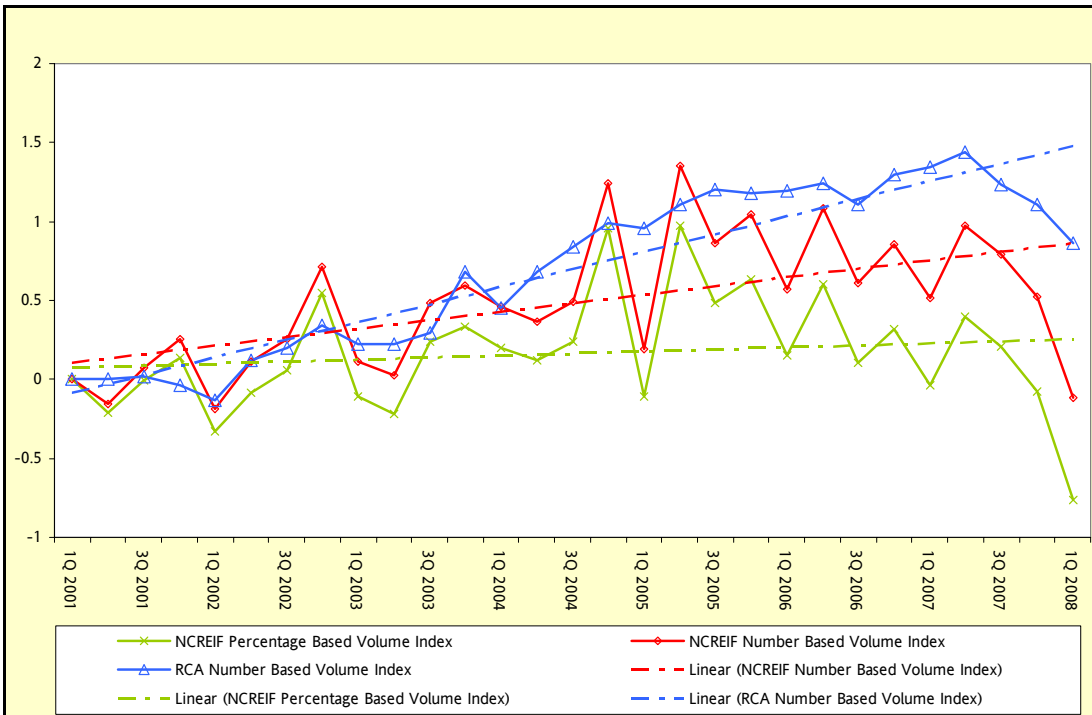


Figure 20: Cumulative Percentage-Based Volume Index Vs. Number-Based Volume Indexes
Based on NCREIF and RCA database: 2001: Q2 – 2008: Q1



NCREIF data from the second quarter of 1984 to the first quarter of 2008. Figure 20 depicts the cumulative volume indexes based on NCREIF and RCA data from the second quarter of 2001 to the first quarter of 2008. Both graphs clearly demonstrate that the number-based volume index displays a long-term trend while the percentage-based volume index tends to be mean-reverting over long time horizons. Ideally, the percentage-based volume index is preferred over the number-based volume index because the former index better reflects the underlying theoretical market model described in Chapter 3. If volume increases merely because of a secular trend in the number of properties included in the underlying population, this does not imply that it is easier to sell individual properties or that buyers or sellers have moved their reservation prices closer together. However, the total number of underlying properties is not available in RCA's data base. Thus, we must base the RCA volume index only on the total number of properties sold, though we might try to include some sort of *ad hoc* de-trending procedure. To decide whether or not to "de-trend" the number-based volume index, let us first consider two statistical measurements in the index.

First of all, the most important information that any index provides is in the "news" they convey each period. The statistical moment that best reflects the magnitude of that "news" is the "true volatility" per period.³² "Volatility" of course is the longitudinal standard deviation across time in the returns (the log-differences in the index). In the raw volume data there is a large "noise" component which needs to be eliminated.³³ But by definition, the "trend" component in the volume index hardly affects the volatility. A "trend" is a constant or nearly-constant component of the periodic return. In essence, the trend has a negligible impact on the periodic

³² "True volatility" refers to the fact that "noise" (the random, transient, non-news component of the periodic return) also adds to the longitudinal standard deviation (STD across time of the returns, the log-differences).

³³ See the next section.

volatility of the SCLI, and hence a negligible impact on the key component of the index that is most fundamental for its usefulness either as an information product or as the basis for derivatives.

A second statistical feature that is important in an index, though not as important for the purpose of the constant-liquidity index as the true volatility, is the “first moment” or “mean” return, the central tendency of the returns over the long run. This component is not very important for conveying “news” (though it does convey some long-run “information” about the asset being tracked), but it is necessary for derivatives traders to understand the nature of this central tendency in order for them to correctly price derivatives products based on the index.³⁴ The central tendency (long-run mean return) of the SCLI will be affected by any trend in the volume data, but if the effect is not too great and index users can get a quantitative idea about the nature and magnitude of the differential drift between the SCLI and the price index, then such differential drift will not much harm the use of the SCLI for its primary purpose, which is short-to-medium term indication of movement in demand-side reservation prices.

The problematical component of the trend in a SCLI based on a number-based volume index is caused by two sources from the underlying property population. Below, these two sources will be specified and their resulting magnitude of the influences to the volume and constant liquidity price index will be roughly estimated.

³⁴ The central tendency is the “expected return”, the constant component or “drift” rate in the return, and therefore figures into what derivatives traders of the index would expect to receive or pay.

1. Growth in the underlying number of properties

The first source that contributes to the trend component in the number based volume index is the growth in the underlying total number of properties. To demonstrate a rough idea of the order of magnitude, let us assume that the growth in the underlying number of properties moves roughly with the GDP real growth rate.³⁵ On average over the long run, the U.S. GDP real growth rate is typically 2% to 3% per year. If the number of properties grows proportionately with this, then the denominator in the ideal (percentage-based) volume index would as a result grow at the rate of 2-3% per annum. But the volume index enters the simplified constant-liquidity price index (SCLI) only via the parameter “m”, which as we will see is around 0.25 for the RCA data.³⁶ So this would impart into the SCLI only about 0.50% to 0.75% per annum of long-run average differential trend relative to the ideal volume index. This is not very much, and more importantly, can be understood and adjusted for by users of the index.³⁷

More importantly, this is a trend magnitude that would be totally swamped by the true volatility in the SCLI, the component that matters most. Volatility measures the short-run movements in the index apart from the central tendency or trend, and as such index volatility is a measure of the magnitude of “*signal*” strength in the “news” that the index conveys. Now consider the effect on the SCLI volatility caused by GDP growth in the (missing) property population denominator of the volume index. Suppose the average GDP growth rate is 2.5% per

³⁵ The assumption here is for the purpose of further discussion in this thesis only. Thus it only serves as a reference. In general, the underlying number of properties does not decline when GDP growth is declining. The relevant measure of GDP would be that pertaining to whatever geographical region the index is covering. In the case of a national aggregate index it would be the national GDP.

³⁶ Please see the following sections on the value of “m”.

³⁷ In some high-growth regions covered by RCA-based indexes, such as South Florida or Southern California, the relevant regional GDP growth rate could be significantly higher (largely due to high population growth from immigration).

year, but the annual volatility in GDP growth is around 1% per year.³⁸ Then the GDP volatility component of SCLI volatility would only be $0.25 \times 1\% = 0.25\%$ per annum. But the total volatility of the sum of two random components equals the SQRT of the sum of the two variances plus twice the covariance:

$$\text{Total Volatility (a+b)} = \text{SQRT}(\text{VOL}_a^2 + \text{VOL}_b^2 + 2 \times \text{COV}(a,b)) = \text{SQRT}(\text{VOL}_a^2 + \text{VOL}_b^2 + 2 \times \text{VOL}_a \times \text{VOL}_b \times \text{CORREL}(a,b)).$$

Suppose “VOL_a” is the true volatility component of the SCLI, maybe around 8% per annum³⁹. Suppose “VOL_b” is the GDP-based trend component, maybe around 0.25% per annum. Suppose the correlation between the two is +50%. Then by the above formula, the increment that the (“noise”) trend component adds to the total SCLI volatility is to increase it from (the true) 8% to:

$$\begin{aligned} \text{Total Volatility} &= \text{SQRT}(.08^2 + .0025^2 + 2 \times .08 \times .0025 \times .5) \\ &= \text{SQRT}(.0064 + .00000625 + .0002) = \text{SQRT}(.006606) = 8.1\%. \end{aligned}$$

In other words, the property population growth component adds only 10 basis-points to the 800 bps of true volatility, which is miniscule.⁴⁰

2. Growth in the average price of properties

The second source that causes the problematical trend component in the number-based volume index comes from the growth trend in the average value of properties. The long-run average growth rate of property prices is probably a bit less than inflation, say, 2% per year. This

³⁸ GDP growth and volatility is estimated from “real” or “price-adjusted” GDP series data from the US bureau of Economic Analysis for the past 20 years.

³⁹ Please see the following section for the magnitude of this estimation

⁴⁰ The effect could be bigger in high-growth places where population growth is a significant source of regional GDP growth, such as Southern California or Florida. Suppose the true volatility component of an index of a high-growth place is 10%, the volatility of the GDP based trend component is 0.5% (two folds of the general GDP growth). Then the estimated total volatility is $\text{SQRT}(0.1^2 + 0.005^2 + 2 \times 0.1 \times 0.005 \times 0.5) = 10.25\%$. This is only 25 bases points higher than the 1000 bases points of the true volatility component.

would mean that in a given population in an average year about 2% more properties would exceed \$5 million in value (or any given fixed-dollar threshold of value) than in the previous year. Via the $m=0.25$ parameter this would inject another +0.5% per year into the long-run trend in the SCLI. (Combined with the similar impact from long-run GDP trend, this would give the SCLI maybe a total of 1-1.25% per year of excess long-run average price growth: not huge, but more importantly, something the market can figure out and take into account.).

In terms of volatility, true price volatility is less than SCLI true volatility. If the latter is around 8% per year, then maybe the former may be 6% per year, of which $0.25*6\% = 1.5\%$ would enter into the SCLI.⁴¹ Assuming price and volume are nearly perfectly correlated, say, around 0.9⁴² and employing the same total volatility formula and assumptions as before:

$$\text{Total Volatility (a+b)} = \text{SQRT}(\text{VOL}_a^2 + \text{VOL}_b^2 + 2*\text{COV}(a,b)) = \text{SQRT}(0.08^2 + 0.015^2 + 2*0.08*0.015*.9) = \text{SQRT}(0.0064 + 0.000114 + 0.001728) = \text{SQRT}(0.008272) = 9.4\%.$$

Thus this adds apparently about 140 bps to the 800 bps of true volatility.

In conclusion, the problematical trend impact on the SCLI caused by using a number-based rather than percentage-based volume index is likely relatively minor and also somewhat quantifiable, so that users of the index can take it into account. At the national aggregate level the differential trend probably averages on the order of 1% per year or a bit more of extra growth trend in the SCLI, with perhaps 150 bps or so of extra annual volatility. Thus, the RCA-data

⁴¹ . The volatility in the Moody's/REAL history has actually been less than 6% so far, but it's been closer to 10% in the 25-yr history of the TBI price index. However, if the ΔP price volatility is greater than 6% then probably the ΔV SCLI volatility would be greater than 8%. The numbers here only provide a rough reference to illustrate the magnitude of the volatility of the volume index.

⁴² The correlation of the price and the volume index based on the RCA database is estimated at 0.9583 in the following sections.

based volume index is defined simply as the change each period in the log of the number of property transactions in the RCA database. In this thesis we do not make any adjustments to “de-trend” this number-based volume index. Figure 21 depicts the volume index based on the RCA database from January 2001 to April 2008 by definition as the cumulative log-value changes. Figure 22 depicts the number of transaction per month recorded by RCA in the same time period.

Figure 21: Unsmoothed Volume Index Based on the RCA database
January 2001 – April 2008

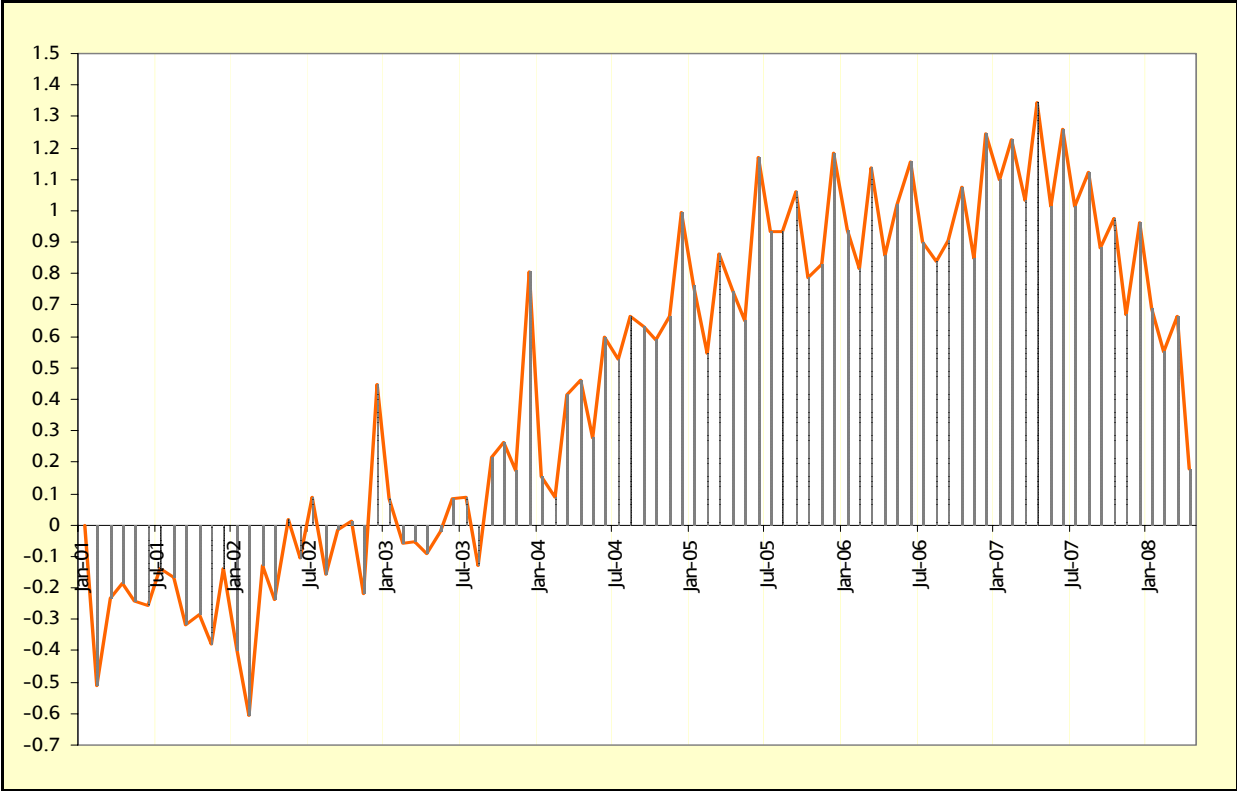
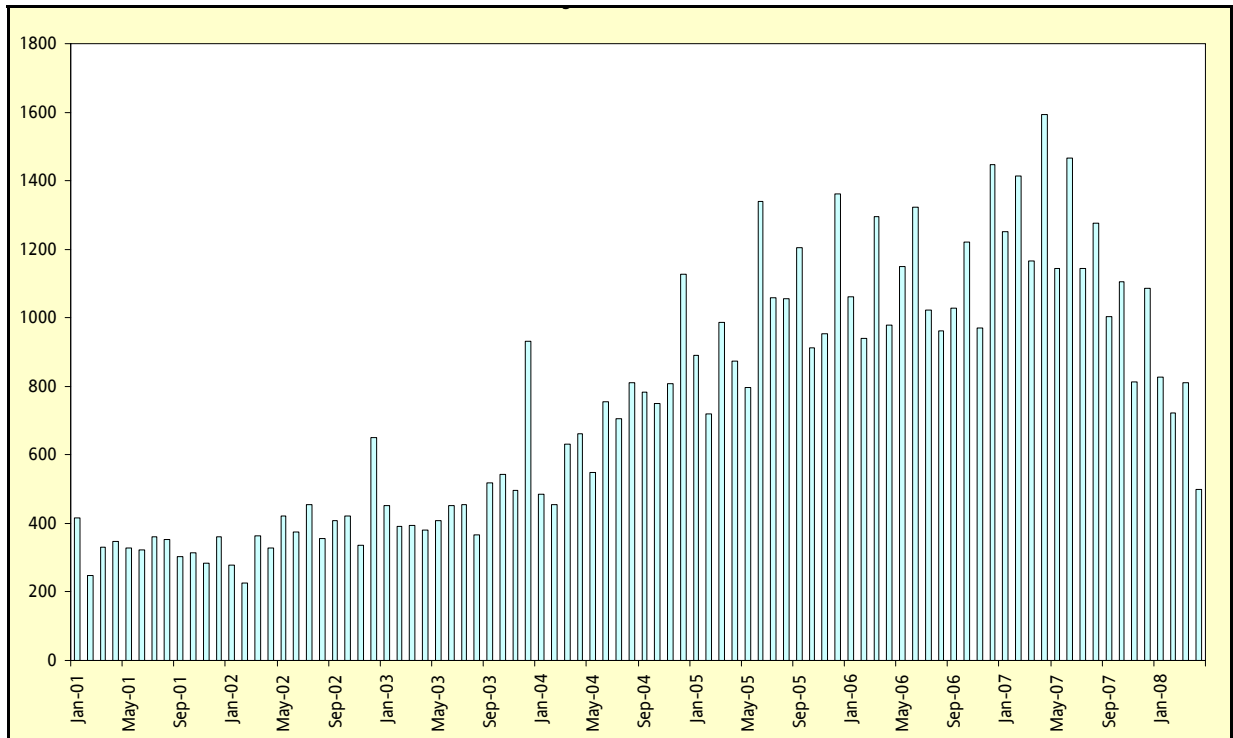


Figure 22: Number of Transactions Based on the RCA Database



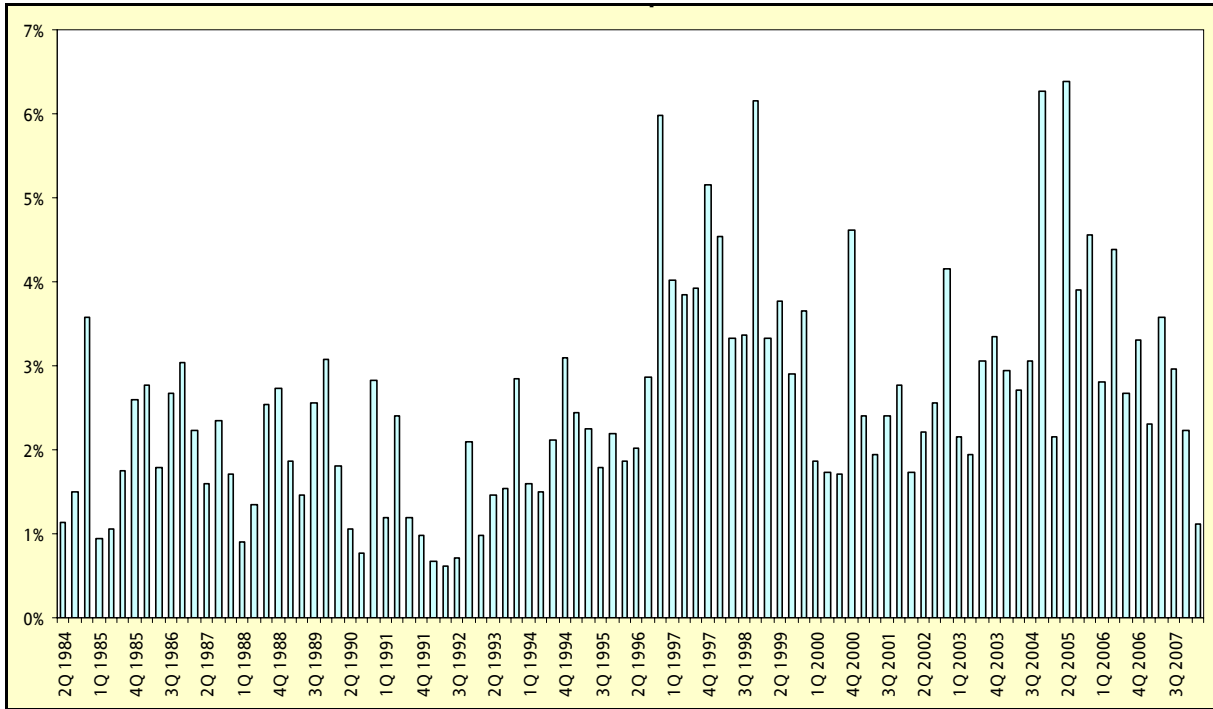
5.1.1 Noise in the RCA Transaction Volume Data

The most important observation in both figure 21 and figure 22 is that the volume index displays “noise”, defined as a purely random component in the monthly transaction volume. Figure 23 below, based on the NCREIF database underlying the TBI, graphs the percentage of the number of transactions over the overall property population in that database. Figure 23 also shows noise at the quarterly frequency. In general, real estate transaction volume data tends to be quite noisy at monthly and quarterly frequencies.⁴³ Even though the NCREIF database is quite consistent and accurate, the noise is still quite obvious from one quarter to the next one. The

⁴³ It is primarily an inherently noisy phenomenon, consisting of discrete events on “lumpy” assets (rather than a smooth flow of a continuous item like sales of shoes, for example). The fundamental or primal variable is the level of the number of transactions each period, not the change in that level. So we see the noise at that level.

analysis of the first order autocorrelation in first-differences is a good indicator of the relative magnitude of the noise component in a time-series.

Figure 23: TBI Monthly Transaction Volume over Total Number of Underlying Properties



Consider the time-series of the volume index changes each period. The 1st-order autocorrelation can be expressed in the following formulas:

Denote Q_t as the observed transaction volume level in period t ,⁴⁴

q_t as the central tendency of the volume (excluding noise) in period t ,

$\tilde{\varepsilon}_t$ as the random noise component in the observed volume data.

Then,

$$Q_t = q_t + \tilde{\varepsilon}_t \rightarrow$$

⁴⁴ All values in natural logs.

$$\Delta Q_t = Q_t - Q_{t-1} = (q_t + \tilde{\varepsilon}_t) - (q_{t-1} + \tilde{\varepsilon}_{t-1}) = \Delta q_t + (\tilde{\varepsilon}_t - \tilde{\varepsilon}_{t-1}), \quad (14)$$

And, $(\tilde{\varepsilon}_t - \tilde{\varepsilon}_{t-1})$ represents first-differences in the noise realizations, as the noise enters into the volume index changes each period. Now consider the 1st-order autocovariance and autocorrelation of the volume changes...

$$\begin{aligned} \text{COV}(\Delta Q_t, \Delta Q_{t-1}) &= \text{COV}(\Delta q_t + (\tilde{\varepsilon}_t - \tilde{\varepsilon}_{t-1}), \Delta q_{t-1} + (\tilde{\varepsilon}_{t-1} - \tilde{\varepsilon}_{t-2})) \\ &= \text{COV}(\Delta q_t, \Delta q_{t-1}) + \text{COV}(\Delta q_t, \tilde{\varepsilon}_{t-1} - \tilde{\varepsilon}_{t-2}) + \text{COV}(\tilde{\varepsilon}_t - \tilde{\varepsilon}_{t-1}, \Delta q_{t-1}) + \text{COV}(\tilde{\varepsilon}_t - \tilde{\varepsilon}_{t-1}, \tilde{\varepsilon}_{t-1} - \tilde{\varepsilon}_{t-2}) \end{aligned}$$

Since noise is by definition uncorrelated with anything (including with itself over time), the above reduces to:

$$\text{COV}(\Delta Q_t, \Delta Q_{t-1}) = \text{COV}(\Delta q_t, \Delta q_{t-1}) - \text{VAR}(\tilde{\varepsilon})$$

The observed 1st order autocorrelation is therefore:

$$\begin{aligned} \text{AC}(1)(\Delta Q) &= \text{COV}(\Delta Q_t, \Delta Q_{t-1}) / \text{VAR}(\Delta Q_t) \\ &= (\text{COV}(\Delta q_t, \Delta q_{t-1}) - \text{VAR}(\tilde{\varepsilon})) / (\text{VAR}(\Delta q) + 2 \text{VAR}(\tilde{\varepsilon})) \end{aligned}$$

If most of the short-run periodic volatility in ΔQ_t is in the noise, then the Δq components vanish, leaving:

$$\text{AC}(1)(\Delta Q) \approx \text{VAR}(\tilde{\varepsilon}) / (2 \text{VAR}(\tilde{\varepsilon})) = -1/2. \quad (15)$$

The above analysis proves that the statistical “signature” of pure noise is a 1st-order autocorrelation of negative 50%. In other words, if the volume index was pure noise then it would have $\text{AC}(1) = -50\%$. In fact, we see that in the TBI volume history shown in figure 23 the 1st-order autocorrelation is -39%. The 1st-order autocorrelation of the previously-defined RCA volume index depicted in Figures 21 and 22 is -54%. This suggests that noise is very strong in the quarterly or monthly commercial property transaction volume series.

As we don't want the SCLI to be too noisy, the next step is to determine a smoothing method to remove much of the noise component.⁴⁵ Four different smoothing methods for filtering out noise are explored for this purpose in this thesis, as explained below:

1. 2-month trailing, 3-month trailing and 3-month centered average

As it shows in formula (14),
$$\Delta Q_t = \Delta q_t + (\tilde{\varepsilon}_t - \tilde{\varepsilon}_{t-1})$$

Denote Δq_t^* as the smoothing index based on the original unsmoothed index ΔQ_t

Thus, The 2-month trailing smoothing index is defined as

$$\Delta q_t^* \text{ (2-month trailing)} = \frac{1}{2} * (\Delta Q_{t-1} + \Delta Q_t), \quad (16)$$

The 3-month trailing smoothing index is defined as

$$\Delta q_t^* \text{ (3-month trailing)} = \frac{1}{3} * (\Delta Q_{t-2} + \Delta Q_{t-1} + \Delta Q_t), \quad (17)$$

The 3-month centered average smoothing index is defined as

$$\Delta q_t^* \text{ (3-month moving average)} = \frac{1}{3} * (\Delta Q_{t-1} + \Delta Q_t + \Delta Q_{t+1}). \quad (18)$$

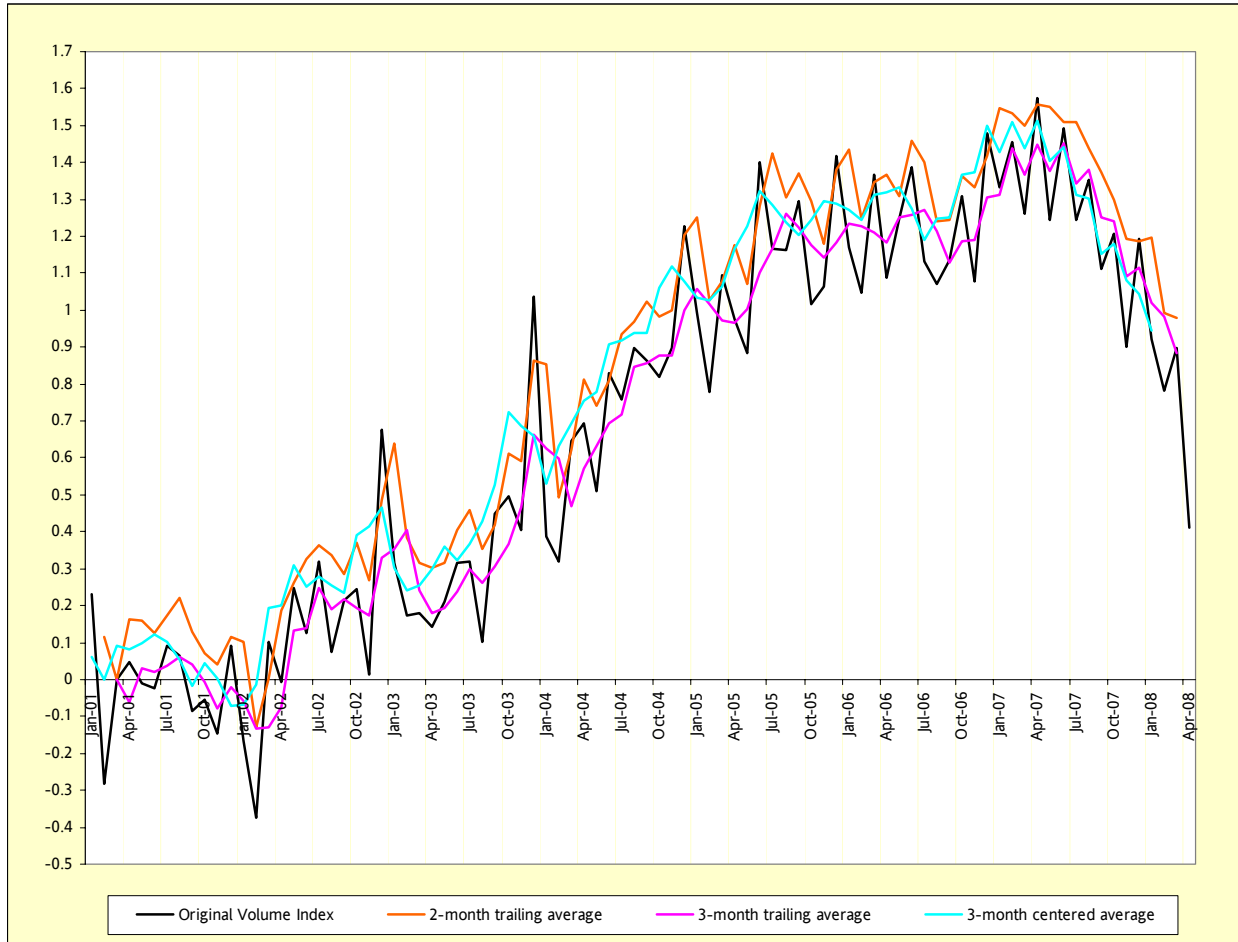
And the 1st order correlation resulting from application of these three methods to the original volume series is that moving averages spanning longer intervals naturally have more smoothing and noise-filtering, so it is not surprising that the two 3-month methods have $AC(1) = +1.05\%$ while the 2-month average has $AC(1) = -10.6\%$.

However, the 3-month centered average smoothing method has a delay in its reporting ability (you have to wait another month later to report it for the preceding month). The slight

⁴⁵ While we don't know the "true" 1st-order autocorrelation of the RCA transactions series central tendency (without noise), a good (and conservative, in terms of not over-smoothing) target is to try to get the $AC(1)$ of the filtered volume index at least close to zero instead of highly negative.

(one month) lag bias in the 3-month trailing average seems a small price to pay to avoid such reporting delay.

Figure 24: Comparison of three different smoothing methods



2. Locally Weighted Scatterplot Smoothing (LOWESS / LOESS) Methods

Other modern smoothing methods are explored as well in this thesis including LOWESS/LOESS regression. The LOWESS/LOESS model denotes a method that is a locally weighted polynomial regression. Many of the details of this method, such as the degree of the polynomial model and the weights, are flexible. The range of choices for each part of the method and the

typical defaults include localized subsets of data, degree of local polynomials, and the weight function. The biggest advantage LOWESS/LOESS has over many other methods is the fact that it does not require the specification of a function to fit a model to all of the data in the sample. Instead the analyst only has to provide a smoothing parameter value and the degree of the local polynomial. However, the LOWESS/LOESS techniques produce a lag bias at the end of the series, and this results in problematical backward adjustments in the subsequent updating of the volume index. The comparison of the frozen index with the backward adjusting index is examined in figure 25 and figure 26 and it shows that the frozen index which would be the preferred index for the users of the RCA-based SCLI displays considerable noise in comparison to the backward adjusted index. So, the LOWESS/LOESS method is rejected in favor of the 3-month trailing average for the purpose of constant liquidity price index which should not be subject to backward adjustments.⁴⁶

⁴⁶ Another consideration is that the 3-month rolling average is well understood by the typical potential users of the RCA-based SCLI, while the LOESS/LOWESS methods are more technical and less well known among practitioners.

Figure 25: LOWESS Backward Adjusting SCLI vs. Frozen SCLI
November 2006 – March 2008

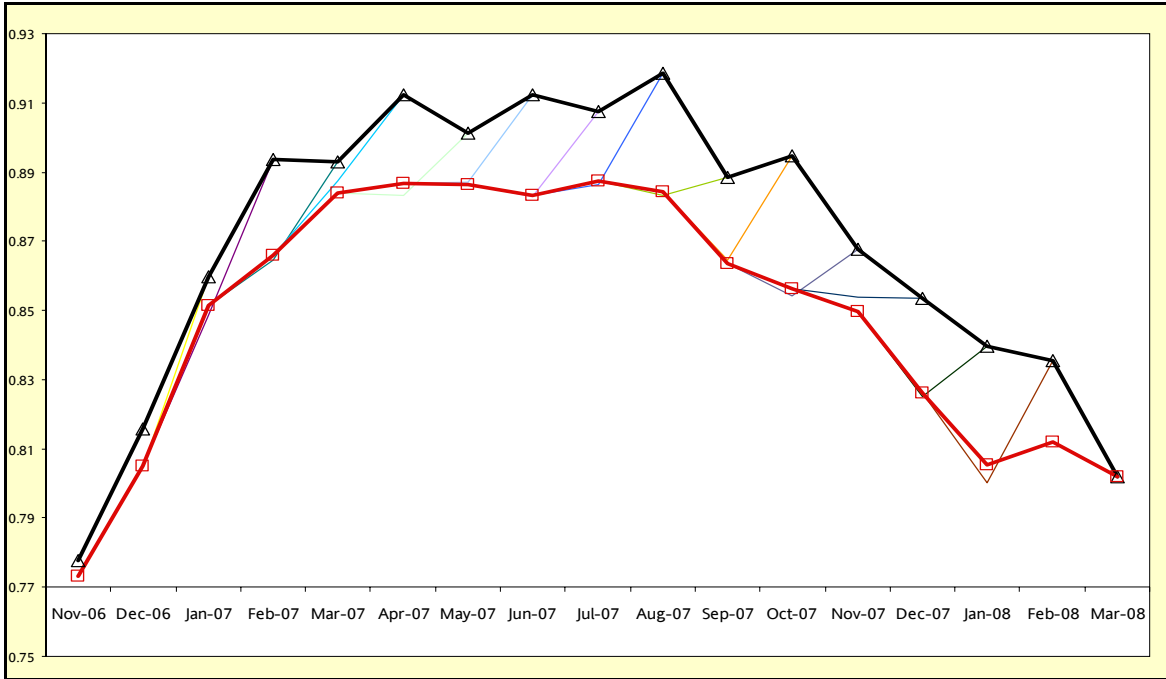
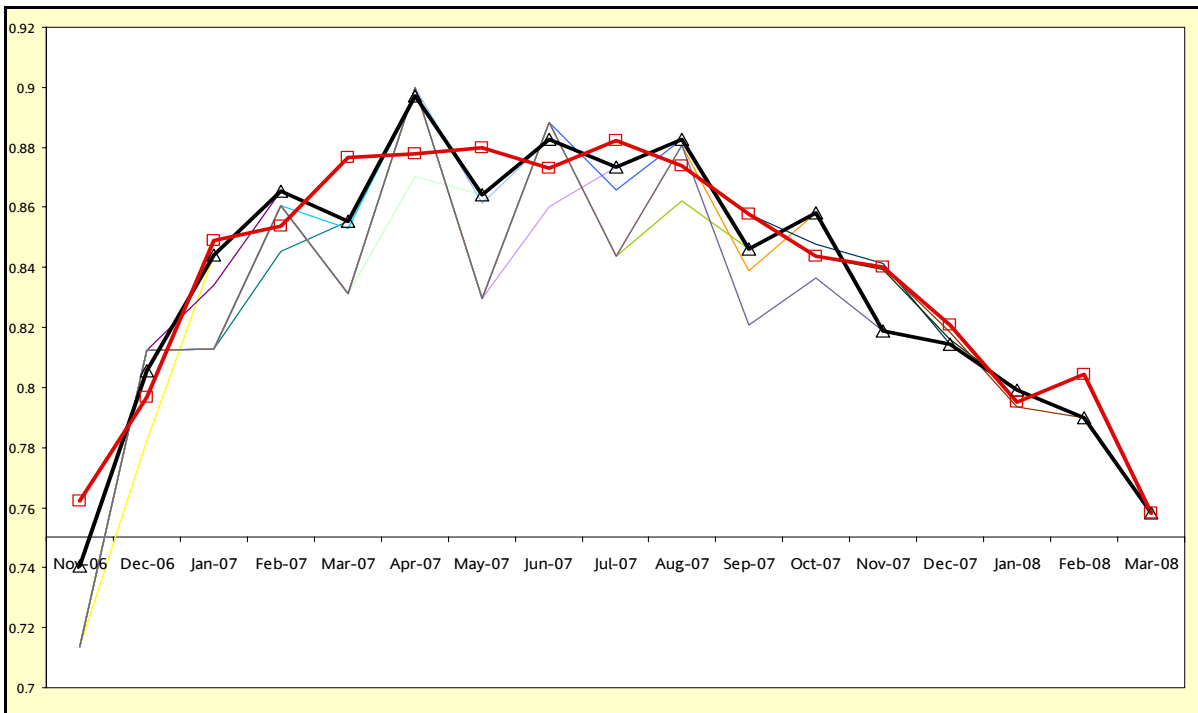


Figure 26: LOESS Backward Adjusting SCLI vs. Frozen SCLI
November 2006 – March 2008

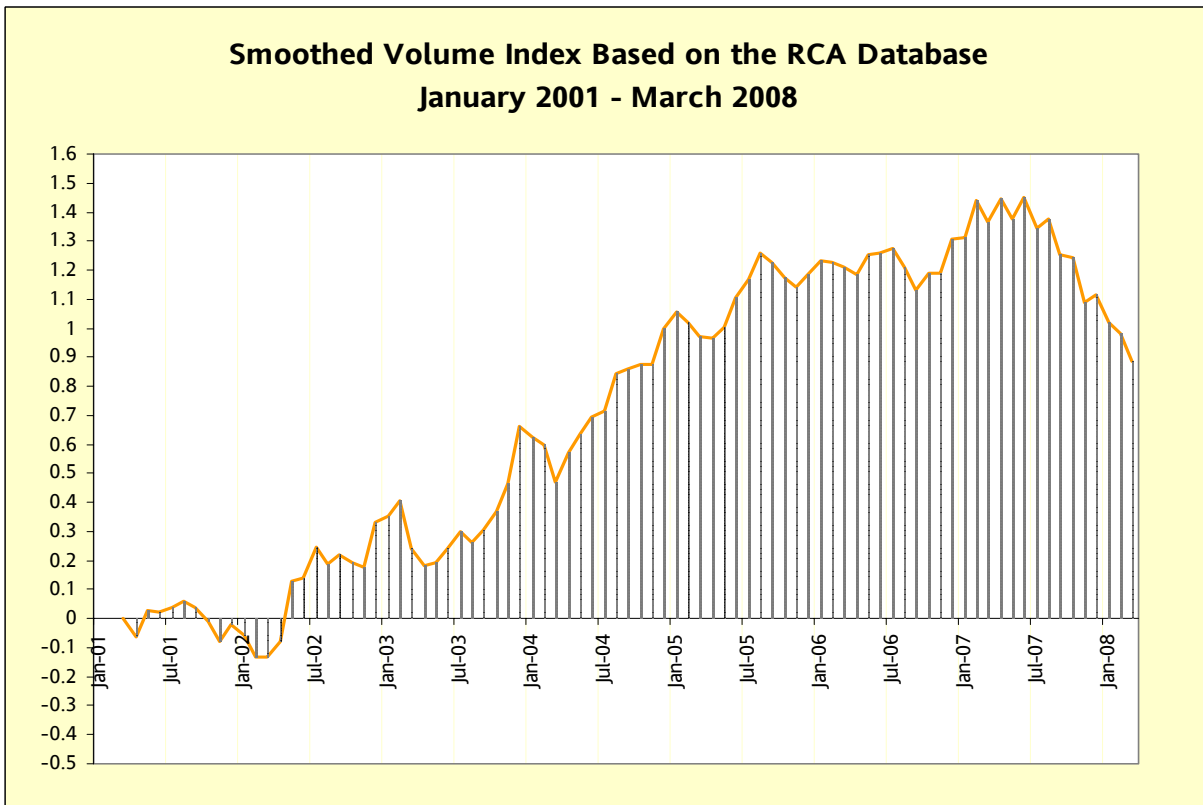
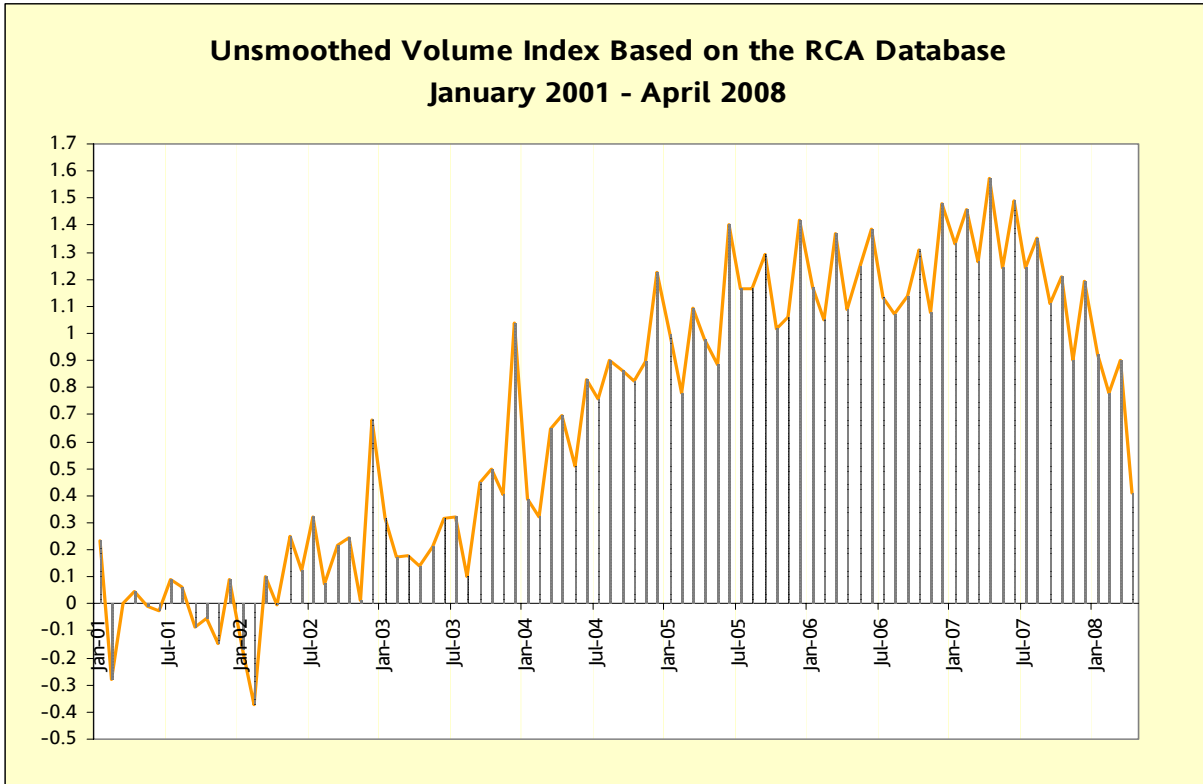


frozen SCLI
 backward adjusting SCLI

In conclusion, the 3-month trailing average smoothing method will be used as the suggested noise-filtering method for the RCA volume index developed in this thesis for purposes of constructing the SCLI. The resulting monthly RCA national aggregate volume index is shown in Figure 27, for the time period from 2001 through April 2008, with and without the 3-month trailing smoothing (on the same vertical scale of cumulative log values). It is obvious that the 3-month-average smoothing eliminates most of the short-term choppiness in the volume without inducing a significant lag.⁴⁷

⁴⁷ The estimated price and volume index correlation is 0.9583 which is referred back to footnote 38.

Figure 27: RCA Unsmoothed and Smoothed Volume Index



5.2 The Calibration of the Demand Slope Parameter “m” for the RCA Database

After the construction of the volume index based on the RCA database, the next and the last step in the construction of the simplified constant liquidity index is to calibrate the magnitude of the demand slope parameter “m” based on formula (13). As discussed in Chapter Four, the demand slope parameter is assumed to be constant for purposes of simplicity and transparency for the index, and because there is insufficient data to model variations in elasticity over time. Furthermore, the application of the simplified model to the NCREIF database indicates that the SCLI with constant elasticity displays very similar attributes to the rigorous econometric-model based constant liquidity index – the TBI demand side index. In this section, a single constant “m” will be specified for the construction of our simplified constant liquidity price index based on the RCA database.

As formula (13) presents:

$$m = \frac{\Delta V_t - \Delta P_t}{\Delta Q_t}$$

The value of “m” equals the difference between the constant liquidity index return and the observable transaction price index return divided by the volume index return. The calibration of this value is straightforward from the price and volume indexes if we have exogenous information about the magnitude of the demand movement for some historical period of time in which we also have values for ΔP and ΔQ .

To trace the demand movement in the real estate market, the historic turning of the U.S. commercial property market in late 2007-early 2008 can provide the exogenous information of ΔV^D that we need to calibrate “m”. There are several sources that can shed light on the

movements of the reservation price on the buyers' side from the end of the second quarter of 2007 to the first quarter of 2008. The first direct source is the MIT-Published (FGGH-based) TBI demand-side index based on the NCREIF database. It has dropped 14% during these three quarters. The second source is evidence from the stock market in the NAREIT share price index which is based on the market prices of publicly traded REIT shares traded in the stock exchange. This is the densest, most liquid market relevant to the trading of real estate equity assets, and so it has the most informationally efficient price discovery.⁴⁸ Furthermore, the stock market is considered to be a sensitive reflector of market sentiment, the same type of sentiment that likely underlies movements on the demand side of the commercial property market during the recent downturn. Indeed, just prior to the downturn REITs were facing a wave of privatizations as buyers representing the demand side of the private property market were buying out entire REITs at once (most famously in the case of Equity Office Properties in early 2007). The NAREIT equity REIT share price index lost approximately 25% from early 2007 through early 2008. The fact that equity REITs have typically 40% average leverage means that a 25% drop in equity value equates to a 15%⁴⁹ drop in the implied valuation of the firms' assets (the underlying property).

A third source that can provide some information about the buyers' side of the private commercial property market in the U.S. during 2007-08 comes from the price quotes of the new commercial property derivatives. The NCREIF swap market showed a price drop from a fixed-rate (per annum) of +8% to -3% from July 2007 to early 2008, on the 2-year total return swap of

⁴⁸ See "Commercial Real Estate Analysis & Investments", Geltner, Miller, Clayton, Eichholtz.

⁴⁹ If average REIT LTV = 40%, and debt value didn't move much, then -25% share price drop implies:

$P_0 = (.60)E_0 + (.40)D_0 \rightarrow P_1 = (.85)P_0 = (.60)E_0(.75) + (.40)D_0$. In other words, an equity value drop of 25% corresponds to a 15% property value drop.

the (appraisal-based) NCREIF Property Index (NPI). That is, in July 2007 you would have to pay 8% per year (of the notional amount of the trade, with zero cash changing hands up front) to receive the NPI total return for two years; by February 2008 you would be paid 3% per year to “receive” the NPI total return (of course, if that return is negative that “receiving” it means paying out cash). Given that the equilibrium price of a swap is the expected return on the index (per annum) minus the required risk premium, and assuming that the risk premium is 2% and the income component of the total return is around 6%, the implication in the February swap price is that the expected 2-year capital return (*per annum*) on the NPI was: $-3\% + 2\% - 6\% = -7\%$.⁵⁰ This implies an index drop of 14% ($7\% \times 2$) by 2009. As swap dealers must be prepared to trade at the quoted price either long or short, and as they are experienced working in the informationally-efficient securities-trading environment, it is likely that the NPI swap price quotes are very sensitive to demand-side sentiment during a market downturn. Thus, the expectations and resulting pricing by the property index swap dealers probably well reflects the movements of the demand side of the commercial property market, and their implied 14% valuation drop also echoes the results of the NCREIF-based TBI demand-side index.

Finally, other sources of market information, such as CMBX spreads and anecdotal market evidence as in typical trade literature interview quotes and common perception as “heard on the street”, also suggests at least an approximately 15% drop in potential buyers’ reservation prices from mid-2007 to early-2008. Hence, based on all of the above considerations, we will take our “exogenous” estimate of ΔV^D to be negative 15% from the middle of 2007 through the first quarter of 2008.

⁵⁰ See “Commercial Real Estate Analysis & Investments”, Geltner, Miller, Clayton, Eichholtz.

In the same time period, ΔP which is represented by the Moody's/REAL CPPI dropped approximately 2%, and ΔQ which is estimated by the RCA volume index described in the last section dropped about 50%. Thus, by using the formula (13):

$$m = \frac{\Delta V_t^D - \Delta P_t}{\Delta Q_t} = \frac{-15\% - (-2\%)}{-50\%} = \frac{-13\%}{-50\%} = 0.26 \approx 0.25^{51}$$

The demand slope parameter is thusly calibrated at 0.25.⁵² So, the simplified constant liquidity price model based on the RCA database is defined and constructed as follows:

$$\Delta V_t = \Delta P_t + 0.25 * \Delta Q_t \quad (19)$$

Where, ΔP_t is the Moody's/REAL CPPI and ΔQ_t is the volume index described previously. Though this simplified model is not based on a rigorous econometric-model given the nature of the available data, the simplicity and the transparency of this model provide understandable information to the general real estate investment community. The constructed index intends to track the short-term to medium-term reservation price movements of the demand side of the real estate market. Because it is to the buyers whom the sellers must sell their properties, price changes that match movements in the demand side's reservation price will reflect changes that keep the ease of selling (liquidity) constant in the market.

⁵¹ Value "m" is an approximation to a round number for the purpose of simplicity.

⁵² In Chapter 6, more evidence will be provided to validate this value.

Chapter Six: Empirical Results – RCA National Aggregate Monthly Constant-Liquidity Price Index

In this chapter, the developed simplified constant liquidity price model will be applied to the RCA database. This thesis will only focus on the construction of the National Aggregate Monthly Constant Liquidity Price Index. Two time periods which have suffered major market downturns during the RCA data history from 2001 to early 2008 will be examined: early 2001 to mid 2002, and mid 2007 to early 2008.

Figure 28: RCA-Based Simplified Constant-Liquidity Price Index (SCLI)
Vs. the Moody's/REAL CPPI
January 2001 – March 2008

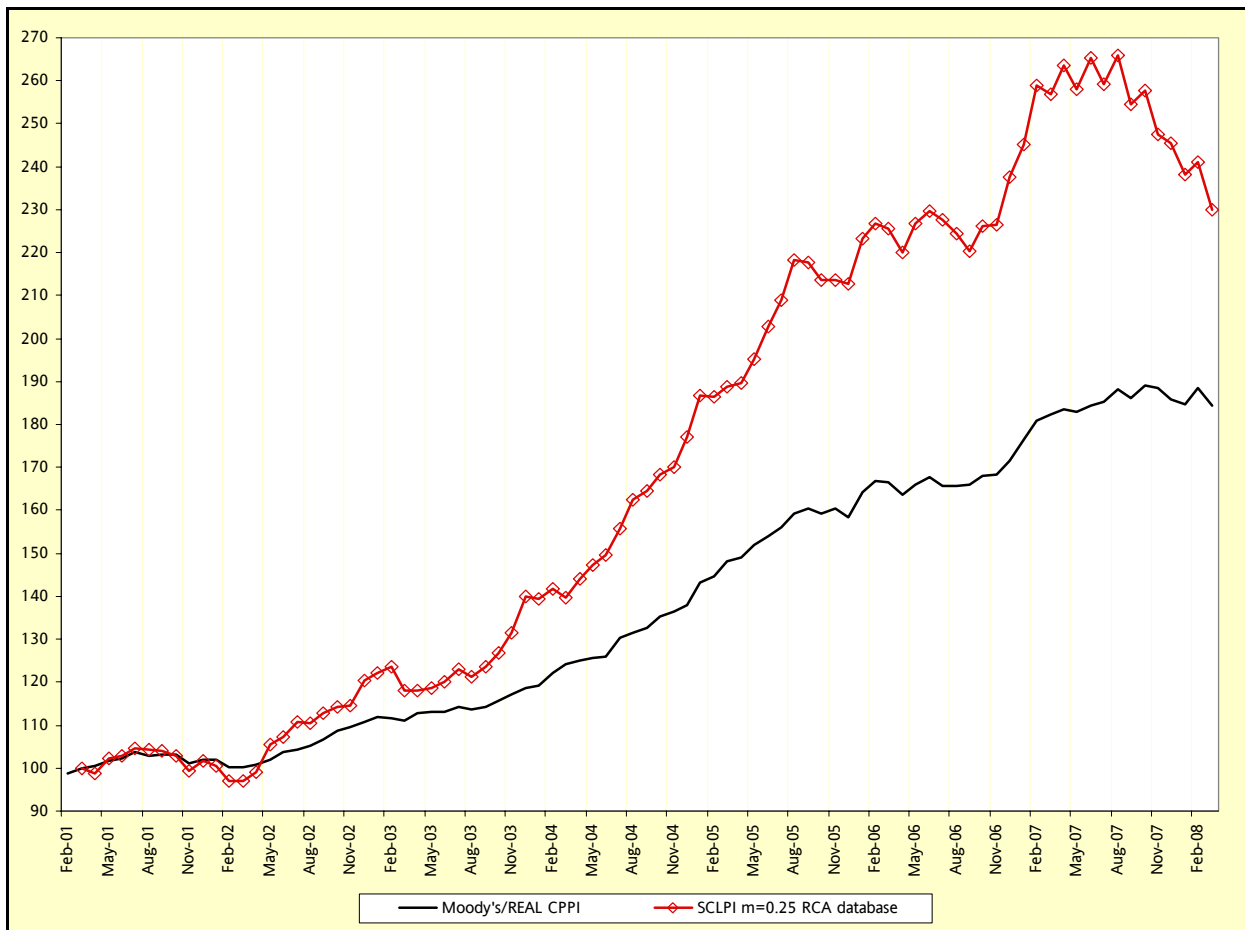
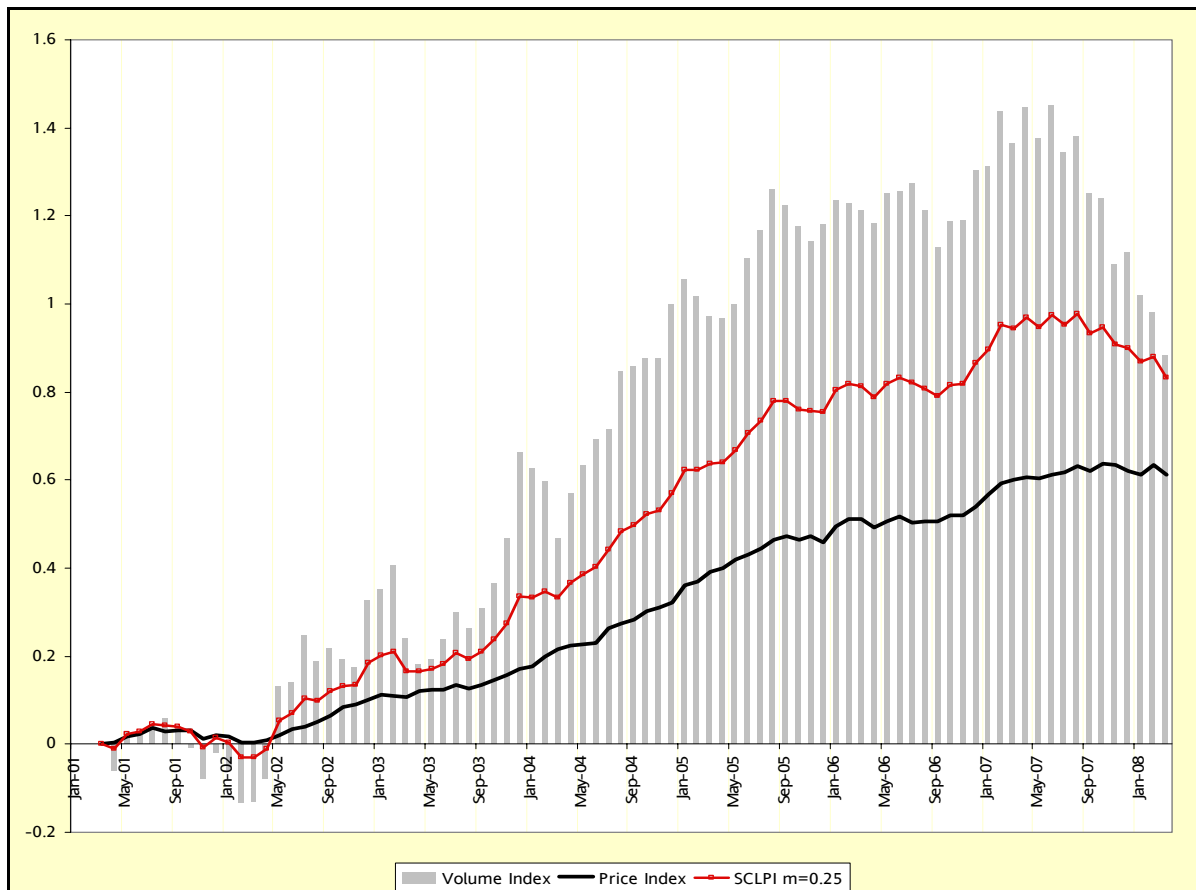


Figure 28 depicts the Moody's/REAL CPPI and the RCA simplified constant liquidity price index (SCLI) for all national properties at a monthly frequency from 2001 to 2008. The graph shows a noticeable long term trend difference between the CPPI and SCLI. Figure 29 superimposes these two indexes with the RCA volume index. It demonstrates clearly that the SCLI inherits the long term trend that appears in the volume index (as mitigated by the conversion parameter "m"). As discussed in the previous chapters, the simplified constant liquidity price index based on the RCA database intends to track short to mid term market changes on the demand side. The long term trend difference between CPPI and SCLI may reflect the RCA volume index "trend" bias discussed in Chapter Five. In principle, the demand-side

Figure 29: RCA Volume Index, SCLI and the Moody's/REAL CPPI
January 2001 – March 2008



reservation price movements cannot, over the long-term, have a substantially different trend than the price trend of the actually closed transactions represented by the Moody's/REAL CPPI. (If they did, then over time either the transaction market would dry up altogether if the demand trend were below the price trend, or the average holding period of individual properties would diminish toward nothing but quick flips if the demand trend were above the price trend, neither of which scenario is realistic in the long run for real estate markets in the US.) Thus, one should ignore the long-term trend differential apparent in Figure 28, and concentrate on short to medium-term movements in the SCLI to trace the movements on the demand side of the market.

If the general U.S. GDP growth adds approximately 2% per year to the total number of properties in the real estate market, and the number of properties that are worth \$5 million or more also grows at 2% annually, then these two growth trends together will add approximately 4% positive trend to the RCA volume index which tracks the number of properties worth \$5 million or more. This 4% positive trend is introduced into the simplified constant liquidity index via “m” (0.25) thereby introducing a 1% upward trend annually into the SCLI.⁵³ In fact during the 2002-2007 market upsurge, displayed in Figure 29, the annual average growth difference between the SCLI and the CPPI is approximately 7% per year. This considerable difference probably reflects not only the particularly strong growth in property prices during that period of time, but as well the maturing of the RCA database during its early years. The trend difference will probably be much less in future. As stated previously, the RCA data-based SCLI should not be used to measure the long-term trend performance of the real estate market (the CPPI should be used for that purpose).

⁵³ From formula: $\Delta V_t = \Delta P_t + m * \Delta Q_t$, $1\% = 0.25 * 4\%$

Figure 30 depicts the volume index, CPPI and SCLI during the recent downturn, from 2007 to the first quarter of 2008. Figure 31 graphs the volume index, CPPI and SCLI during the earlier (and generally agreed lesser) downturn from 2001 to the first half of 2002 (reflecting the 2001-02 recession). From mid 2007 to early 2008, the volume index dropped approximately 50%, while the CPPI only showed a slight drop of 2%. The SCLI dropped about 15%, very similar to the drop in the TBI demand index which is 14%. Of course, this result is by our calibration of the elasticity parameter, “m”. However, we did not calibrate “m” based on the earlier downturn, and we see that from early 2001 to mid 2002 the volume index dropped about 20%, while the CPPI dropped only about 3%. The TBI demand index at the same period had a drop of about 6%. Using the value 0.25 for the demand slope parameter “m”, the SCLI displays approximately an 8% drop. The fact that the SCLI exhibits the similar results to the TBI demand index during the 2001-2002 downturn by using the “m” value(0.25) calibrated from the 2007-2008 downturn provides support for our calibration of “m”.

Figure 30: RCA Volume Index, CPPI and SCLI
2007 -2008

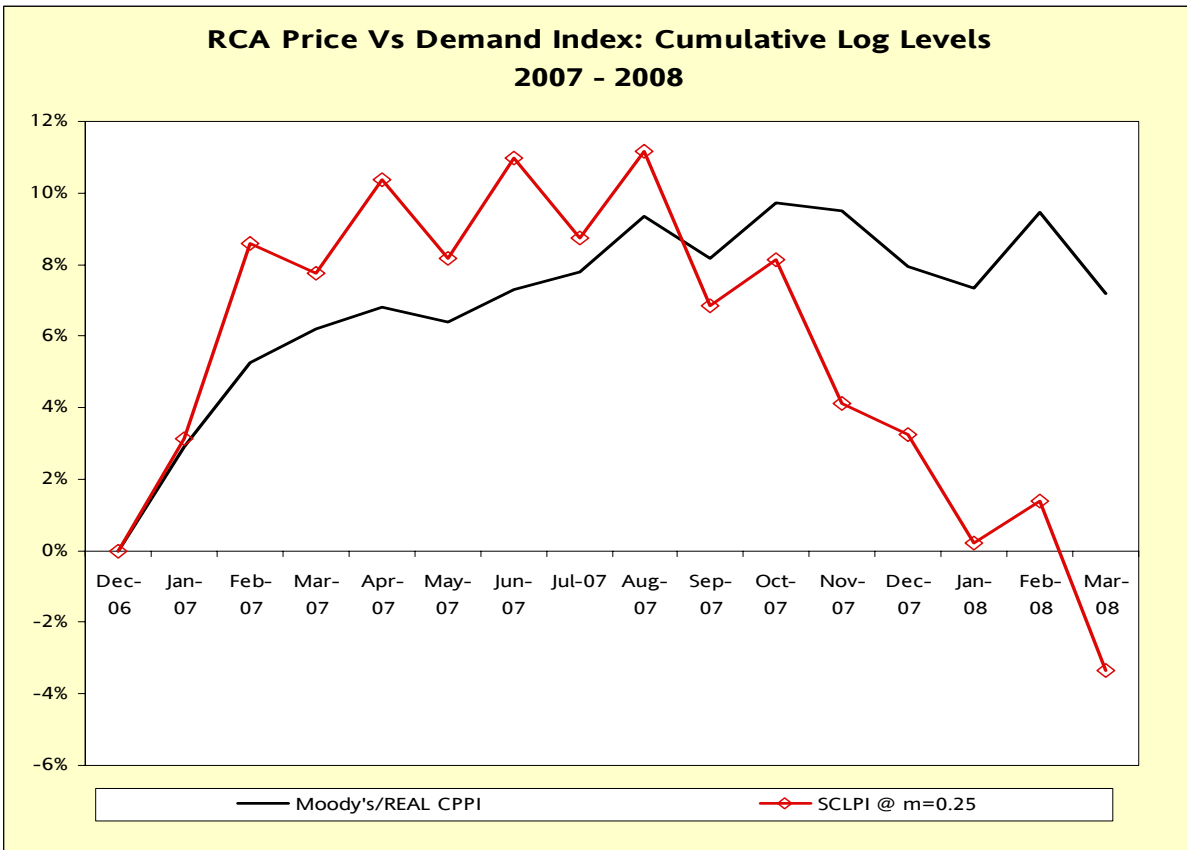
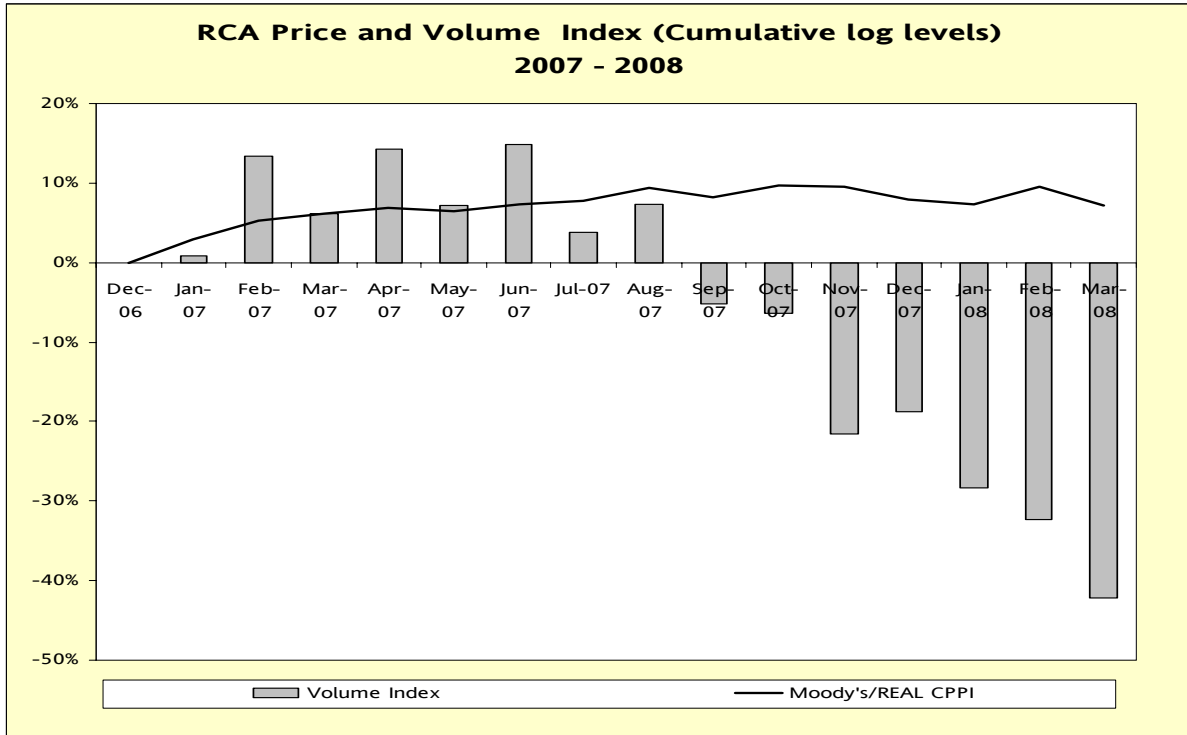
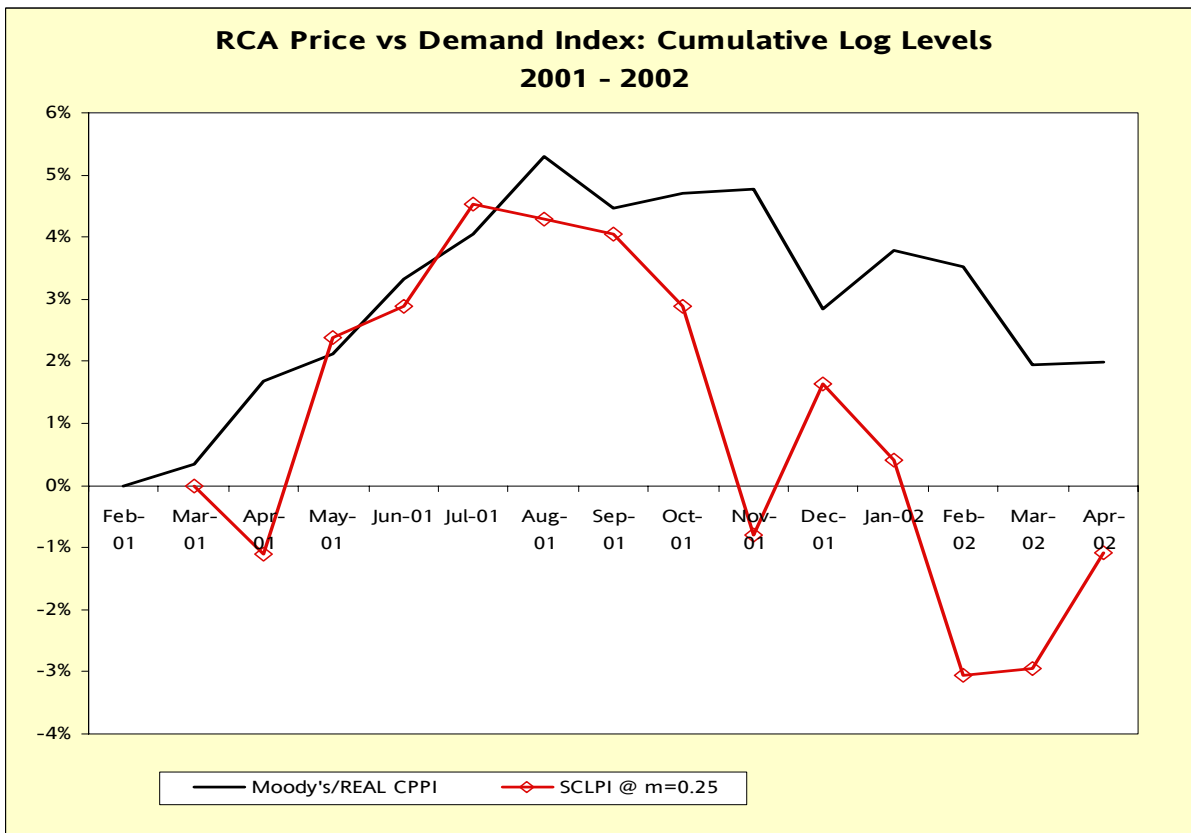
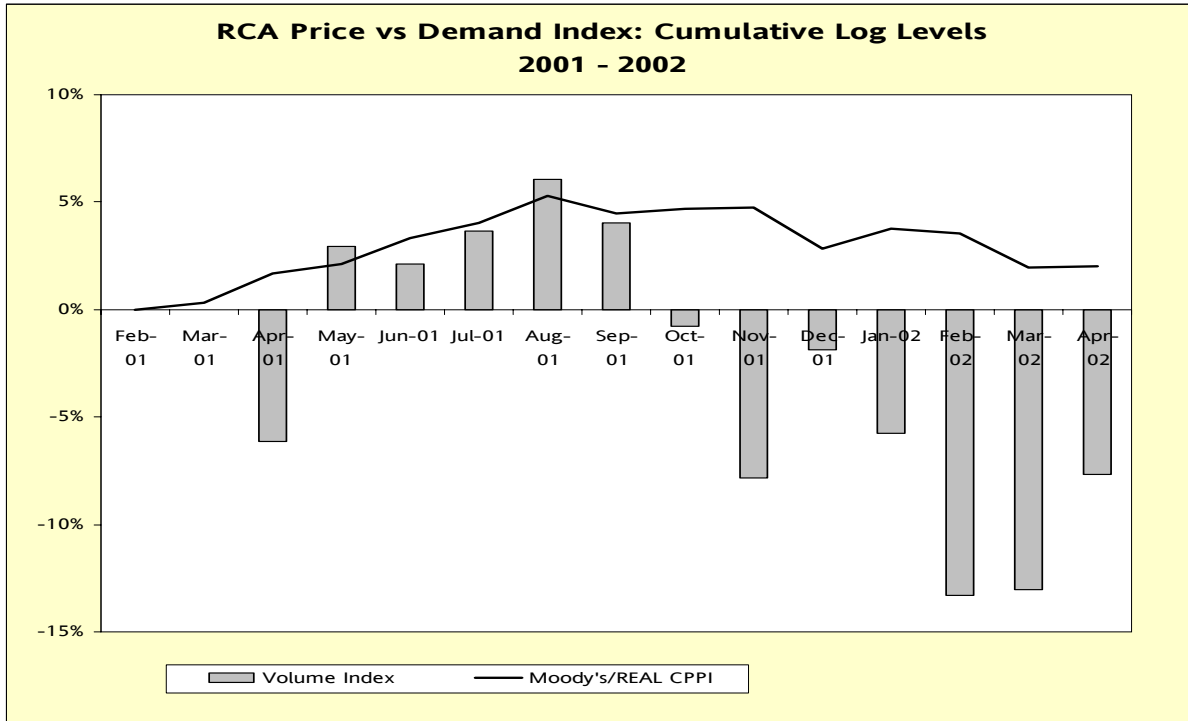


Figure 31: RCA Volume Index, CPPI and SCLI
2001 -2002



Chapter Seven: Conclusions and Further Study Recommendations

Based on the “constant liquidity value” concept first proposed by Fisher, Gatzlaff, Geltner and Haurin (2003), this thesis has developed a simplified constant-liquidity price index (SCLI) of U.S. commercial real estate, (SCLI) which is constructed based on the RCA-based realized transaction price index (Moody’s/REAL Commercial Property Price Index) and a volume index that tracks changes in the RCA trading volume of properties with values \$5 million or more. The SCLI intends to track the movements in the reservation prices on the demand side of the property asset market. It tracks the change of the buyers’ side reservation price by combining the change in the observable transaction price with the change in the observable trading volume in the market by using a price-elasticity-based parameter. The RCA monthly aggregate commercial property simplified constant liquidity price has been constructed and presented in this thesis. The process of the development of the SCLI has led to a number of observations which hopefully will add to the knowledge and understanding of the real estate market.

First, compared to publicly-traded securities financial asset markets, the real estate market is importantly characterized by two statistics: property price and trading volume, rather than just by the price. When the market is up, the observed average transaction prices reflect an ability to sell more assets, more quickly and easily, than those observed in a down market. The liquidity which is defined as the asset transaction volume in the private asset market tends to vary across time. Liquidity is positively correlated with the asset market cycle. The transaction volume is typically greater when the market is up and the price is rising, and the transaction volume is less when the market is down and the price is falling. This market characteristic is

caused by “loss-aversion” or “sticky price” behavior on the part of property owners (the supply side of the asset market). Investors should care not only the about the average closed transaction prices in the market, but also about how easy is it to sell properties at that average price level, because the realized prices reflect pro-cyclical variable liquidity.

Secondly, the observed transaction price and transaction volume are jointly determined by two opposite-sloped functions: the underlying demand and supply functions in the market. These two functions are derived from the underlying reservation price distributions of the buyers and sellers, which suggests a method to identify and separate the movements of the demand and supply side of the market. The observed transaction price reflects the average of the buyers and sellers reservation price valuations, and the observed transaction volume reflects the difference (or overlap) of the reservation price valuations between these two groups. The “constant-liquidity” value combines contemporaneous information from both the observable realized transaction prices and the observable trading volume in the market to provide a single, price-based metric that integrates the price and volume information in order to track movements in the demand side of the market. The “constant-liquidity value” reflects the reservation prices of the buyers’ side because it is to the buyers whom the sellers must sell their properties. Buyers drawn from the demand side of the market provide the “liquidity” in the transaction marketplace. Price changes that match movements in the demand side’s reservation price will reflect changes that keep the ease of selling constant on the market.

Thirdly, the constant liquidity price index is defined by the natural log change of the constant liquidity value at any specific time period.⁵⁴ The simplified constant liquidity price index can be constructed by combining the information of the transaction price index and the volume index which tracks the change of transaction volumes in the market over time. The “constant-liquidity” price-change equals the observable price index change plus the magnitude of the demand slope parameter multiplied by the volume index change as shown in the formula below:

$$\Delta V_t = \Delta P_t + m * \Delta Q_t$$

Where, ΔV_t represents the percentage change in the constant liquidity value in the market,

ΔP_t represents the observed percentage change in the observable transaction price in the market,

ΔQ_t represents the percentage change in the observable trading volume in the market,

m represents the absolute value of the demand slope parameter .

In this simplified model, “m” is assumed to be constant over time.

Fourthly, to construct a simplified constant liquidity price index based on a specific database requires a same data based price index, a volume index and an estimated value of the demand slope parameter “m”. If data is available for both sold and unsold properties as is the case for the NCREIF database, the trading volume can be defined as the percentage of number of transactions over the entire property population at a specific time period. If there is no consistent

⁵⁴ Quoting the index in logs and returns in log-differences has been done throughout this thesis only for mathematical and expositional convenience. In the real world, if the SCLI is actually published, the log-values would be “exponentiated” (take “antilog”) to convert them to straight-levels, and the returns would be defined and quoted as the geometric (ratio) differences in the index straight levels over time (simple returns for individual periods, compounded over time).

and complete data available for unsold properties as in the RCA database, the trading volume can be defined as the number of transactions at a specific time period. Note that, the volume index constructed by the tracking the change of number of properties transacted over time may contain long term “trend” components caused by the growth of the number of total properties and the growth of the value of the underlying property population (if there is a value threshold to the database). The long term “trend” in this type of volume index has not been adjusted here because its impact on the SCLI, which is designed to track short to medium term market movements, is gradual and somewhat quantifiable. The users of the index can take it into account and factor it into their considerations. The volume index also tends to have “noise” from one period to the next period. An appropriate smoothing method that does not produce much lag bias or backward-adjustments at the end of the series should be employed to eliminate the “noise” component. The calibration of “m” can be done by using information from the price index and constructed volume index together with market indications of the demand side of the movement for example from a historic time period with a notable market turning point. The value of “m” can be tested by comparing the constructed SCLI with the TBI demand side of the index within a different time period.

Finally, the construction of the RCA-based Monthly National Aggregate Simplified Constant Liquidity Price Index for the U.S. Commercial Properties reveals that the index captures the short to mid term movements of the demand side of the market which are comparable to those displayed in the TBI demand side of the index. The SCLI thus may serve as a useful complement to the realized price index provided by the Moody’s/REAL CPPI.

Further study is recommended in several areas. First, the same market model that underlies the demand-side index can apply as well to the supply side. The idea of a supply-side index is that it tracks movements in the average reservation price at which property owners are willing to sell. Like the NCREIF-based TBI produced by the MIT/CRE that includes a supply-side index as well as a demand-side index, it is possible to construct a simplified index of supply-side movements based on the RCA database as well. Together with the demand side of the index, the supply side of the index can provide information on both the buyers' side and sellers' side for the real estate investors. The movements in between these two indexes, which reflect the movements of the reservation price of buyers' and sellers' sides, can give an indication of market liquidity over time. If they are moving toward each other (demand price increasing relative to the supply price), then market trading volume and "liquidity" are increasing. If the two sides are moving away from each other (supply price increasing relative to the demand price), then trading volume and "liquidity" are decreasing. Having the two indexes allows these changes in liquidity to be measured in price terms, that is, as a percentage of the average transaction price in the market.

Another recommendation for further exploration is to apply the results of the constant liquidity index in the context of modern portfolio allocation, the mean variance portfolio optimization framework pioneered by Markowitz. As stated in the introduction part of this thesis, one of the motivations for the development of the constant liquidity index is to allow a more "apples to apples" comparison of the risk characteristics of real estate assets with those of public traded financial assets such as stocks and bonds. It will be interesting to see how much difference

it will make to the optimal percentage allocation of real estate assets in a multi-assets portfolio by comparing the results of constant liquidity price index with other price indices.

Finally, this thesis is based on the RCA database which records transaction information of U.S. commercial properties from 2001. As the database matures and develops to include more consistent and broader data points, or even, more importantly, to include the information for the total number of properties on the market, it is recommended that this study be conducted again to observe the effectiveness of the developed index and further improve this index by possibly eliminate the long term trend component in the underlying volume index.

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