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Real Estate, Stocks, and Bonds as a Deflation Hedge

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With inflation rates remaining close to zero in all major developed economies for long periods of time, especially from 1998 - 2015, investors have become increasingly concerned about the potential effects of deflation on asset value. Negative inflation rates were observed between 1998 and 2009 in Hong Kong and Japan, and those economies faced several years of deflation. There is a rich body of literature on the effects of inflation hedging on the returns of stocks, bonds, and real estate. We examine asset returns for these products between 1986 and 2009, and use an ARIMA model to explore whether they offer a deflation hedge. We show that rents and real estate prices are closely linked to consumer prices, which confirms previous findings on inflation hedging. Since the relationship is generally positive and over proportional, we find that real estate is not an effective hedge against deflation. In contrast, we find no relationships between stocks or bonds and inflation. Only for Japanese bonds are we able to find a significantly negative relationship with unexpected deflation.

Keywords

Inflation-Hedging; Deflation; Real Estate Investments; House Prices

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1. Introduction

Ongoing low interest rates and the slow recovery of all of the major economies after the 2008- 2009 recession have resurrected the fear of investors around deflation. One particularly chilling possibility is the possibility of falling into a state where inflation turns negative, and we endure a Japan-style outcome. Direct real estate investment is often regarded as a hedge against inflation, while bond investments are typically associated with exposure to inflation risk. The cash flow and repayment of bond capital are fixed ex ante. Thus, any inflationary losses are fully captured in purchasing power. Income sources from real estate investments, such as rent, however, are subject to renegotiation and renewal at regular intervals. Therefore, they are linked to a decrease in monetary value. Following this reasoning, real estate should decrease its nominal value under deflation (negative inflation rates), and bonds should protect against an increase in monetary value, since a negative interest rate is uneconomical. On the other hand, a deflationary environment is often accompanied by an economic crisis. Therefore, normal market relationships may be weak.

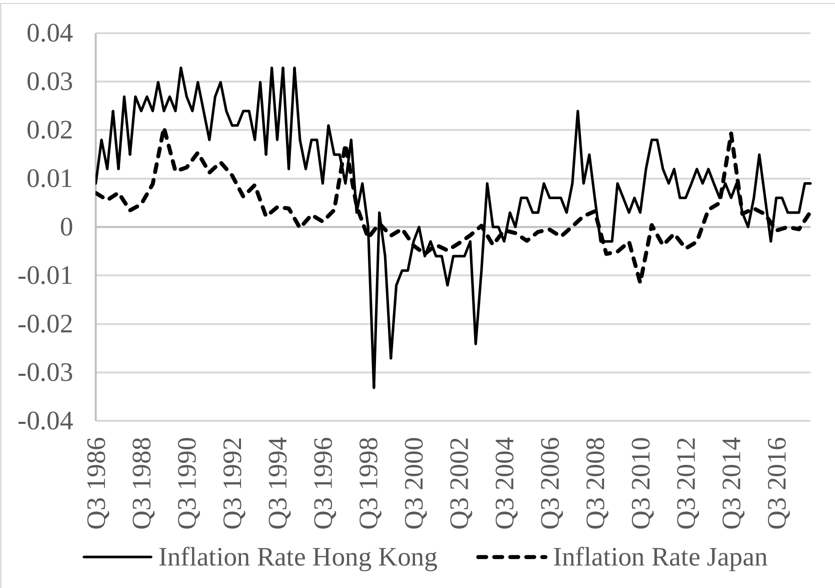
To further elaborate on what we mean by inflation and deflation protection, consider the following. The purchasing power of assets or protection against inflation is usually defined so that the nominal value of an investment increases in proportion to inflation. Thus, real value remains unchanged. In the context of an econometric investigation, we can define a perfect hedge against inflation or deflation as follows. The coefficients of the regression of the expected or unexpected inflation or deflation on the nominal return on an investment, by considering the Fama and Schwert (1977) model, are not statistically or discernibly different from one. In other words, nominal returns increase or decrease, just as inflation and deflation can be compensated for changes.

In an inflationary environment with increasing prices, it is relevant to retain the purchasing power of the investment. This is not the case in a deflationary environment. Protection against deflation means that the nominal value remains constant, so the real value increases. From the viewpoint of an owner-occupier without leverage, deflation protection is only a protection against an illusory value loss. From the viewpoint of any other investor, e.g., an institutional investor, however, deflation protection is much more relevant. This is especially true when obligations/liabilities are fixed in nominal terms, and must be serviced by the returns on assets. Moreover, under most regulations, losses in nominal terms will affect the results in the annual report of the respective company.

Note that real estate assets, which are a good inflation hedge, may be especially prone to deflation risk. The best hedge against deflation would then be an investment in nominally denominated assets such as bonds. The aim of our paper is twofold: first, we analyze whether the deflation risk of real estate is symmetric to the inflation hedge characteristics. Second, we examine whether stocks or bonds provide a hedge against deflation. We choose two markets that have experienced longer periods of deflationary regimes: Japan and Hong Kong. Both areas exhibited a measurable decrease in consumer prices over the period of 1998- 2010. The inflation rates in Hong Kong have been generally more positive since 2005. In Japan, monetary value remained very stable at around 0% until the end of 2013. Figure 1 illustrates the inflation rates for both areas in our research period, and shows that both experienced overall deflationary phases beginning in 1998.

The remainder of this paper is organized as follows. Section 2 reviews the related literature, while Section 3 provides a discussion of the Fama and Schwert (1977) framework, the extension of their model, and our data. Section 4 analyzes the data for the two given markets with respect to their inflationary and deflationary periods. Finally, the main findings are summarized and interpreted in Section 5.

Figure 1 Inflation Rates of Japan and Hong Kong



***Notes*:** Inflation rate of Japan is derived from half-yearly values compared to the quarterly observations for Hong Kong. The issue of data availability will be discussed in Section 4.1.

2. Survey of the Literature

Early studies by Bodie (1976), Jaffe and Mandelker (1976) and Fama and Schwert (1977) find that nominal stock returns are negatively related to actual inflation. This relationship holds even when the expected and unexpected components of inflation are examined separately. Although the Fama-Schwert (1977) model has been criticized for the lack of distinction between long-term equilibrium adjustments and short-term dynamic movements, it has been applied in numerous papers. In more recent studies, however, this classic model is usually supplemented by other models, such as cointegration tests, that capture long-run relations.

Gultekin (1983) shows that results based solely on the relationship between stock returns and inflation can also be justified for many other countries. The finding that stocks provide a negative hedge against inflation seems counterintuitive at first, given that shares represent claims on cash flows from real assets. Among the various investment categories examined by Fama and Schwert (1977) for the U.S. (short- and long-term government bonds, residential real estate, stocks, human capital), residential real estate offers the only complete hedge against inflation. In contrast, short- and long-term government bonds provide protection only against expected, but not unexpected, inflation. Studies on the characteristics of commercial real estate have found that it has at least a partial hedging capability. While American commercial real estate seems to provide a hedge against expected inflation, there is no clear evidence with regard to unexpected inflation (see, for example, Brueggeman et al. (1984), Hartzell et al. (1987), Gyourko and Linneman (1988), and Rubens et al. (1989)). Additionally, Gyourko and Linneman (1988) attest to the effective hedging capabilities of U.S. real estate investment trusts (REITs), at least against expected inflation, for the period of 1972-1986. According to Park et al. (1990), REIT investments provide negative inflation hedging against both expected and unexpected inflation during the same period of time. In contrast to Gyourko and Linneman (1988), the rate of inflation is not predicted by means of an autoregressive–moving-average (ARMA) model, but rather by using three-month interest rates.

In comparison to direct real estate investments, the correlation of real estate stocks (REITs) to expected and unexpected inflation has been determined to be zero or negative. The studies cited above use monthly to annual returns in their investigations. Boudoukh and Richardson (1993) examine the long-term dependencies for the U.S. and U.K. markets by using one- and five-year returns. They find that annual returns on stocks are negatively correlated with inflation, while five-year returns are positively correlated.

Yobaccio et al. (1995) extended the approach in Fama and Schwert (1977) with a market parameter in order to examine the returns of different types of U.S. REITs for the period of 1972-1992. They find that REITs provide some hedging capabilities against anticipated, but not unanticipated, inflation. Liu et al. (1997) investigate the inflation hedging characteristics of property trusts in seven countries for 1980-1991. They find that U.S. property trusts, similarly to common stocks, are rather perverse inflation hedges. However, they find no evidence that real estate securities in other countries provide any better hedging capability against inflation than common stocks. In fact, property trusts can be even more perverse as hedging instruments than common shares in some countries. In addition to short-term capabilities, Adrangi et al. (2004) also examine the long-term hedging characteristics of REITs by means of cointegration tests. They find no evidence that REITs significantly protect against inflation in the long run. Moreover, Maurer and Sebastian (2002) focus on the hedging properties of real estate securities in France, Germany, Switzerland, and the U.K. from 1980-2000. They find that only German open-end real estate funds, and not real estate stocks in Germany or other countries, have hedging capabilities against anticipated inflation. Their approach follows an autoregressive integrated moving average (ARIMA) time series model, with ex post inflation rates used as the inflation predictor. They also determine shortfall risk measures for real returns of real estate stocks and German real estate funds. More recently, Obereiner and Kurzrock (2012) analyze German open-end real estate funds, special funds, and real estate stocks in order to test their hedging effectiveness against inflation. In addition to using the Fama and Schwert (1977) approach, they conduct cointegration and Granger causality tests, and find that real estate yields in the short run are almost independent of inflation. On the other hand, the cointegration tests demonstrate that real estate investments are long-term inflation hedges. The causality tests also indicate that real estate returns are influenced by inflation over the long run.

With a focus on the Hong Kong market, Ganesan and Chiang (1998) and Glascock et al. (2008) find that real estate was less effective as an inflation hedge for the periods of 1984-1994 and 1998-2006. Ganesan and Chiang (1998) implemented cointegration methods, as well as the basic Fama and Schwert (1977) approach with quarterly data. They conclude that financial assets would have provided a better hedge against inflation in Hong Kong. Real assets, such as real estate, are of no use as a hedge during inflationary phases. Glascock et al. (2008) use short- and long-term methods and Granger causality tests, and conclude that real estate is not an effective hedge against inflation. They also construct subsamples for different types of properties, which show various inflation hedging characteristics.

During times of deflation, bonds are viewed as a typical hedge against deflation. Both bonds and equities have high real returns in a deflationary environment. Several studies have shown that bonds can outpace stocks in terms of real returns during severe deflation (see for example, Dimson et al. (2012)). Hence, the real rate of return depends on the inflation rate, and seems to share a negative correlation coefficient. The correlation depends on the country and its specific macroeconomic factors, as well as on its central bank policy. Treasury inflation-protected securities (TIPS) are also a deflation hedging method.

According to Fleckenstein et al. (2014), the principal of a TIPS issue is protected against deflation because the amount received by a TIPS holder at maturity cannot be less than par. Hence, they feature a deflation floor.

However, bonds are not the only safe hedge against deflation. In an environment of falling prices, investors flee to perceived safe havens, such as gold. According to Day (2015), gold can appreciate during inflationary or deflationary phases. We note further that real estate may also be considered a safe haven. However, borrowing to hedge with real estate is a riskier investment during deflationary phases, because it makes repayment of debts more difficult.

Due to the lack of long-term deflationary phases in most Organisation for Economic Co-operation and Development (OECD) countries in recent years, few articles have explored such time intervals in a focused manner. To the best of our knowledge, a solid study that covers the development of real estate prices and rents within deflationary market phases is lacking. Therefore, our study contributes to the literature by examining the suitability of real estate as a deflation hedge.

3. Methods Used in Empirical Studies

The approach in Fama and Schwert (1977) for quantifying the characteristics of inflation hedges has been widely applied in the literature to a host of investment categories in different countries. The model has been used to gauge the degree to which the nominal returns of an investment depend on expected and unexpected changes in consumer prices. This approach has been modified a number of times because it only examines short-term dependencies and not long-term correlations. Moreover, even the more sophisticated versions have not yielded substantially different results to date. Hence, the international empirical literature still basically relies on the Fama and Schwert (1977) model. Therefore, we will also use the approach for our analysis here. We will extend this basic approach by means of an ARIMA model. A brief summary of the method follows.

3.1 Fama and Schwert Methodology

According to Fisher (1930), the nominal interest rate on an investment can be divided into the real interest rate and price level changes. In reality, the problem of uncertain price level changes arises. Therefore, the nominal rate of interest I_{nom} can be written as the equilibrium of expected real interest rate $E(I^{real})$ plus the expected inflation rate $E(\pi)$ under uncertainty and imperfect foresight. Fama and Schwert (1977) extend Fisher's hypothesis to (nominal) risk-bearing investments:

$$E(R_{i,t}^{n} \mid \phi_{t-1}) = E(R_{i,t}^{r} \mid \phi_{t-1}) + E(\pi_t \mid \phi_{t-1}) \tag{1}$$

where:

$E(R_{i,t}^{n} \mid \phi_{t-1})$ = the anticipated nominal investment return of Periods t-1 to t, given information in t-1.

$E(R_{i,t}^{r} \mid \phi_{t-1})$ = the anticipated real return on investment from Periods t-1 to t, given information in t-1.

$E(\pi_t \mid \phi_{t-1})$ = the expected change in consumer prices from Periods t-1 to t, given information in t-1.

For Fisher's hypothesis to be valid, the anticipated real interest rate and the expected rate of inflation π_t^e, therefore the real and the monetary sectors, must be independent quantities. Under these conditions, the effectiveness of any investment hedge can be examined by using the following empirical regression model:

$$R_{i,t}^{n} = \alpha_i + \beta_i \pi_t^e + \gamma_i \left[\pi_t - \pi_t^e \right] + \varepsilon_{i,t} \tag{2}$$

where:

$R_{i,t}^{n}$ = the nominal return on the i[th] asset from Periods t-1 to t.

π_t^e = the rate of inflation expected from Periods t-1 to t.

π_t = the realized rate of inflation from Periods t-1 to t.

$\pi_t - \pi_t^e$ = unexpected inflation from Periods t-1 to t.

$\varepsilon_{i,t}$ = error term, $\varepsilon_{i,t} \sim WN(0, \sigma^2)$.

The parameters α_i, β_i and γ_i must be estimated individually for each asset. The regression parameter β_i describes the hedge effectiveness of the i[th] investment with respect to the expected change in consumer prices. According to Fama and Schwert (1977), an asset is considered a perfect hedge when $\beta_i = 1$, while an investment is regarded as a negative hedge if $\beta_i < 0$. A short position would then be an inflation hedge. The second predictive variable of the regression model provides additional information about the sensitivity of the nominal asset return to unexpected changes in consumer prices. Table 1 summarizes the abovementioned dependence of hedge characteristics on the regression coefficient value and direction of changes in consumer prices.

Next, we test the estimated parameters against two hypotheses:

1) $H_0 : \beta_i = 0$ vs $H_1 : \beta_i \neq 0$

If the null hypothesis can be rejected statistically, it will indicate that the i[th] investment is either a positive or negative hedge against expected inflation, depending on the sign of the estimated parameter (see Table 1). The second test evaluates the influence exerted by unexpected changes in consumer prices:

Table 1 Classification of Inflation and Deflation Hedges

Value of β, γ coefficient	$]-\infty; 0[$	0	$]0; 1[$	1	$]1; 2[$	2	$]2;\infty[$
Hedge - Classification	negative hedge	no hedge	positive hedge				
			weak hedge	perfect hedge	Over hedge		
Risk participation under inflation ($\Delta\pi = 1$)	over $\Delta R < -1$	complete $\Delta R = -1$	partial $-1 < \Delta R < 0$	none $\Delta R = 0$	over (risk turns to reward) $\Delta R > 0$ $\Delta R = 1$ $\Delta R > 1$		
Chance reward participation under deflation ($\Delta\pi = -1$)	over $\Delta R > 1$	complete $\Delta R = 1$	partial $0 < \Delta R < 1$	none $\Delta R = 0$	over (reward turns to risk) $-1 < \Delta R < 0$ $\Delta R = -1$ $\Delta R < -1$		

Notes: Classification of investment as either an inflation or a deflation hedge, and participation in risk from changes in real return ΔR or reward from changes in inflation rate Δπ, are shown to be dependent on regression values. We account for the coefficients β, and γ, where the nominal return is an endogenous variable, and inflation rates are exogenous.

2) $H_0 : \gamma_i = 0$ vs $H_1 : \gamma_i \neq 0$

If the null hypothesis can be rejected statistically, it will indicate that the i^{th} investment is either a positive or a negative hedge against unexpected inflation, depending on the sign of the estimated parameter (see Table 1).

3.2 ARMA Extension

The significant autocorrelation of the returns themselves, as well as of the residuals produced by the above regression equation, call for an extension of the Fama and Schwert (1977) approach with an ARMA model. We posit that the integration of past returns into this model is justified on economic grounds. Real estate properties normally cannot be traded as quickly as stocks, since they incur high transaction costs. Their market is also not transparent, so new information is absorbed into prices slowly. Therefore, we extend the previous Fama and Schwert (1977) model as follows:

$$R_{i,t}^{n} = \alpha_i + \beta_i \pi_t^e + \gamma_i [\pi_t - \pi_t^e] + \sum_{j=1}^{p} a_j R_{i,t-j}^{n} + \sum_{k=1}^{q} b_k \varepsilon_{i,t-k} + \varepsilon_{i,t} \tag{3}$$

Here, the most recent asset returns p and residuals q have been factored into the regression. To keep parameterizing to a minimum, the correct number of p and q terms is calculated by using the Schwarz information criterion (or Bayesian information criterion (BIC)), and the corrected coefficient of determination.

3.3 Methodology for Inflation Expectations

The capital markets model presented above is based largely on the expected inflation rate. This variable must be determined by other means because it cannot be observed. Models grounded in macroeconomics or univariate time series models are the most commonly used in the literature (Fama and Gibbons (1982), Gultekin (1983), Hartzell et al. (1987), Limmack and Ward (1988) and Harvey (1991). Fama and Schwert (1977) estimate expected inflation from the three-month interest rate of a Treasury bill with a one-period lag. Assuming that the creditworthiness/likelihood of default of a country remains unchanged, the real interest on a Treasury bill should remain constant over time. The expected future rate of inflation π^e can be obtained directly because the nominal single-period interest rate is known ex ante. This corresponds to the changes in the nominal interest rate, given the constant real interest rate.

$$\pi_t^e = R_{TBill,t}^{n} - \left(R_{TBill,t-1}^{n} - \pi_{t-1} \right) = R_{TBill,t}^{n} - R_{TBill,t-1}^{r} \tag{4}$$

Fama (1975) is able to confirm this hypothetical constant real interest rate by studying American government bonds for the period of 1953-1971.

For univariate time series models, the empirically observable, realized inflation rate is used, with the underlying stochastic process approximated for with an ARMA model.

$$\pi_t^e = c + \sum_{j=1}^{p} a_j \pi_{t-j}^n + \sum_{k=1}^{q} b_k \varepsilon_{t-k} \tag{5}$$

The inflation expectation synthesized at the end of Period *t-1* to *t* is calculated here as the weighted mean of the past realized inflation rates *p* and the past disturbance terms *q*. This model implies that economic actors only use past changes in price levels to formulate their expectations of future price levels. Lizieri et al. (2008) compare various models for the U.S. and U.K. markets. Using an error correction process, they conclude that there is little evidence of short-term adjustments to changes in either anticipated or unexpected inflation. In the long run, public market asset returns are linked to anticipated inflation. Therefore, adjustments to changes in inflation occur through an error-correcting adjustment process on the long-run relationship.

4. Empirical Study

4.1 Data

Our data for Japan are derived from usage-based indices for commercial and industrial properties and residential real estate that are published annually in March and October by the Japan Real Estate Institute. The NIKKEI 225 Stock Average Price Index, the Government Bond Index, and the Consumer Price Index (CPI) data come from Thomson Reuters Datastream. The real estate indices limit the duration and frequency of the data, so we examine Japan on a semi-annual basis, from the first half of 1986 to the first half of 2010. For Hong Kong real estate data, we rely on the transaction-based indices of the Hong Kong Rating and Valuation Department. The department publishes separate rent and price indices for the residential, office, commercial, and industrial real estate sectors. The indices have been published at least quarterly since 4Q1985. The time series for the Hang Seng Stock Price Index and CPI are also sourced from Thomson Reuters Datastream.

A Hong Kong bond index with sufficient historical data is not available, so our Hong Kong research is based on quarterly data from 1Q1986 through to 4Q2009. All the time series are denominated in the local currency in order to avoid exchange rate problems. The nominal asset returns are the first differences of the logarithmized prices: $R_{i,t}^n = \ln\left(P_{i,t} / P_{i,t-1}\right)$.

Although there are other ways to measure inflation, such as the GDP deflator, we use the CPI as the proxy for inflation. CPI is a measure of the change in prices over time for a typical basket of consumer goods and services. Just as for asset returns, the realized changes in consumer prices are computed as the first differences π of the logarithmized price levels: $\pi_t = \ln(CPI_t / CPI_{t-1})$.

As the term suggests, expected inflation is based on the expectations of the market actors and information available up until Period t-1 (Hamelink et al. 1997). Unexpected inflation describes the random error terms that refer to differences between the expected and actual inflation. These errors stem from market inefficiencies that arise because complete information was not priced in ex ante. For our purposes, using Treasury bill returns for estimating expected inflation would lead to distorted results, because, as we noted earlier, negative interest rates for Treasury bills do not make economic sense. This is why we estimate an ARIMA(p, l, q) model in Equation (5) here to forecast inflation. Unexpected inflation then becomes simply the ex post difference between inflation and the ARIMA projection.

4.2 Descriptive Statistics and Correlation Analysis

Table 2 provides the categorization of the different phases. From 1986 to 1997 and 2010 to 2017, the two markets experienced overall inflationary phases. The focus of our analyses is the deflationary phase from 1998 to 2010. Since we want to draw implications about the hedging properties during times of deflation, and also contrast these abilities with those in times of inflation, it is not relevant which inflationary phase is chosen for the analyses. Due to more observations, we opt for the first inflationary period.

Table 2 Inflation Rate for Each Subsample

	Inflation Rate Japan		Inflation Rate Hong Kong	
	Annual Mean	Standard Deviation	Annual Mean	Standard Deviation
3Q1986 – 1Q2018	0.48%	0.90%	3.77%	2.50%
3Q1986 – 4Q1997	1.66%	0.76%	8.63%	1.38%
1Q1998 – 1Q2010	-0.37%	0.35%	-0.35%	2.00%
2Q2010 – 1Q2018	0.19%	0.90%	3.11%	0.94%

Table 3 provides an overview of the historical statistics of both areas for our sample period (mean, standard deviation, and autocorrelation), as well as the means and standard deviations for the two sub-periods of 1986-1997 and 1998-2010. For Hong Kong, the first sub-period marks a time of rising prices and substantial economic growth, while the second signals a deflationary phase and sinking rental returns. In Japan, the situation is similar. Hence, distinguishing between the two sub-periods enables us to shed additional light on the results across the two different market phases.

The overall results demonstrate that the real estate prices of Hong Kong perform substantially better than those of Japan. In Hong Kong, the prices increase between 6.86% for industrial properties and 9.9% for commercial properties. In

Japan, we observe a negative trend that ranges from -0.99% for residential properties to -3.39% for commercial property. Despite substantially higher inflation rate of 4.05% in Hong Kong, average real returns are positive throughout. Rents develop moderately, generally at about half the increase in prices. The highest returning asset in Hong Kong is stocks, with a 10.87% return; but stocks also have the highest standard deviation, at 29.79%. In contrast, stocks perform below average in Japan with a 1.39% return at a higher standard deviation. Here, government bonds, with a 4.15% return, are the best-performing assets.

The transaction-based Hong Kong indices show significantly higher volatility (price changes that range from 12.18% for industrial properties to 19.93% for office buildings) because of how they are constructed; however, rents, which range from 6.22% to 10.71%, are less volatile. On the other hand, the appraisal-based price indices in Japan behave very smoothly. Their volatility ranges from 5.20% to 8.18%. The methodology of the appraisers is also reflected in autocorrelations that range from 0.87 to 0.94. In Hong Kong, the price index autocorrelations are significantly lower but also positive throughout. Thus, rents are generally more stable than prices. We note that the inflation volatility in Hong Kong is nearly three times higher than that of Japan.

An analysis of the two sub-periods reveals clear structural thresholds in both areas. From 1Q1986 through to 4Q1997, Hong Kong experienced a period of extreme growth, marked by high price returns, strong growth in rents, and higher inflation. In stark contrast, the 1Q1998 through to 4Q2009 period saw an average 0.41% rate of deflation, with rent levels simultaneously sinking in all four sectors. Only industrial and commercial properties and stocks generated price returns of, respectively, 2.60%, 3.88% and 6.09%. From 1986 to 1997, Japan also experienced a growth phase, although it was marked overall by moderate growth rates and inflation. Government bonds returned an above-average 6.47%. From 1998 to 2010, our second sub-period, inflation averaged -0.37%, real estate and stocks simultaneously lost value disproportionately, and only bonds (like those in the first period) showed positive returns. Table 4 shows the cross-correlations between the realized rate of inflation and the nominal investment returns/changes in rents. Economic theory, in the context of information-efficient financial markets, posits that new information will be priced in immediately by the market actors. In the real world, information efficiency is not a given, and therefore we simultaneously control for intertemporal relationships here. We study the correlations with the inflation rate lagged for up to twelve months.

We assume actual market changes are gradually incorporated, especially for appraisal-based real estate indices. However, even transaction-based indices may feature market and information inefficiencies. To avoid capturing only short-term effects, we calculate the correlations in each case for quarterly (Hong Kong only), semi-annual, and annual frequencies.

Table 3 Annual Means and Standard Deviations (in %) for Returns and Consumer Price Changes

		1986-2010		1986-1997		1998-2010		Autocorrelation
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	1st order
Hong Kong								
Residential properties	Prices	7.61%	13.28%	16.64%	10.84%	-1.22%	14.05%	0.47
	Rents	4.13%	7.54%	9.69%	5.68%	-1.31%	8.19%	0.51
Office Properties	Prices	8.25%	18.93%	15.16%	17.96%	1.48%	19.42%	0.43
	Rents	4.35%	10.71%	9.99%	10.63%	-1.18%	10.15%	0.79
Commercial properties	Prices	9.90%	13.88%	9.90%	11.35%	3.88%	12.89%	0.43
	Rents	4.76%	6.22%	7.97%	9.12%	-2.05%	6.87%	0.45
Industrial properties	Prices	6.86%	12.18%	17.36%	12.50%	2.60%	14.32%	0.62
	Rents	2.91%	8.40%	10.17%	5.88%	-0.54%	5.38%	0.37
Stocks		10.87%	29.79%	15.75%	32.73%	6.09%	26.74%	-0.1
Inflation realized		4.05%	2.84%	8.60%	1.36%	-0.41%	2.00%	0.74
Japan								
Residential properties	Prices	-0.99%	3.68%	2.00%	4.28%	-3.75%	1.20%	0.87
Commercial properties	Prices	-3.39%	5.79%	0.87%	6.87%	-7.30%	2.37%	0.94
Industrial properties	Prices	-1.37%	3.95%	2.34%	4.06%	-4.79%	1.67%	0.91
Stocks		-1.39%	22.94%	1.37%	21.45%	-3.94%	24.53%	0.06
Govt. bonds		4.15%	4.79%	6.47%	6.01%	2.01%	2.61%	0.06
Inflation realized		0.60%	0.93%	1.66%	0.76%	-0.37%	0.35%	0.77

Note first that the real estate properties exhibit positive estimators for the correlations of all the examined frequencies and periods. The estimated correlations are highly significant only for the overall period because of the strong autocorrelations of inflation, the rent and the real estate indices, as well as the corrected sample size according to Dawdy and Matalas (1964). In the sub-periods, a few estimates diverge significantly from null. However, without exception, the parameter estimators for all the other investment categories are not statistically significant. If the correlation coefficient is an indicator of the inflation hedge characteristics of an investment, then the correlations for the increasing return frequency seem to increase for all indices (for example, Hong Kong housing rents increase from 0.5 for a quarterly frequency to 0.68 for an annual frequency for the overall period). At the same time, we detect fixed time-delayed effects in only a few instances, primarily in the first sub-period of 1986-1997, and most frequently for real estate. Only here are the lagged cross-correlations greater than the basis correlation. We interpret these two results to mean that returns and inflation are related in a time-delayed manner, but the relationship is unstable over time because of the missing clear lag relationship. Furthermore, real estate in both areas is noticeably more tightly linked to consumer prices in the second sub-period than in the first (inflationary) sub-period.

Therefore, in view of the pronounced autocorrelation of the indices, we use the augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests to check for the stationarity of the time series. In a few isolated instances (Japanese real estate indices), we find that weak stationarity of the returns at a 5% significance level could not be proven, or, to put it another way, the hypothesized non-stationarity could not be disproved.

We then estimate two ARIMA time series models each for both areas in order to construct the inflation forecast. First, we allow for both autoregressive terms and the running average of the disturbance terms. We then suppress the autoregressive terms. Each time, we use the BIC to decide on the lag duration in order to minimize overfitting difficulties.

Note that the BIC disproportionately penalizes each additional included term. Therefore, we propose an ARIMA(1,1,1) and an ARIMA(1,1,0) model in equal measure for both areas. The forecast goodness of fit, or the coefficient of determination, for the ARIMA(1,1,1) model is 0.67 for Hong Kong and 0.61 for Japan.

Table 4 Maximum (cross-) Correlations between Inflation Rate Lagged by k and Rent/Price Changes

		Cross-correlations with inflation 1986-2010						Cross-correlations with inflation 1986-1997						Cross-correlations with inflation 1998-2010					
		Quarterly		Semi-annual		Annual		Quarterly		Semi-annual		Annual		Quarterly		Semi-annual		Annual	
		k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$	k	$\rho(R^n, \pi^k)$
Hong Kong																			
Residential	Prices	1	**0.34****	0	**0.5****	0	**0.64****	1	0.13	0	0.15	0	0.17	0	0.2	0	**0.42***	0	0,61
properties	Rents	0	**0.5*****	0	**0.61*****	0	**0.68****	0	**0.34****	0	0.43	0	0.44	0	**0.38****	0	**0.56****	0	0,65
Office	Prices	0	0.22	0	0.37	0	0.42	1	0.09	0	0.23	0	0.37	0	0.2	0	**0.46***	0	0,47
properties	Rents	0	**0.4***	0	**0.45***	0	0.49	0	0.12	0	0.21	0	0.22	0	**0.5****	0	**0.6****	0	0,71
Commercial	Prices	0	**0.32****	0	0.47	0	0.5	1	0.1	0	0.3	0	0.31	0	0.24	0	0.41	0	0,34
properties	Rents	0	**0.47*****	0	**0.62*****	0	**0.76***	1	**0.25***	0	0.46	0	0.65	0	0.28	0	**0.42***	0	0,56
Industrial	Prices	0	**0.33***	0	**0.37***	0	0.36	0	0.16	0	0.34	0	0.33	0	**0.53*****	0	**0.58****	0	**0,63***
properties	Rents	0	**0.36*****	0	**0.52****	0	0.6	1	0.19	0	0.25	0	0.33	0	**0.39****	0	**0.58****	0	**0,78****
Stocks		1	0.01	0	0.1	0	0.12	1	0.08	0	0.08	1	0.37	0	-0.15	0	-0.05	1	-0,09
Japan																			
Residential properties	Prices			0	**0.61***	0	0.64			1	0.35	0	0.35			0	0.42	0	0,55
Commercial properties	Prices			0	0.59	0	0.64			1	0.45	0	0.46			0	0.27	0	0,38
Industrial properties	Prices			0	**0.69***	0	0.75			1	0.48	0	0.48			0	0.36	0	0,51
Stocks				0	0.03	0	0.09			0	-0.07	0	-0.14			1	-0.05	1	0,05
Govt. Bonds				0	0.24	1	0.33			0	-0.01	0	-0.01			1	0.29	0	0.14

Notes: ***, ** and * indicates significance at the 1, 5 and 10% level. The effective sample size has been corrected in accordance with proposed method by Dawdy and Matalas (1964), by which first-order autocorrelation is taken into account.

4.3 Findings from Fama and Schwert Analysis

The regression described by Equation (2) tests the hedge characteristics of investments against expected and unexpected changes in consumer prices. The results of this research can be found in Table 5, which analyzes the overall period as well as each of the sub-periods. The expected changes in consumer prices for both areas are estimated for these models by using the ARIMA(1,1,0) model.

For Hong Kong, the estimated coefficients of expected changes β_i are positive for all investments and range from 0.08 to 1.597. For the unexpected changes γ_i the estimated coefficients range from -0.199 to 1.756. The lowest coefficients are on stocks (β_i = 0.008 and γ_i = -0.199), but they are not statistically significant at any level. The coefficients for changes in real estate prices and changes in rents, with respect to expected inflation, all diverge from null at least at a 10% significance level. The magnitude of prices and rents varies drastically, from slightly incompletely hedged to somewhat overhedged. The coefficients of unexpected changes are qualitatively very similar, although universally not statistically significant. Residential real estate offers the most strongly significant hedge against expected inflation; for unexpected inflation, it is industrial properties. Japanese real estate also exhibits very good hedging behavior (β_i from 2.288 to 3.551; γ_i from 1,585 to 2.529); it strongly overhedges against expected as well as unexpected price changes. The coefficients all diverge from null at a 5% significance level. Japanese stocks act as a negative hedge (β_i = -0.309) for expected consumer price changes, but seem to react against unexpected inflation by overhedging (no statistical significance). Although government bonds offer high coefficients, the null hypothesis cannot be rejected. Thus, they do not offer protection against changes in consumer prices.

Just as with the cross-correlations, the lack of stability in the estimated results for both sub-periods is striking. The values of the first-period often differ markedly from those of the second period. In Hong Kong, the shift is unidirectional: real estate strongly overhedged during deflationary periods, except for commercial properties. During the same period, stocks performed as a strongly negative hedge with regard to expected deflation. Only the coefficients of housing rents diverged significantly from null in all periods (β_i = 0.949 and 1.268, or γ_i = 1.418 and 1.48) and overhedged the changes in consumer prices. Hence, housing rents adjust upward during inflationary phases and downward during deflationary phases. Japanese real estate provided a significant overhedge against expected changes in consumer prices during both periods. No significant hedge characteristics are detected in stocks. Government bonds seem to have a particularly significant and negative relationship (γ_i = -4.679) to unexpected deflation. The coefficient is also negative, albeit not statistically significant. The government bonds therefore offer unique opportunities in a deflationary environment. Note that the corrected coefficient of determination is relatively low for all models; only the strongly autocorrelated Japanese real estate indices attain values from 0.36 to 0.51. However, the Durbin-Watson (DW) test points to strong serial correlation in the disturbance terms for all of the real estate indices. Apparently, the Fama and Schwert (1977) model does not capture the relevant factors for these returns. In addition, the exclusion of key factors can lead to distorted estimators. Hence, we must interpret the estimator results for real estate in Table 5 cautiously.

4.4 Findings from ARMA Extension

We apply the extended regression model (Equation 3) to the complete set of real estate indices because of the low coefficients of determination and the DW statistics in the previous regression. Stocks and government bonds exhibit neither a strong autocorrelation nor serial correlation in the residuals, so they are disregarded in the extended ARMA model. The BIC only proposes an AR(1) for all of the Hong Kong cases, and an AR(3) model for Japan. However, we do not consider the second AR term to be meaningful, and so it is suppressed. In contrast to the Fama and Schwert (1977) model earlier, the DW statistics are now non-problematic (between 1.666 and 2.128), and all the adjusted coefficients of determination have increased substantially.

Note further that the high autocorrelation of the real estate indices gives the first AR term a significant degree of influence; for Japanese industrial properties, only the third AR term diverges significantly from null. The hedging characteristics of Hong Kong real estate against expected inflation remain qualitatively the same. Only office properties do not diverge from null at any significance level. We observe similar results for the coefficient related to unexpected consumer price changes. Although the estimated coefficients are now universally smaller, they continue to have the same sign and diverge significantly from null.

Japanese real estate behaves similarly relative to expected inflation: the terms estimated in the ARIMA regression are smaller in amount than in the Fama and Schwert (1977) regression, and they still overhedge. Commercial properties do not offer any significant hedge. Unlike our previous findings, the coefficients for unexpected inflation do not diverge significantly from null. Japanese real estate properties do not generally offer any protection here.

We also examine periods of inflation and deflation for both areas separately by using the extended ARIMA model because we are interested in the deflation hedging abilities of real estate. Tables 7 and 8 show the estimated values for both phases.

Table 5 Results of Regression Analysis with Fama and Schwert (1977) Approach

		1986-2010				1986-1997		1998-2010	
Predicted variable		β_i	γ_i	adj. R^2	DW-Stat.	β_i	γ_i	β_i	γ_i
Hong Kong									
Residential properties	Prices	**1.597*** **	0.704	0.108	1.200	0.748	-0.818	1.232	1.233
	Rents	**0.965*** **	**1.349*** **	0.233	1.327	**0.949* **	**1.418** **	**1.268* **	**1.48*** **
Office properties	Prices	**1.307* **	1.176	0.032	1.246	1.461	0.381	1.494	**1.96* **
	Rents	**1.153** **	**1.486*** **	0.146	0.531	1.037	0.959	**2.07** **	**2.406*** **
Commercial properties	Prices	**1.015** **	**1.756*** **	0.082	1.361	1.22	0.505	0.253	**2.31*** **
	Rents	**0.844*** **	**0.872*** **	0.198	1.525	1.058	0.365	0.229	**0.964* **
Industrial properties	Prices	**0.81* **	**1.819*** **	0.098	0.867	1.962	1.378	**2.236*** **	**3.569*** **
	Rents	**1.033*** **	0.638	0.124	1.492	1.119	-0.034	**1.151** **	**1.256* **
Stocks		0.08	-0.199	-0.021	2.189	1.156	-1.42	**-3.291* **	-0.91
Japan									
Residential properties	Prices	**2.288** **	**1.585*** **	0.373	0.542	2.398	1.093	**1.137*** **	1.057
Commercial properties	Prices	**3.551*** **	**2.529** **	0.360	0.317	**4.968** **	1.994	1.42	2.345
Industrial properties	Prices	**2.905*** **	**1.744*** **	0.514	0.556	**3.038** **	1.145	**1.382** **	0.899
Stocks		-0.309	4.076	-0.032	1.793	-5.103	1.204	-3.034	-0.169
Govt. Bonds		1.06	0.824	0.011	1.987	-1.093	0.545	-0.902	**-4.679* **

Notes: The estimation method used is ordinary least squares (OLS). ***, ** and * indicates significance at the 1, 5 and 10% levels, respectively. The t-statistics of the regression coefficients have been adjusted for heteroscedasticity and autocorrelation by using the method in Newey and West (1987). Expected inflation for both areas are estimated by using ARIMA(1,1,0) model.

Table 6 Results of ARIMA Regression on Real Estate Indices for Entire Sample Period (1986-2010)

Predicted variable		1986-2010						
		β_i	γ_i	AR(1)	AR(3)	ARIMA-Model	adj. R^2	*DW*-Stat.
Hong Kong								
Residential properties	Prices	**1.483****	-0.177	**0.445*****	-	(1.1.0)	0.262	1.955
	Rents	**0.982*****	**1.016*****	**0.364*****	-	(1.1.0)	0.318	2.036
Office properties	Prices	1.206	-0.105	**0.424*****	-	(1.1.0)	0.182	2.005
	Rents	0.836	**0.702***	**0.765*****	-	(1.1.0)	0.629	1.666
Commercial properties	Prices	**1.048***	**0.981****	**0.358*****	-	(1.1.0)	0.181	2.029
	Rents	**0.798*****	**0.632****	**0.248****	-	(1.1.0)	0.240	2.059
Industrial properties	Prices	**1.162****	**1.221****	**0.603*****	-	(1.1.0)	0.405	2.126
	Rents	**1.057****	0.284	**0.284****	-	(1.1.0)	0.179	2.128
Japan								
Residential properties	Prices	**2.143***	0.338	**0.914*****	-0.202	(1.1.1)	0.763	1.804
Commercial properties	Prices	1.219	-0.002	**1.06*****	-0.172	(1.1.1)	0.877	1.961
Industrial properties	Prices	**2.156***	0.136	**0.983*****	**-0.187****	(1.1.1)	0.834	1.911

Notes: The estimation method used is OLS. ***, ** and * indicate significance at the 1, 5 and 10% levels. The t-statistics of the regression coefficients have been adjusted for heteroscedasticity and autocorrelation by using method in Newey and West (1987). The lag length of ARIMA model is determined by using BIC. Expected inflation is estimated with ARIMA(1,1,0) or ARIMA(1,1,1) model as determined by BIC.

Table 7 Results of ARIMA Regression on Real Estate Indices for Sub-Period 1986-1997 (Inflation)

Predicted variable		1986-1997						
		β_i	γ_i	AR(1)	AR(3)	ARIMA-Model	adj. R^2	DW-Stat.
Hong Kong								
Residential properties	Prices	0.847	**-1.642***	**0.537*****	-	(1.1.1)	0.220	1.605
	Rents	0.744	**1.575****	0.085	-	(1.1.1)	0.089	1.958
Office properties	Prices	0.219	-0.996	**0.474*****	-	(1.1.1)	0.129	1.923
	Rents	0.826	0.498	**0.779*****	-	(1.1.0)	0.584	1.497
Commercial properties	Prices	1.748	0.787	0.121	-	(1.1.0)	-0.036	1.650
	Rents	**1.472****	0.589	0.055	-	(1.1.0)	0.025	2.017
Industrial properties	Prices	2.34	1.241	**0.551*****	-	(1.1.0)	0.264	2.057
	Rents	1.278	-0.175	0.268*	-	(1.1.0)	0.039	2.137
Japan								
Residential properties	Prices	2.886	0.102	**0.922*****	-0.24	(1.1.1)	0.637	1.966
Commercial properties	Prices	**2.614***	-0.108	**1.064*****	-0.21	(1.1.1)	0.824	2.137
Industrial properties	Prices	**3.474****	-0.039	**0.979*****	**-0.256***	(1.1.1)	0.713	2.200

Table 8 Results of ARIMA Regression on the Real Estate Indices for Sub-Period 1998-2010 (Deflation)

		1998-2010						
Predicted variable		β_i	γ_i	AR(1)	AR(3)	ARIMA-Model	adj. R^2	*DW*-Stat.
Hong Kong								
Residential properties	Prices	1.18	0.011	**0.39***	-	(1.1.0)	0.111	2.110
	Rents	1.144	0.653	**0.522*****	-	(1.1.0)	0.306	1.876
Office properties	Prices	1.405	0.041	**0.403*****	-	(1.1.0)	0.127	2.019
	Rents	0.821	0.885	**0.746*****	-	(1.1.0)	0.598	1.821
Commercial properties	Prices	-1.231	1.244	**0.408*****	-	(1.1.1)	0.264	2.245
	Rents	-0.718	0.384	**0.494*****	-	(1.1.1)	0.267	1.793
Industrial properties	Prices	**1.987*****	**2.34*****	**0.606*****	-	(1.1.0)	0.523	2.184
	Rents	0.868	0.643	**0.342***	-	(1.1.0)	0.180	1.986
Japan								
Residential properties	Prices	**-0.83***	**-0.353***	**1.037*****	**-0.312****	(1.1.1)	0.783	1.624
Commercial properties	Prices	-0.135	-0.083	**1.176*****	**-0.328****	(1.1.1)	0.859	1.931
Industrial properties	Prices	-0.523	-0.402	**1.089*****	**-0.331*****	(1.1.1)	0.805	2.040

Notes: The estimation method used is OLS. ***, ** and * indicate significance at the 1, 5 and 10% levels. The t-statistics of the regression coefficients have been adjusted for heteroscedasticity and autocorrelation by using method in Newey and West (1987). The lag length of the ARIMA model is determined by using BIC. The expected inflation is estimated with ARIMA(1,1,0) or ARIMA(1,1,1) model as determined by BIC.

With this model, we demonstrate a distinct change in the estimated coefficients from one period to the next. The number of significant values drops considerably because of the reduced sample size. During both periods, none of the coefficients for either country diverges significantly from null. House prices in Hong Kong react very negatively (γ_i = -1.642) to unexpected inflation; rents, however, do so in a disproportionately positive way (β_i = 1.575). The rents of commercial properties appear to provide an overhedge against expected inflation. During deflationary periods, industrial properties overhedge against expected and unexpected deflation; in other words, nominal prices decline more steeply than the purchasing power of money increases. Prices and rents for commercial properties react negatively to expected deflation, and the estimated values are not statistically significant.

The results for the Fama and Schwert (1977) model during the inflationary period are confirmed for Japanese real estate. All three categories overhedge (statistically significant only for commercial and industrial properties) against expected inflation. The estimators for unexpected inflation are not statistically significant. During the deflationary period, real estate appears to represent a negative hedge against expected and unexpected deflation. The coefficients for residential real estate in both cases diverge from null at the 10% significance level.

5. Conclusion

This study examines the historical asset returns for Hong Kong and Japan over the period of 1986-2009 to determine whether real estate, stocks, and bonds can provide a hedge against inflation or deflation. We divide our dataset into two subsamples of an inflationary period and a deflationary period. We are able to empirically show that real estate prices and rents are strongly linked to consumer prices. This confirms the extant studies on this subject.

Our results show that real estate almost perfectly hedges, or even overhedges, against expected changes in consumer prices. By comparison, we find no statistically significant link to consumer prices for stocks or government bonds. In Hong Kong, residential real estate constitutes the best hedge against expected changes, and industrial real estate the best hedge against unexpected changes. For Japan, residential as well as industrial real estate properties equally overhedge against expected changes in consumer prices.

The results for the sub-periods of 1986-1997 (inflationary phase) and 1998-2009 (deflationary phase) are somewhat more difficult to interpret. We find that asset prices in the two areas behave differently. Using the Fama and Schwert (1977) model and enhanced with ARIMA specifications, the results in the first sub-period phase qualitatively resemble those of the overall period, although with parameters that are often not statistically significant. The residential real estate prices in Hong Kong provide a negative hedge, and residential rents a positive hedge, against unexpected inflation, while rents for commercial properties increase simultaneously and disproportionately against expected inflation. In Japan, commercial and industrial real estate succeed in overcompensating for expected inflation.

Statistically insignificant parameters are also pervasive in the second, or deflationary, phase. Here, we observe that industrial real estate prices in Hong Kong adjust excessively for expected and unexpected deflation, and real values decline as a result. In contrast, Japanese housing prices provide a negative hedge against expected and unexpected inflation. We therefore conclude that, in a deflationary environment, real estate provides value stability in real terms (i.e., deflation protection). Our conclusions about stocks and government bonds are similar to those reached in other studies of diverse markets and time periods. Neither investment constitutes a significant hedge against consumer price changes. Only during the second sub-period in Japan do we observe a significant negative relationship to unexpected deflation for government bonds. However, this result is economically questionable, given that interest rates on government bonds usually adjust gradually to prevailing inflation levels.

References

Adrangi, B., Chatrath, A. and Raffiee, K. (2004). REIT Investments and Hedging Against Inflation. *The Journal of Real Estate Portfolio Management*, 10 (2): 97–112.

Bodie, Z. (1976). Common Stocks as a Hedge Against Inflation. *The Journal of Finance*, 31 (2): 459–470.

Boudoukh, J. and Richardson, M. (1993). Stock Returns and Inflation: A Long-Horizon Perspective. *The American Economic Review*, 83 (5): 1346–1355.

Brueggeman, W.B., Chen, A.H. and Thibodeau, T.G. (1984). Real Estate Investment Funds: Performance and Portfolio Considerations. *Real Estate Economics*, 12 (3): 333–354.

Dawdy, D.R. and Matalas, N.C. (1964). Statistical and Probability Analysis of Hydrologic Data. in: *Handbook of Applied Hydrology: A Compendium of Water-Resources Technology,* Chow, V.T. (ed.), New York, McGraw-Hill Book Company, 3, 868–890.

Day, A. (2015). *Investing in Resources: How to Profit from the Outsized Potential and Avoid the Risks*. Wiley, 1–352.

Dimson, E., Marsh, P. and Staunton, M. (2012). Global Investment Returns Yearbook 2012. Credit Suisse AG, 1–64.

Fama, E.F. (1975). Short-Term Interest Rates as Predictors of Inflation. *The American Economic Review*, 65 (3): 269–282.

Fama, E.F. and Gibbons, M.R. (1982). Inflation, Real Returns and Capital Investment. *Journal of Monetary Economics*, 9 (3): 297–323.

Fama, E. F. and Schwert, W.G. (1977). Asset Returns and Inflation. *Journal of Financial Economics*, 5: 115–146.

Fisher, I. (1930). The Theory of Interest – As Determined by Impatience to Spend Income and Opportunity to Invest It. *Journal of Monetary Economics*, 4: 2151–2197.

Fleckenstein, M., Longstaff, F.A. and Lustig, H. (2014). The Tips-Treasury Bond Puzzle. *The Journal of Finance*, 69 (5): 2151–2197.

Ganesan, S. and Chiang, Y.H. (1998). The Inflation-Hedging Characteristics of Real and Financial Assets in Hong Kong. *The Journal of Real Estate Portfolio Management*, 4 (1): 55–67.

Glascock, J., Feng, L., Fan, L. and Bao, H. (2008). Inflation Hedging Characteristics of Real Estate Assets in Hong Kong. *Statistics & Decisions*, 301: 107–109.

Gultekin, N.B. (1983). Stock Market Returns and Inflation: Evidence from Other Countries. *The Journal of Finance*, 38 (1): 49–65.

Gyourko, J. and Linneman, P. (1988). Owner-Occupied Homes, Income-Producing Properties, and REITs as Inflation Hedges: Empirical Findings. *The Journal of Real Estate Finance and Economics,* 1: 347–372.

Hamelink, F., Hoesli, M. and MacGregor, B. (1997). Inflation Hedging Versus Inflation Protection in the U.S. and the U.K. *Real Estate Finance*, 14: 63–73.

Hartzell, D., Hekman, J.S. and Miles, M.E. (1987). Real Estate Returns and Inflation. *Real Estate Economics*, 15 (1): 617–637.

Harvey, A. (1991). *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge University Press.

Jaffe, J.F. and Mandelker, G. (1976). The “Fisher Effect” for Risky Assets: An Empirical Investigation. *The Journal of Finance*, 31 (2): 447–458.

Limmack, R. and Ward, C. (1988). Property Returns and Inflation. *Land Development Studies*, 5 (1): 47–55.

Liu, C., Hartzell, D. and Hoesli, M. (1997). International Evidence on Real Estate Securities as an Inflation Hedge. *Real Estate Economics*, 25: 193–221.

Lizieri, C., Hoesli, M. and MacGregor, B. (2008). The Inflation Hedging Characteristics of US and UK Investments: A Multi-Factor Error Correction Approach. *The Journal of Real Estate Finance and Economics,* 36: 183–206.

Maurer, R. and Sebastian, S. (2002). Inflation Risk Analysis of European Real Estate Securities. *Journal of Real Estate Research,* 1(24): 47–78.

Newey, W.K. and West, K.D. (1987). A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix. *Econometrica* 55 (3), 703–708.

Obereiner, D. and Kurzrock, B. (2012). Inflation-Hedging Properties of Indirect Real Estate Investments in Germany. *Journal of Property Investment & Finance*, 30 (3): 218–240.

Park, J.Y., Mullineaux, D.J. and Chew, I.-K. (1990). Are REITs Inflation Hedges? *The Journal of Real Estate Finance and Economics*, 3 (1): 91–103.

Rubens, J.H., Bond, M.T. and Webb, J.R. (1989). The Inflation-Hedging Effectiveness of Real Estate. *The Journal of Real Estate Research*, 4 (2): 45–55.

Yobaccio, E., Rubens, J.H. and Ketcham, D.C. (1995). The Inflation-Hedging Properties of Risk Assets: The Case of REIRs. *The Journal of Real Estate Research,* 10 (3): 279–296.

Appendix

Variable Descriptions

$R^n_{i,t}$	Nominal investment return of asset I in time t
$R^r_{i,t}$	Real investment return
$R^n_{TBill,t}$	Return of U.S. Treasury bill, used as the constant real interest rate
ϕ_t	Information on which expectations are based
π_t	Actual inflation rate
π^e_t	Expected inflation rate
$\pi_t - \pi^e_t$	Unexpected inflation rate
α_i	Intercept of regression model
β_i	Regression coefficient, signals hedging effectiveness to expected inflation
γ_i	Regression coefficient, signals hedging effectiveness to unexpected inflation
$\varepsilon_{i,t}$	Residuals of estimated model
a_j	Coefficient of AR-component of ARIMA model
b_k	Coefficient of MA-component of ARIMA model
$P_{i,t}$	Price of asset i in time t
CPI_t	Consumer Price Index in time t