



Discussion Paper  
**No. 0315**

**Trends and Spectral Response: An Examination  
of the US Realty Market**

**Patrick J. Wilson and Ralf Zurbruegg**

**May 2003**

**University of Adelaide  
Adelaide 5005 Australia**

## CENTRE FOR INTERNATIONAL ECONOMIC STUDIES

The Centre was established in 1989 by the Economics Department of the Adelaide University to strengthen teaching and research in the field of international economics and closely related disciplines. Its specific objectives are:

- to promote individual and group research by scholars within and outside the Adelaide University
- to strengthen undergraduate and post-graduate education in this field
- to provide shorter training programs in Australia and elsewhere
- to conduct seminars, workshops and conferences for academics and for the wider community
- to publish and promote research results
- to provide specialised consulting services
- to improve public understanding of international economic issues, especially among policy makers and shapers

Both theoretical and empirical, policy-oriented studies are emphasised, with a particular focus on developments within, or of relevance to, the Asia-Pacific region. The Centre's Director is Professor Kym Anderson ([kym.anderson@adelaide.edu.au](mailto:kym.anderson@adelaide.edu.au)).

Further details and a list of publications are available from:

Executive Assistant  
CIES  
School of Economics  
Adelaide University  
SA 5005 AUSTRALIA  
Telephone: (+61 8) 8303 5672  
Facsimile: (+61 8) 8223 1460  
Email: [cies@adelaide.edu.au](mailto:cies@adelaide.edu.au)

Most publications can be downloaded from our Home page:  
<http://www.adelaide.edu.au/cies/>

ISSN 1444-4534 series, electronic publication

**CIES DISCUSSION PAPER 0315**

# **Trends and Spectral Response: An Examination of the US Realty Market**

**Patrick J. Wilson and Ralf Zurbrugg**

School of Finance and Economics  
University of Technology, Sydney

School of Commerce  
University of Adelaide  
ralf.zurbrugg@adelaide.edu.au

**May 2003**

The authors are grateful for the insightful comments and helpful suggestions of Walter Enders as well as for the many suggestions for improvement from several anonymous referees. This research was supported by various UTS and University of Adelaide Research Grants. Some of this research was undertaken while the first named author was Visiting Fellow at the Department of Economics, University of Wollongong.

## **ABSTRACT**

This paper sets out to consider whether changes in economic fundamentals in the United States can impact on international real estate markets. To this end a two-step approach is pursued. In the first step cointegration techniques are used to determine whether common trends exist in international property markets. Once common trends are identified amongst securitised property markets, a potential common driver is isolated by substituting US Gross Domestic Product for US property. The paper then uses a spectral response technique to examine the impulse response between shocks in the US economy and reactions in foreign real estate markets. The results support a linkage between the economic growth of an important member of the international economic community and international real estate performance.

**Keywords:** International Real Estate Markets, Securitised Property, Cointegration, Spectral Analysis, Impulse Response

**JEL classification:** Non-agricultural and Non-residential Real Estate Markets (R330); Housing Economics (including urban and non-urban housing) (9320); International Financial Markets (G150).

## **1. Introduction**

The question of whether international markets are related or not is important from the perspective of the investment portfolio manager. In the case of property markets, the benefits from international diversification will be limited if global real estate markets follow similar trends. In reality, due to a host of political, legal, social and economic factors the existence of complete market integration across international boundaries is unlikely. However, there may exist a partial relationship between markets. The presence of even a partial relationship can also suggest the existence of some common driving factor or factors and if such factor(s) can be identified then a more formative model of how property markets are linked across countries can be examined. In particular, such a model can help portfolio strategists develop forecasts for market allocation dependent on these factors.

The objectives of this paper are to identify the inter-relatedness of property markets around the world, to consider whether there may be a common factor driving such inter-relatedness, and to examine how property markets might react to shocks in this common factor. This can be done by examining the role that an important economy, such as the United States, might play as a potential driving factor which influences other property markets. Specifically, rather than focusing on how correlated these property markets are with each other, a two step approach is taken in the present study. First a multivariate Johansen (1991, 1995) cointegration framework is adopted that provides for an analysis of whether these markets are integrated over the long-run, specifically whether there appears to be a long run equilibrium relationship between the US economy and world property markets. This is followed by a study of how world property markets might react to spikes in the US economy.

Other research has established that economic performance and property market performance are related. For example, recent research by Case, Goetzmann and Rouwenhorst (2000) and Quan and Titman (1999) has shown a link between real estate performance and economic growth. Both of these studies utilized data from a greater number of countries than was available for the current research but, importantly, both pieces of research included the same countries that are covered by the present case study. Case et.al. (ibid) and Quan and Titman (ibid) found clear evidence linking movements in Gross Domestic Product and property prices. In this paper we isolate the United States as a case study in how economic fluctuations in a large economy can influence international property market returns. The research takes as its base the findings of Case et. al. (2000) along with that of Quan and Titman (1999) on the link between GDP and real estate across a broad cross section of countries and extends this research by establishing a link between movements in US Gross Domestic Product and movements in offshore securitised real estate markets. For this purpose impulse response functions within the frequency domain are used to examine the impact of how a change in fundamentals within the US economy may influence international property market performance.

The outcomes from this paper suggest that international property markets are related and that at least one common factor in this inter-relationship appears to be the performance of the US economy. However it also appears that international property markets may not respond equally to shocks in the US economy, suggesting different degrees of dependence. In our eight country study the property market most responsive to changes in the US economy appears to be Australia. Also, European property markets appear to be less responsive than Asian markets to shocks in the US economy. Information from ‘what if’ simulations such as this may provide portfolio managers with assistance in developing diversification and re-weighting strategies.

The remainder of the paper is as follows. Section 2 briefly reviews the literature on international inter-relatedness in property markets. Section 3 describes the data and presents the outcomes from cointegration analysis. Section 4 then describes the use of moving spectral regressions in the study of impulse response functions and presents the results. Section 5 provides a conclusion while Appendix A provides more detail on the spectral analysis.

## **2. International Real Estate Market Integration**

The relative dearth of empirical research conducted on the integration and inter-relationships between national real estate markets is in stark contrast to the intensive study conducted on international stock market co-movements. Such work is typified by Eun and Shim (1989), Hamao, Masulis, and Ng (1990), Chan, Karolyi and Stultz (1992), Login and Solnik (1995) and Francis and Leachman (1998), among others. Along with various models of market segmentation, analysis of correlations and diversification benefits across international financial markets, the work can seem contradictory at times. However, a general consensus is that international market co-movements tend to transfer information efficiently across markets [see Tse, Lee and Booth (1996) for an example] with markets becoming increasingly more integrated [See Phylaktis (1999) and Hsieh, Lin and Swanson (1999) on interest rates and money markets, respectively].

There has also been a recent focus on analyzing common stochastic trends within capital markets. Evidence of capital market integration in interest rates is provided by Phylaktis (1999), on currencies by Baillie and Bollerslev (1994) and Aggarwal and Mougoue (1998), and on money markets by Hsieh, Lin, and Swanson (1999). Using cointegration analysis and impulse response functions, the above papers were able to determine the extent of integration between

financial markets as well as sometimes identifying the primary markets that linked and were responsible for the driving force between these inter-relationships.

Related to the recent literature on common stochastic trends in capital markets is research on common cycles, much of which evolved from the work of Engle and Kozicki (1993) and Vahid and Engle (1993). The difference between the two concepts is that cointegration (and common trends) is concerned with long run relationships between sets of non-stationary variables, while common cycles is a short-run phenomenon concerned with the co-movement amongst stationary variables. Both long and short run relationships may co-exist, or only one type of relationship may exist. For example Morely and Pentecost (2000) found that stock prices and exchange rates do not exhibit common trends, but do exhibit common cycles.

Data limitations have resulted in less research being undertaken on the question of whether property markets (securitised and physical) are integrated internationally and whether diversification benefits follow. However, for the research that does exist in this area the outcomes suggest that diversification benefits may be higher for real estate markets compared to other financial instruments. Initial research conducted by Giliberto (1990) found diversification benefits existed by combining US real estate equities with foreign real estate equities. Asabere, Kleiman and McGowan (1991), using a mean-variance model, similarly found that there were substantial benefits from international diversification of investments in securitised property markets.

Using correlation analysis Sweeney (1993) showed that the correlation coefficients between prime office indices in major cities across the world were negative, implying diversification benefits through pursuing a strategy of prime office real estate investment. Also, using correlation analysis Eichholtz and Lie (1995) found that there were increasing correlations

among real estate markets within continents and decreasing correlations between continents, suggesting a process of regionalization rather than globalization.

Of course, currency fluctuations may play a crucial role. For instance, Ziobrowski and Curcio (1991) highlighted the importance of exchange rate fluctuations in analysing the benefits of international diversification. These authors concluded that currency fluctuations were largely responsible for their finding that United States real estate did not improve foreign portfolio performance - implying there were no benefits from international diversification. Balanced against this we have more recent research by Eicholtz and Hartzell (1996), Eicholtz, Huismand, Koedijk and Sehuin (1998) and Liu and Mei (1998) to indicate that there are benefits to international diversification in real estate.

Some real estate analysts have also utilized cointegration techniques in assessing inter-relatedness<sup>1</sup>. Wilson and Okunev (1996) in a study of securitised property in three countries (US, UK and Australia) used Engle-Granger cointegration methods to find no evidence of a long run equilibrium relationship between any corresponding pair of countries. On the other hand, later research by Wilson and Okunev (1999), in which they used spectral regression techniques in a search for long co-memory, found some evidence of co-dependence across international property markets for the same three countries. This outcome reflects the limitations that may be imposed by the application of econometric techniques that have different underlying constraints.

Very little, if any, research has been undertaken on common cycles across international real estate markets, although in a domestic context MacGregor and Schwann (1999) have undertaken a study on common cycles across commercial real estate markets in the United Kingdom. This research found evidence to support the existence of common cycles amongst

regional rates of return for commercial properties in the UK and this, of course, has very specific and important implications for portfolio diversification.

More recently Case, Goetzman and Rouwenhorst (2000), using appraisal based property data for 22 countries, presented strong evidence to support the notion of globalization of property markets. These authors argued that, since property is location specific there would, on an intuitive level, be no reason to suppose that such markets should be linked. Quite significantly their research, in fact, suggested that world real estate markets are correlated and that this correlation was due, in part, to common exposure to fluctuations in the global economy, as measured by an equally weighted index of international GDP changes.

With increased globalization and integration of capital markets, world economic growth will inevitably impact domestic markets, including real estate prices. For example, economic growth encourages demand for floor space as businesses expand to facilitate extra demand for products and services.

As the United States is the largest economy in the world and, either directly or indirectly, has trading and capital links with most of the world's economies, it will have the largest impact upon world economic growth. Therefore, it is reasonable to suppose that economic changes in the United States may filter through to trading partners. More particularly, economic events which have an impact on US property markets will also have some impact on international property markets through the shock effect of changes in the US economy on local economies. A good starting point, then, in a study on market inter-relatedness may be to commence with the US as a potential common driver of international property markets.

### **3. Data Description and Preliminary Analysis on Long Run Inter-relationships**

#### *Data*

Data for eight real estate markets are examined in this paper. The United States is one of the world's largest economies and hence forms the basis for our case study. Three countries were chosen as examples of European property markets (the UK, France and the Netherlands) and four countries were selected from the Australasian region viz. Japan, Singapore, Hong Kong and Australia. While securitised property market indices (both total and price returns series) from Datastream International were available for each country from the first quarter, 1973, the analysis was constrained to quarterly data from the period 1980 to 2000, the major reason for this being the lack of sufficient funds that made up some of the property indices before 1980<sup>2</sup>. Quarterly Data on US GDP was obtained from the International Monetary Fund *International Financial Statistics*. Also, all the time series were exchange adjusted and expressed in real US dollars, with exchange rate data taken from Global Financial Data Ltd. Inflation and exchange rate adjustments are made to ensure no cointegrative relationships emerge due solely from these factors. This is important as previous research has already shown a link in national real estate markets through these channels (see Myer, Chaudhry and Webb, 1997).

While the property indices used in this study had a common source, there are some differences in the indices across countries that may or may not impact on the outcomes achieved in the analysis. For example, the securitised property series for the US comprise a mix of various REITS including Equity and Mortgage REITS. Equity REITS, for example invest in real estate equities on a long term basis, with their principal source of income being rents. They invest in real properties such as apartment buildings, office and industrial buildings as well as shopping centres. Mortgage REITs frequently finance every phase of a real estate venture

including land acquisition and development. Such trusts must distribute at least 95 per cent of income and, provided certain conditions are met, REITS are not taxed at source i.e. they qualify as a tax free intermediary.

In the UK securitised property companies (which includes companies involved in both development and investment activities) do not receive special tax treatment i.e. income is taxed at source. Securitised property companies in Australia similarly may be involved in development or investment or both types of activity. Tax treatment of property investment trusts can be complicated although, essentially, property trusts do not pay tax on income that is distributed to unit-holders (there is no requirement to distribute some given proportion of income as US REITS) and undistributed income is taxed at standard company rates. In terms of the Australian Taxation Act the property trust is treated as a separate entity so that it can claim deductions such as depreciation and interest payments. If the income is distributed then property trust unit holders can reduce their assessable income by these deductions. Unlike REITs there is no minimum period for property trusts to hold properties. On disposal of the property any capital gain in excess of inflation creates assessable income which may be passed through to unit holders (cf. Rowland, 1997, pp.42-43 and p.137).

There are other features of the various indices that may complicate interpretation of the analytical outcomes. For instance the indices for most countries typically reflect investment in domestic real estate assets. This is not necessarily true for either the Netherlands or Hong Kong. Securitised property companies in the Netherlands may reflect a significant foreign property component while securitised property companies in Hong Kong may reflect a significant mainland China component. So, for example, since the Dutch index may reflect significant off-shore diversification the index may show more 'resilience' in the face of various monetary

and/or fiscal policy changes. A final consideration relates to the composition of the indices in terms of the number of companies making up the index in each country. In table 1 we present a brief comparison of two important sources of property data viz. the GPR property indices and the DataStream property indices. For the eight study countries it can be seen that, apart from the US, the UK and France, the number of companies making up each index is roughly comparable. For the US the GPR index comprised about four times as many companies as the DataStream index, for the UK it was about one and a half times as many while for France it was about twice as many companies. However for both the US and the UK the DataStream sample was fairly large relative to the GPR sample (39 vs 156 and 32 vs 50 companies respectively within the index), so it was not a concern. While we were not as comfortable with the French sample (9 vs 23) DataStream did have the longer series in all cases, so we settled on this source.

Table 1 about here

### *Preliminary Analysis*

Before applying Johansen cointegration trace tests, the stationarity of the variables must first be tested. Generally, most economic variables, as pointed out by Nelson and Plosser (1982), have  $I(1)$  processes, and the real estate market is no exception. Table 2 provides the Phillips-Perron unit root test results for each property index - all indices are stationary in logarithmic first differences (returns).

Table 2 about here

From the results in table 2 it is clear that a standard Johansen (1991, 1995) cointegration test can be conducted. The Johansen methodology is well established and widely used, so a detailed

discussion will not be presented. Of the comprehensive output that is available through use of the Johansen procedure primary interest here centres on the number of common trends that exist within the system<sup>3</sup>. This information is extracted by determining the order of cointegration, that is the number of distinct cointegrating equations linking the variables in the system since there is a simple linear relationship between the number of cointegrating equations and the number of common trends. It is well established that if there are  $v$  variables (series) in the system under analysis there can at most be  $r = v - I$  cointegrating equations (vectors). Stock and Watson (1988) illustrate that cointegrated variables share common stochastic trends and if the number of cointegrating equations in a system is  $r = v - I$ , then there is a single common trend (i.e.  $v - r = I$ ) driving all  $v$  series. In economic terms, this implies that the benefits to diversification over the long-run are minor as each series will not follow divergent price paths. Conversely, the larger the number of stochastic processes within the system (i.e. the smaller the number of cointegrating vectors) the greater the opportunity for risk reduction through diversification in the long-run.

Starting with the set of eight countries, the first column in table 3 shows the number of cointegrating equations present within the system when the US property market is excluded. Trace test statistics are presented, along with the 5% critical values for the rejection of the null hypothesis of there being  $r$  or less cointegrating equations. The lag length of the Johansen procedure was determined by the Schwarz Information Criterion (SIC) on the undifferenced VAR (See Schwarz, 1978) while ensuring all residual series from the VAR were uncorrelated. From this, four lags were considered optimal for minimizing the SIC and guaranteeing no autocorrelation problems. Since eighty four observations were available for an eight variable VAR with four lags the degrees of freedom available were deemed adequate.

Table 3 about here

Without the US, world property markets seem to display a system with several stochastic processes and only one cointegrating restriction. This indicates that there may be ample benefits present for the international fund manager interested in diversifying risk through the purchase of securitised real estate funds. With only one cointegrating vector long-run relationships will not necessarily be strong, and does not provide evidence of strong integration among international real estate markets. However, with the inclusion of the US property market in column two, the number of cointegrating relations jumps up to three. However, there is also evidence that there may be four cointegrating equations present as the trace statistic of 67.81 is only marginally below the 5% critical value<sup>4</sup>. The rise in cointegrating restrictions indicate a far more integrated system when the US is included.

The above analysis has, however, not analyzed the impact of the US economy upon world property markets. Nor has it been able to explain the underlying economic rationale for the long-run relationships found. For this purpose, the inclusion of the US economy and examination of impulse response functions can be utilized to determine the degree of influence that the US economy has on other markets, and possible reasons for this.

#### **4. Impulse Response in the Frequency Domain**

Quan and Titman (1999) show that property market behavior can be partially explained through local economic growth. In addition, Case, Goetzmann and Rouwenhorst (2000) argue that since local economies are linked to a 'world' economy, the higher than expected correlations

that they found amongst international property markets could be seen as being at least partially driven by the interlinkage between world economies.

In their development of a 'world' economy concept Case et.al (2000) used an equally weighted index rather than a market weighted index. That is, the GDP of all 22 countries making up their 'global' index carried an equal weight. Now, it is reasonable to suppose that if each GDP entering the index were weighted according to size then the largest economies entering the index might be expected to play a more dominant role in the movements of the overall index. While such a market weighted GDP index is not developed here it is nevertheless informative to ascertain how important the United States might be in such an index. To some extent table 4 helps to answer this question. The table shows US Gross Domestic Product as a proportion of GDP from : (i) all OECD countries; (ii) European OECD countries inclusive of the US; and (iii) the Major Seven economies in the world. In addition, the table also lists the Major Seven as a proportion of all OECD countries. For present purposes this is a useful table since six of the eight countries are members of the OECD (only Singapore and Hong Kong are not included)<sup>5</sup>. The table clearly indicates the dominant position that the US may be expected to play in a 'world' GDP index. About 40% of the GDP in an OECD 'world' economy is attributable to the United States. More significantly, the Major Seven economies comprise more than 80% of the OECD Gross Domestic Product, and the United States comprises about half of the Major Seven's Gross Domestic Product.

Since the United States seems to have had a large influence on the long-run relationship world property markets have with each other as shown in table 3, and since US Gross Domestic Product represents a dominant force in the world economy, it would be reasonable to suppose that changes in economic fundamentals in the US may either (i) have an impact on local US real

estate markets which may have flow through effects to international property markets, or (ii) may have flow through effects to international real estate markets indirectly because of the impact that such changes in economic fundamentals have on international economies.

To show this the third column in table 3 contains the trace test results when the US property market series is replaced with US Gross Domestic Product. With four cointegrating equations at the 5% critical value, the number of long-run relationships has not altered. These results show that the US economy can as well demonstrate a number of co-integrating relationships with international real estate markets as the US property series does<sup>6</sup>.

As tables 3 and 4 indicate that US Gross Domestic Product does play an important part in the cointegrating process, it would be useful to analyze the extent to which shocks in US GDP have upon foreign real estate markets. One way to consider the impact that changes in US economic fundamentals may have on markets within the suggested cointegrated system is by examination of impulse response functions in an vector autoregression (VAR) model or error correction model (ECM) framework. Impulse response functions allow an understanding of the possible dynamics of interaction within the system since an impulse response function measures the time profile of the effect of shocks at a given point in time on the (expected) future values of variables in the system. However, interpretation of the outcome of such impulse response functions within either a VAR or ECM framework is not straightforward. This is because the error terms (innovations) are usually correlated, so that they have a common component which cannot be associated with a specific variable (market). Econometricians generally deal with this issue in a somewhat arbitrary fashion by attributing all of the effect of any common component to the variable that comes first in the VAR system. If we do not have a pre-determined structural

model within which we are operating then this may be an unsatisfactory method since changing the order of variables will change the outcome of the impulse response.

One way around this problem may be to consider impulse response initially within a frequency domain (with subsequent re-transformation to a time domain framework). The use of impulse response in this context derives from the work of Ridley and Mobolurin (1987) and Ridley (1994) who have extended the work of researchers such as Welch (1967), Engle (1974), Harvey (1978) and other pioneers to the concept of regression in the frequency domain. The tool used in the present analysis is known as a moving window spectral regression and a summary of the approach is presented in Appendix A. While theoretical development is available in Ridley and Mobolurin (1987) and others as noted above, a practical application in property markets is available in Wilson et.al. (2000).

Lets consider an intuitive notion of the method where the following is a summary of the discussion in Wilson et. al. (ibid). The initial focus in spectral analysis is on the amplitude-frequency domain. That is, spectral analysis commences with the assumption that any series,  $\{Y_t\}$ , can be transformed into a set of sine and cosine waves such as:

$$Y_t = \mu + 2 \sum_{j=1}^p [C_j \cos(2\pi f_j t) + S_j \sin(2\pi f_j t)] \quad (1)$$

where  $\mu$  is the mean of the series,  $t$  is a time index ranging from 1 to  $P$  where  $P$  is the number of periods for which we have observations,  $f_j = j/P$  is the  $j$ th harmonic of the fundamental frequency  $1/P$  (i.e. the inverse of the sample length) and  $j$  ranges from 1 to  $p$  where  $p = P/2$  with the amplitude given by  $C_j$  and  $S_j$ . The highest observable frequency (the Nyquist frequency) in the series is  $p/P$  (i.e. 0.5 cycles per time interval). High frequency dynamics (large  $f$ ) are akin to

short cycle processes while low frequency dynamics (small  $f$ ) may be likened to long cycle processes.

To initiate the moving window regression a dominant cycle is identified for the full data set – this becomes the size of the window that is subsequently moved through the data series. Within this window size the sub-set series are again decomposed into their respective frequencies as the window is moved forward one observation at a time. This permits the analyst to observe the relationship between frequencies as the window size determined by the dominant cycle is rolled through the series. A hypothetical intuitive notion of this is presented in figure 1, which is derived from Wilson et. al. (2000). Lets suppose preliminary spectral analysis determines that the dominant frequency (cycle) is 12 quarters. This determines the size of the window that will be moved through the data series. Now a spectral analysis of this first window (data set) is undertaken. That is, if a fast Fourier transform is undertaken on this smaller sub-set of the data then the data set in this window can be decomposed into its respective frequency components as shown for the hypothetical case in figure 1. In other words we now have information on the relationship between the dominant frequency and other frequencies in this window frame. Now we move the window forward one time unit and undertake a spectral analysis on the second window, and so on through the data series. If we can establish the relationship between the frequency components of one window with those of the previous window then we have the basis for examining how the changing alignment of cycles will affect the data set. This is essentially what the moving spectral regression is doing. Now, if we have one hundred quarterly observations available in the time domain there will be eighty-eight paired observations (windows) available for each spectral regression (since twelve observations as

determined by our hypothetical dominant frequency are 'used up' in the first 'roll' through the data set).

Figure 1 about here

Following this procedure, and in transforming the time domain model to the frequency domain, Ridley (1994) presents the following spectral regression model for estimation:

$$Y_m(\omega) = Y_{m-1}(\omega)B(\omega) + E_m(\omega) \quad (2)$$

for window numbers  $m=2,3,\dots,n-M+1$  and frequencies  $\omega = ! 0,1,2,\dots,Int(M/2)$  for  $-\pi < \omega < \pi$  where  $B(\omega)$  is the spectral density function of the impulse response function  $B_k$ , and  $Int$  refers to the integer part.

It is clear that the size of the moving window used in the spectral regression plays an important role in the analysis – different sized windows may well yield quite different results. While a variety of options are available for determining the window size, we have followed Wilson et.al (2000) by superimposing a four year window on the system since there is sufficient research to suggest that this window size is reasonable. Furthermore, if the purpose is to examine United States GDP as a potential driver then this window length is a practical starting point in any attempt to gauge the dynamics within the system. This is because research by the National Bureau of Economic Research suggests that the average American business cycle has about a four year duration, while the most common cycle length is about three years (Valentine and Ellis, 1991). However it is well to bear in mind that there is an important limitation in pursuing this approach. The procedure of introducing multiple series into a moving window

spectral regression in order to study the impulse response requires each series to have the same dominant frequency (moving window size). That is, superimposing a four year window based on the US business cycle as a possible driving factor 'forces' the various property series to adhere to a four year cycle, even if such a cycle is not suitable for each individual series. However, irrespective of the 'true' average cycle length for any given series, the moving window spectral regression may still capture potentially useful inter-relationships in the frequency domain.

An impulse response in this framework, then, can be regarded as an output from the system arising from an input which appears as an impulse, or spike. It is a useful tool for isolating the impact of an input that is suddenly imposed on the system for a very short period of time (Ridley, 1994). Using the above framework, figures 2 through 8 demonstrate how international property markets are likely to behave in the future if there was a sudden, one-off change in United States GDP. For example, figure 2 suggests that, other things being equal, the Australian property market is likely to have the strongest immediate response with a sharp jump in the quarter following the spike. However the market settles down quickly within the second quarter, with little or no ensuing memory of the spike. The *y-axis* data are indicative of the strength of the likely response. Thus, if US Gross Domestic Product had instantaneously spiked, say one unit before returning to its previous level, then the ensuing reaction in the Australian property market would be a change of between 0.7 and 0.8 of a unit in the following quarter. The property market that has the least reaction to a US Gross Domestic Product spike is the Dutch market where there is virtually no impulse response to a one unit spike (less than 0.05 of a unit) and no lingering memory. This response in the Dutch market may well be determined by the very much 'off-shore' nature of investments by Dutch property companies as mentioned earlier. While the reaction in other property markets is very much smaller than the initial

response in the Australian market, there often seems to be more lingering memory of the spike than in the Australian market, this memory appearing to be least in the European markets and most in the Asian markets.

The sharp initial response of the Australian market is not surprising in view of its strong trade links to the United States. The Australian economy across the board is likely to respond in a very positive fashion to a sudden strengthening of the US economy, and this will have strong flow through effects to Australian securitised property markets<sup>7</sup>. It is also not surprising that the UK and French markets respond in a somewhat similar fashion with a moderate initial movement in the market followed by some mild, lingering response over the next couple of years. In a broad sense the European community is more 'inward looking' than the other economies in terms of trade and general economic development, not only since the establishment of the common market concept of the European Economic Community in 1957, but even more so since the emergence of the stronger European Union in 1993. This 'inward looking' approach has been further strengthened by the eventual materialization of the Euro currency in the late 1990s. This interpretation ought not to be viewed as unhealthy. While the European Union, with its embedded vision of developing a single European market, may one day become a serious economic rival to the United States, a current beneficial side effect is that European Union markets may have become more insulated from external economic shocks. This appears to be reflected in the relatively small response from the European property markets to a spike in US Gross Domestic Product - with the average response in the quarter following the spike being 0.2 of a unit.

Likewise the Asian property markets react in a similar fashion to each other, but differently to the reaction in European markets. While the initial response in the Asian markets

is not too unlike the initial response in the European markets (though greater), the Asian property markets appear to have a great deal of difficulty returning to their original levels after a sudden spike in the US economy. This outcome certainly warrants further investigation which is outside the bounds of this study. For example, the different responses in the European vs. Asian markets may be as a result of the differing emerging monetary unions. While the European Monetary Union is now fact, research by Aggarwal and Mougoue (1996,1998) suggests the emergence of an Asian monetary union by stealth based on the Japanese Yen. While ASEAN is emerging as an embryonic economic union of South East Asian countries, the individual countries within the association maintain strong trade and investment links outside the region, and hence are much more susceptible to external shocks. In addition, there were two serious and sustained crises in the Asian region over the period of analysis which may well have impacted on the results from this study. First we note that the Japanese economy entered a downturn that commenced in the early nineties and this downturn has, more or less, been sustained since that time. As the Japanese economy is the second largest in the world, and the largest in the Asian region, it seems reasonable to suppose that other Asian economies might not only be sensitive to what happens in the US economy, but also may be sensitive to changes in the Japanese economy (with consequent flow through effects to property markets). Second, the Asian Financial Crisis that commenced in 1997 may also have had an impact on these results, and this has not been factored into the present analysis<sup>8</sup>.

While it is intuitively appealing to present the impulse response analysis transformed from the frequency domain to the time domain (as shown in figures 2 through 8), it may be more instructive to examine at least some of this information in the domain of analysis – the frequency domain. The relative importance of the response in each property market to a spike in US Gross

Domestic Product can be gauged from table 5, which presents the response amplitude and standard error at each frequency. Column 2 refers to the number of complete cycles (frequencies) per window length of four years (our dominant frequency), so the first frequency refers to this dominant frequency. Higher frequencies, consequently, refer to successively shorter components within this window. Column 3 shows the response of the amplitude at the given frequency to a spike that occurred in the US Gross Domestic Product in the previous time period. This is a regression parameter obtained from the moving spectral regression analysis in equation (2), and columns 4 and 5 indicate whether the regression parameter is significant or not. That is, from columns 4 and 5 it can be determined whether the magnitude response to a spike in US Gross Domestic Product in the previous period is significantly different from zero. Two important observations can be made from the table. First, in the case of Australia the amplitude response at all frequencies is significant at the 5% level, thereby suggesting the reliance of Australian securitised property markets on developments in the United States economy, and the size of the response is largest at the high frequency end (the short cycle end). The second important observation is that in all other cases only half or less of the amplitude responses are significant, and in the case of the Netherlands there is no significant response (other than the long cycle) to a spike in US GDP.

A final consideration that needs to be borne in mind is how well securitised property markets might provide information on likely movements in direct property markets. While this question is not pursued here there is some research which suggests that securitised property is more reflective of stock market movements than direct property market movements (cf. studies by Liu, Hartzell, Grieg and Grissom (1990) and Myer and Webb (1993)). Other research sees securitised property as a source of price discovery on direct property market movements.

Supportive research on this for the United States market may be found in Gyourko and Keim (1992, 1993), although a study on price discovery in the Hong Market by Chau, MacGregor and Schwann (1999) showed there was little information flow from securitised property to direct real estate. However, if securitised property behaves more like common stocks than property then perhaps what we are seeing in this study on international property market integration amounts to flow through news effects and their general impact on stock markets, and the securitised property markets are simply following suit, with the most important news announcements being the state of the US economy. If there is price discovery between securitised and direct markets then such announcements may have flow through effects as to how investors perceive the underlying value of their assets. That is, good news on the US economy might be interpreted as having an impact on exchange rates - driving down the value of other currencies against the dollar, which improves the trade position of those countries. Improved trade stimulates the relevant economy, increases employment etc., with the buoyancy flowing through to direct property.

## **5. Summary and Future Research**

The work in this paper follows on from the recent research by Myer, Chaudhry and Webb (1997), Quan and Titman (1999) and Case, Goetzman and Rouwenhorst (2000). These studies have found international linkages in property markets and their work has suggested that this relationship is linked to the inter-relatedness of economic factors. In this paper a question was posed whether securitised property markets are linked internationally and, if so, the role that a large economy such as the United States might play in such a system. Eight countries were analyzed and assessed for international integration in two stages.

First, international property markets were tested for cointegration. The results showed the greatest equilibrating force was brought to the system through the United States. Second, we asked if there was a long run equilibrium relationship between United States economic fundamentals and a world property market system that excluded the US. Again, the results indicated a role for US GDP in a long-run equilibrium relationship.

To help understand some of the dynamics of the suggested inter-relationships impulse response analysis within the frequency domain was then applied to assess the likely impact on world property markets emerging from one-off spikes in the US economy. The results indicated that, in general, the sharpest responses would emerge in the Australasian property markets while the weakest responses would emerge in the European markets.

What are the implications of these findings for a fund manager? First, if in fact international property markets are inter-related, the strength of this linkage needs to be carefully assessed to ascertain the degree of diversification benefits. The current analysis indicates that while there are some cointegrating relationships, world property markets are by no means fully integrated, suggesting scope for diversification. Second, the relationship between the fundamentals in a large economy such as the US and international property markets needs to be further investigated since this may have the potential to provide advance signals on possible movements in these markets. Moreover, if the impulse response functions are indicative of the likely speed of international property market reactions to changes in US fundamentals, then fund managers have some perception of the time available to them in order to undertake any required portfolio re-weightings, and which markets are likely to be most affected.



In addition, we note that there are some limitations to the type of analysis undertaken in this paper. More research into the dynamic links that exist between world property markets must

be examined. Specifically, although this paper considered one aspect, that of the US economy driving world property markets, it is by no means the only possible driver for the international real estate sector. It may well be that movements in other large economies such as the UK, Japan or even an integrated EU have similar sorts of impacts. This is an important issue for future research. Finally, a further examination into the impact of structural changes, such as the 1997 Asian financial crisis, upon the relationships discussed in this paper may also help provide more information about the long-run factors that drive these markets.

## 6. Bibliography

- Aggarwal, Raj and Mdogja Mougoue (1996) "Cointegration Among Asian Currencies: Evidence of the Increasing Influence of the Japanese Yen" *Japan and the World Economy*, **8**, , 291-308.
- Aggarwal, Raj and Mdogja Mougoue (1998) "Common Stochastic Trends Among Asian Currencies: Evidence for Japan, Aseans and the Asian Tigers" *Review of Quantitative Finance and Accounting*, **10**, 193-206.
- Asabere, Paul K., Kleiman, Robert T. and McGowan, Carl B. (1991) "The Risk Return Attributes of International Real Estate Equities", *The Journal of Real Estate Research*, **6** (2), 1991.
- Baillie, Richard T and Bollerslev, Tim. (1994) "Cointegration, Fractional Cointegration, and Exchange Rate Dynamics". *Journal of Finance*, **49** (2), 737-45.
- Case, Bradford, William N. Goetzmann and K.Geert Rouwenhorst (2000) "Global Real Estate Markets – Cycles and Fundamentals", *NBER Working Paper Series*, Cambridge MA, February, 2000.
- Chan, K., Karolyi, A. and R., Stultz (1992) "Global Financial Markets and the Risk Premium on US Equity", *Journal of Financial Economics*, **32**, 137-167.
- Chau, Kwong Wing, Bryan D MacGregor and Gregory M Schwann (1999) "Price discovery in the Hong Kong real estate market", *Aberdeen Papers in Land Economy*, University of Aberdeen, (December).
- Chaudhry, Mukesh K., F.C. Neil Myer and James R. Webb (1999) "Stationarity and Cointegration in Systems with Real Estate and Financial Assets" *Journal of Real Estate Finance and Economics*, **18** (3), 339-349.
- Eichholtz, Piet M. A. and David J. Hartzell. (1996) "Property Shares, Appraisals and The Stock Market: An International Perspective," *Journal of Real Estate Finance and Economics*, **12** (2), 163-178.
- Eichholtz, Piet, Ronald Huisman, Kees Koedijk and Lisa Sehuin (1998) "Continental Factors in International Real Estate Returns", *Real Estate Economics*, **26** (3), 493-509.
- Eichholtz, Piet and Lie, Robert (1995) "Globalization of Real Estate Markets?", *11th Annual ARES Conference*, Hilton Head Island.
- Engle, R.F. (1974) "Band Spectrum Regression" *International Economic Review*, **15** (1), 1-11.
- Engle, R.F. and Kozicki, S. (1993) "Testing for Common Features", *Journal of Business and Economic Studies*, **11**, 83-113.
- Eun, C.S. and S. Shim.(1989) "International Transmission of Stock Market Movements", *Journal of Financial and Quantitative Analysis*, **24** (2), 241-56.
- Francis, B. and L., Leachman (1998) "Superexogeneity and the Dynamic Linkages among International Equity Markets", *Journal of International Money and Finance*, **17**, 475-492.

- Giliberto, M.(1990) "The Salomon-Russell Global Equity Index Property Sector", *Salomon Brothers Bond Market Research*, (February).
- Glascok, John L., Chiuling Lu and Raymond W. So (2000) "Further Evidence on the Integration of REIT, Bond and Stock Returns" *Journal of Real Estate Finance and Economics*, **20** (2), 177-194.
- Gyourko, J and Keim, D B (1992) "What does the stock market tell us about real estate returns?", *Journal of the American Real Estate and Urban Economics Association*, **20** (3), 457-86.
- Gyourko, J and Keim, D B (1993) "Risk and Return in Real Estate: Evidence from a Real Estate Stock Index", *Financial Analysts Journal*, Sept, 39-46.
- Hamao, Y., Masulis, R. and V., Ng, (1990) "Correlation Price Changes and Volatility Across International Stock Markets", *Review of Financial Studies*, **3**, 281-307.
- Harvey, A.C. (1978)  Linear Regression in the Frequency Domain, *International Economic Review*, **19** (2), 507-512.
- Hsieh, Nigel C T; Lin, Antsong; Swanson, Peggy E. (1999) "Global Money Market Interrelationships". *International Review of Economics and Finance*, **8** (1), 71-85.
- Johansen, Soren. (1995) *Likelihood-based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press, Oxford.
- Johansen, S., (1991) "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models", *Econometrica*, **59**, 1551–1580.
- Juselius, Katarina. (1995) "Do Purchasing Power Parity And Uncovered Interest Rate Parity Hold In The Long Run? An Example Of Likelihood Inference In A Multivariate Time-Series Model," *Journal of Econometrics*, **69** (1), 211-240.
- Liu, C.D., Hartzell, D., Greig, W. and Grissom, T (1990) "The Integration of the Real Estate Market and the Stock Market: Some Preliminary Evidence", *Journal of Real Estate Finance and Economics*, **3**, 261-282.
- Liu, Crocker and Mei, Jian-Ping (1998) "The Predictability of International Real Estate Markets, Exchange Rate Risks and Diversification Consequences" *Real Estate Economics*, **26** (1), 3-39.
- Longin, Francois and Bruno Solnik. (1995) "Is The Correlation In International Equity Returns Constant: 1970-1990?," *Journal of International Money & Finance*, **14** (1), 3-26.
- MacGregor, Bryan D and Gregory M Schwann (1999) "Common Cycles in U.K. Commercial Real Estate Returns" *Aberdeen Papers in Land Economy*, Department of Land Economy, University of Aberdeen (December).
- Morely, Bruce and Eric J. Pentecost (2000) "Common Trends and Cycles in G-7 Countries Exchange Rates and Stock Prices" *Applied Economics Letters*, **7**, 7-10.


- Muscatelli, Vito Antonio and Stan Hurn (1995) "Econometric Modelling Using Cointegrated Time Series" in Oxley, Les et.al. *Surveys in Econometrics*, Blackwell, Oxford.
- Myer, F. C. Neil and James R. Webb (1993) "Return Properties Of Equity REITs, Common Stocks, And Commercial Real Estate: A Comparison," *Journal of Real Estate Research*, **8** (1), 87-106.
- Myer, F.C.Neil, Mukesh K. Chaudhry and James R. Webb (1997) "Stationarity and Co-Integration in Systems with Three National Real Estate Indices", *Journal of Real Estate Research*, **13** (3), 369-381.
- Nelson, Charles R. and Charles I. Plosser (1982) "Trends And Random Walks In Macroeconomic Time Series: Some Evidence And Implications," *Journal of Monetary Economics*, **10** (2), 1982.
- Osterwald-Lenum, M. (1992) "A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics", *Oxford Bulletin of Economics and Statistics*, **54**, 461-72.
- Phylaktis, Kate. (1999) "Capital Market Integration in the Pacific Basin Region: An Impulse Response Analysis". *Journal of International Money and Finance*, **18** (2), 267-87
- Quan, Daniel C. and Sheridan Titman (1999) "Do Real Estate Prices and Stock Prices Move Together? An International Analysis" *Real Estate Economics*, **27** (2), 183-207.
- Ridley, A.D. and Mobolurin, A. (1987)  Application of a Spectral Analysis Algorithm (MWS) to Time Series Forecasting of Automobile Demand" *Proceedings, The Twenty-Fourth Annual Symposium of the Washington Operations Research/Management Science Council* (November)
- Ridley, A.D. (1994)  The Global Univariate Moving Spectral Window Method, *Supercomputer Computations Research Institute*, Florida State University ( February).
- Rowland, P.J. (1997) *Property Investments and their Financing*, Law Book Company, Sydney.
- Schwarz, G., (1978) "Estimating the Dimension of a Model." *Ann. Stat.* **6**, 461-464.
- Sweeney, F.(1993) "Mapping a European Property Investment Strategy", *Journal of Property Valuation and Investment*, **11**, 1993.
- Stock, J.H. and Watson, M.W (1988) "Testing for Common Trends" *Journal of the American Statistical Association*, **83**, 1097-1107.
- Tarbert, Heather. (1998) "The Long Diversification Benefits Available from Investing Across Geographical Regions and Property Type: Evidence from Cointegration Tests" *Economic Modelling*, **15**, 49-65.
- Tse, Y., Lee, T-H., & Booth, G. (1996) "The International transmission of information in Eurodollar futures markets: a continuously trading market hypothesis". *Journal of International Money and Finance*, **15** (3), 447-465.
- Vahid, F. and R.F. Engle (1993) "Common Trends and Common Cycles" *Journal of Applied Econometrics*, **8** (4), 341-381.

Valentine, Loyd M. and Dennis F. Ellis (1991) *Business Cycles and Forecasting*, South Western, Cincinnati, 8<sup>th</sup> ed..

Welch, P. (1967) "The Use of Fast Fourier Transform for Estimation of Power Spectra: A Method of Time Averaging over Short, Modified Periodograms", *IEEE Transactions in Audio Electroacoustics*, **AU-15**, 70-73.

Wilson, Patrick J. , Okunev, J, Ellis, C., Higgins. D (2000) "Comparing Univariate Forecasting Techniques in Property Markets", *Journal of Real Estate Portfolio Management*, **6** (3), 283-306.

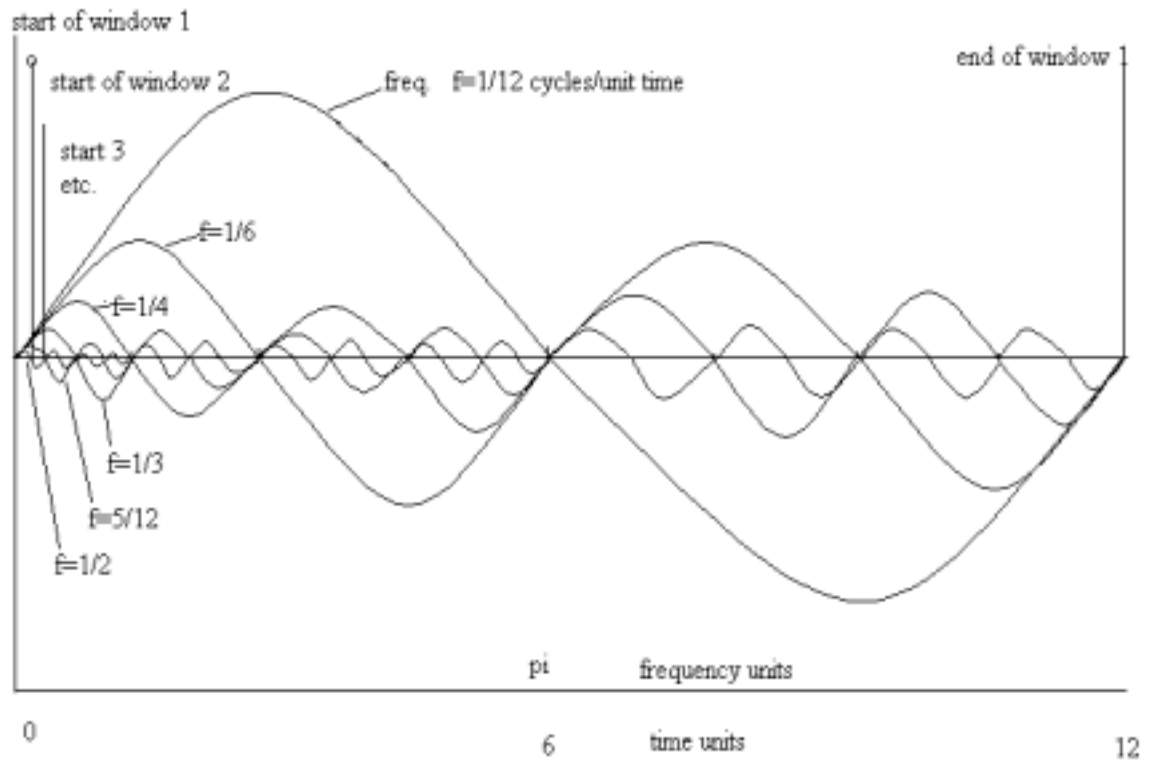
Wilson, Patrick .J., and Okunev, John. (1999)  Spectral Analysis of Real Estate and Financial Assets Markets, *Journal of Property Investment and Finance*, **17** (1), 61-74.

Wilson, Patrick .J., and Okunev, John (1996)  Evidence of Segmentation in Domestic and International Property Markets, *The Journal of Property Finance*, **7** (4), 78-97.

Wilson, Patrick J. and Ralf Zurbruegg (2002) "Structural Breaks, Diversification and International Real Estate Markets – Some New Evidence" *Briefings in Real Estate Finance*, **1** (4) , 348-366.

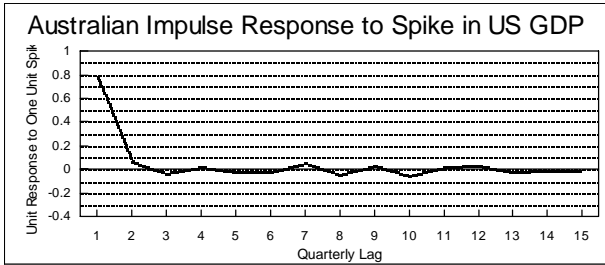
Ziobrowski, A.J. and Curcio, R.J.(1991) "Diversification Benefits of U.S. Real Estate to Foreign Investors", *Journal of Real Estate Research*, **6** (2) 119-142.

Figure 1  
Hypothetical Frequency Decomposition for Moving Window Determined by Dominant Cycle

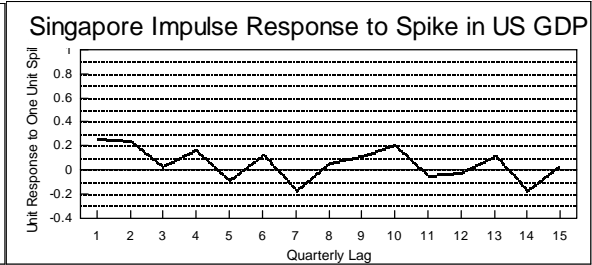


Source: Wilson et. al. (2000)

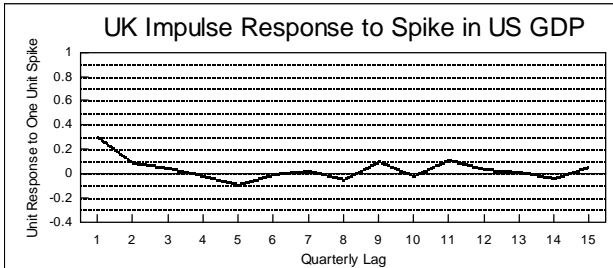
**Figure 2**



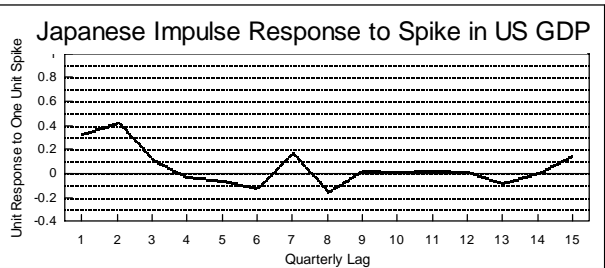
**Figure 3**



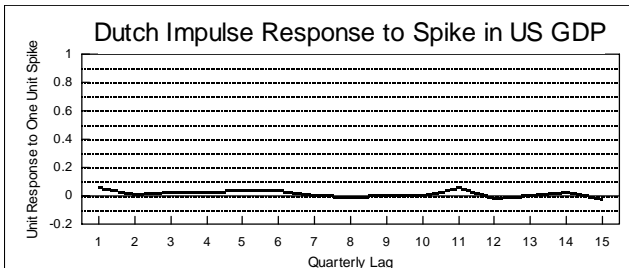
**Figure 4**



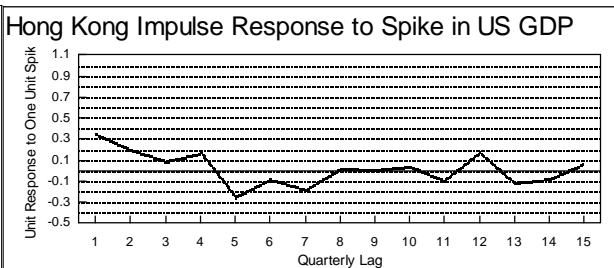
**Figure 5**



**Figure 6**



**Figure 7**



**Figure 8**

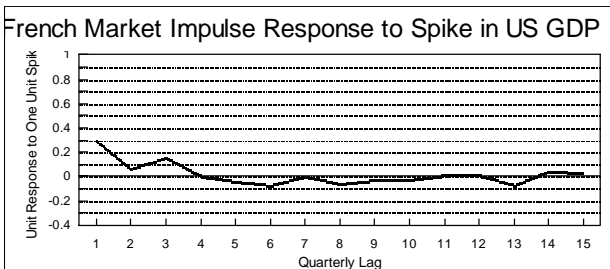


Table 1 Property Index Composition – DataStream vs GPR

Country Index	No. of Companies in Index: DataStream 2000*	No. of Companies in Index: GPR 1999**
United States	39	156
Australia	26	24
Singapore	13	12
Hong Kong	23	25
Japan	23	20
United Kingdom	32	50
France	9	23
Netherlands	10	12

\* July in last year of study period

\*\* Last period available to authors, August 1999.

Table 2. Phillips-Perron Unit Root Tests

Country	<i>LEVELS</i>	<i>DIFFERENCES</i>
US	-1.99	-7.17 <sup>a</sup>
Australia	-3.03	-8.95 <sup>a</sup>
Hong Kong	-2.18	-8.07 <sup>a</sup>
Singapore	-2.19	-6.64 <sup>a</sup>
Japan	-1.21	-6.85 <sup>a</sup>
UK	-2.17	-6.39 <sup>a</sup>
France	-2.02	-5.63 <sup>a</sup>
Netherlands	-1.25	-7.71 <sup>a</sup>

All Phillips-Perron (PP) tests are conducted on logarithmic values where the test statistic is corrected for heteroskedasticity and autocorrelation of unknown form using the Newey-West consistent estimator. The number of truncation lags were 3, based on a floor function from the Newey-West estimator and the number of observations.

<sup>a</sup> Indicates significance at the 1% confidence level.

Table 3. Johansen Trace Tests.

	<i>Excluding US Property Market</i>		<i>All Property Markets</i>		<i>Substituting USGDP for US Property</i>	
	$\lambda_{Trace}$	5% critical value	$\lambda_{Trace}$	5% critical value	$\lambda_{Trace}$	5% critical value
$r=0$	147.11	124.2	207.18	156.0	215.74	156.0
$r \leq 1$	89.55	94.2	154.93	124.2	157.11	124.2
$r \leq 2$	53.44	68.5	107.41	94.2	109.05	94.2
$r \leq 3$	29.00	47.2	67.81	68.5	69.87	68.5
$r \leq 4$	12.79	29.7	43.65	47.2	43.21	47.2
$r \leq 5$	5.48	15.4	25.17	29.7	23.63	29.7
$r \leq 6$	1.11	3.8	8.29	15.4	9.22	15.4
$r \leq 7$			1.28	3.8	1.47	3.8

The results presented are the Johansen trace tests with the hypothesis that the system of equations contains at most  $r$  cointegrating vectors.  $\lambda_{Trace}$  is calculated as  $\lambda_{Trace}(r) = -T \sum_{i=r+1}^n \log(1 - \lambda_i)$  where  $\lambda_i$  is the  $i^{th}$  largest eigenvalue. Results tabulated assume no trend component. Critical values are taken from Osterwald-Lenum (1992). 4 lags were considered optimal for minimizing the SIC and guaranteeing no autocorrelation problems.

Table 4. Relative Size of US Gross Domestic Product.

Sample period for GDP data: 1970 to 2000	US GDP* as a proportion of GDP in:			Major Seven as Proportion of Full OECD
	(i) Full OECD	(ii) Europe OECD plus US	(iii) Major Seven	
Maximum	40%	51%	49%	82%
Minimum	36%	47%	45%	81%
Average	38%	48%	47%	81%
*GDP by expenditure measured in Blns \$US at Current Prices with PPP as at 1995. Note also that the number of countries within the OECD has grown over time. This should have acted to decrease the US influence. In fact US GDP as a proportion has remained relatively constant. For example, the proportions for the March Qtr.1970 and the June Qtr. 2000 were: (i) 39.5% & 39.9%; (ii) 48.6% & 51.2%; (iii) 48.1% & 49.4% and the final column was 82.1% & 80.7%.				Source: OECD

Table 5 Frequency Domain Parameter Estimates for Response to Spike in USGDP

Country	Frequency (cycles per window of length 16)	Amplitude (magnitude of the cycle response) <sup>+</sup>	Std. Error	t-statistic
Australia	1	0.329	0.067	4.90*
	2	0.662	0.096	6.90*
	3	0.991	0.129	7.69*
	4	1.036	0.154	6.74*
	5	1.310	0.187	7.01*
	6	1.592	0.195	8.17*
	7	1.269	0.214	5.93*
	8	1.580	0.215	7.36*
Hong Kong	1	0.207	0.164	1.263
	2	1.128	0.296	3.813*
	3	0.857	0.309	2.771*
	4	0.378	0.499	0.759
	5	0.714	0.568	1.257
	6	1.423	0.565	2.520*
	7	1.207	0.649	1.861
	8	0.047	0.518	0.090
Singapore	1	0.472	0.168	2.808*
	2	0.960	0.285	3.365*
	3	0.576	0.282	2.039*
	4	0.947	0.585	1.618
	5	0.328	0.539	0.608
	6	0.831	0.559	1.486
	7	1.375	0.520	2.645*
	8	0.229	0.489	0.467
Japan	1	0.801	0.119	6.738*
	2	0.804	0.215	3.736*
	3	0.557	0.272	2.042*
	4	0.628	0.403	1.557
	5	0.378	0.456	0.830
	6	0.782	0.431	1.817
	7	0.171	0.568	0.302
	8	0.632	0.561	1.126

Table 5 Continued

Country	Frequency	Amplitude	Std. Error	t-statistic
United Kingdom	1	0.062	0.105	0.588
	2	0.526	0.171	3.082*
	3	0.476	0.184	2.591*
	4	0.388	0.240	1.617
	5	0.384	0.272	1.410
	6	0.720	0.264	2.723*
	7	0.469	0.389	1.206
	8	0.862	0.272	3.168*
France	1	0.524	0.053	9.931*
	2	0.421	0.116	3.633*
	3	0.245	0.112	2.195*
	4	0.181	0.225	0.808
	5	0.295	0.218	1.354
	6	0.461	0.193	2.388*
	7	0.403	0.244	1.650
	8	0.520	0.242	2.149
Netherlands	1	0.108	0.035	3.096*
	2	0.100	0.084	1.198
	3	0.076	0.089	0.846
	4	0.093	0.111	0.839
	5	0.136	0.162	0.840
	6	0.142	0.171	0.835
	7	0.020	0.234	0.085
	8	0.064	0.213	0.303

*The t-test is based on the system regression parameter estimates*

<sup>†</sup>System regression parameters obtained from the moving window spectral regression

$$Y_m(\omega) = Y_{m-1}(\omega)B(\omega) + E_m(\omega)$$

\* Significant at 5% level

## 7. Appendix - Moving Window Spectral Regression

The following summary of the moving window spectral approach is derived from Ridley and Mobolurin (1987), Ridley (1994) and Wilson et. al. (2000). Ridley and Mobolurin (ibid) and Ridley (ibid) have done much to extend the work of Welch (1967) to practical applications in the business environment. Assume  $\{Y_t\}$ ,  $t$  contained in  $n$ , is the realisation of a stationary stochastic process occurring at time  $t$ , where  $n$  is the set of time points at which the process is defined. To estimate possible relationships occurring within the system a moving window of length  $M$  in the time domain is defined. The window is moved forward to generate a sequence of observations in the time domain. Each pair of windows in the sequence contains an observation on the input and output process for each frequency in the frequency domain.

Once the paired sequences have been extracted the time series model underlying the system may then be viewed as:

$$Y_t = \sum_{k=1}^M Y_{(t-k)} B_k + E_t \quad (1)$$

where  $B_k$  is the coefficient of  $Y$  lagged  $k$  time periods;  $E_t$  is the unobservable error term, a sequence of *iid* random variables that are  $N(0, \sigma^2)$ ; and  $t=1, 2, \dots, n$ .

The problem is that, while the lag structure of equation 1 can be estimated by ordinary least squares, the model would be cumbersome to estimate and there may be degrees of freedom and serial correlation problems. An alternative approach is to assume that the variable in the model is generated by a stable stochastic process that depends on different frequencies. In that case the complex fast Fourier transform may be used to estimate the spectrum for the input and output processes from:

$$Y_m(\omega) = \sum_{k=1}^M Y_{(m+M-k)} e^{-i\omega k} \quad (2)$$

where:  $m=1,2,\dots,n-M+1$  is the window number and the index of an observation at frequency  $\omega$ , for  $\omega = 0,1,2,\dots,Int(M/2)$  where  $Int$  denotes the integer part;  $e$  is the exponential base of the natural logarithm; and  $i=\sqrt{-1}$ . Similarly, for the system parameters and errors:

$$B(\omega) = \sum_{k=1}^M B_{(k)} e^{-i\omega k} \quad (3)$$

$$E_m(\omega) = \sum_{k=1}^M E_{(m+M-k)} e^{-i\omega k} \quad (4)$$

where each of :  $Y_t$  and  $Y_m(\omega)$ ;  $B_k$  and  $B(\omega)$ ; and  $E_t$  and  $E_m(\omega)$  are complex Fourier transform pairs.

Since the spectral densities for real valued time series are symmetric about  $\omega=0$ , once the positive frequencies are known the negative frequencies can be calculated directly. In that case only the integer part of  $(M/2)+1$  non-negative frequencies need be considered in the regression model.

In transforming the time domain model (equation 1) to the frequency domain Ridley (1994) presents the following spectral regression model for estimation:

$$Y_m(\omega) = Y_{m-1}(\omega)B(\omega) + E_m(\omega) \quad (5)$$

for  $m=2,3,\dots,n-M+1$  and  $\omega = \frac{2\pi k}{M}$ ,  $k=0,1,2,\dots, \text{Int}(M/2)$  for  $-\pi < \omega < \pi$  where  $B(\omega)$  is the spectral density function of the impulse response function  $B_k$ .

## CIES DISCUSSION PAPER SERIES

The CIES Discussion Paper series provides a means of circulating promptly papers of interest to the research and policy communities and written by staff and visitors associated with the Centre for International Economic Studies (CIES) at the Adelaide University. Its purpose is to stimulate discussion of issues of contemporary policy relevance among non-economists as well as economists. To that end the papers are non-technical in nature and more widely accessible than papers published in specialist academic journals and books. (Prior to April 1999 this was called the CIES Policy Discussion Paper series. Since then the former CIES Seminar Paper series has been merged with this series.)

**Copies of CIES Policy Discussion Papers may be downloaded from our Web site at <http://www.adelaide.edu.au/cies/> or are available by contacting the Executive Assistant, CIES, School of Economics, Adelaide University, SA 5005 AUSTRALIA. Tel: (+61 8) 8303 5672, Fax: (+61 8) 8223 1460, Email: [cies@adelaide.edu.au](mailto:cies@adelaide.edu.au). Single copies are free on request; the cost to institutions is US\$5.00 overseas or A\$5.50 (incl. GST) in Australia each including postage and handling.**

**For a full list of CIES publications,** visit our Web site at <http://www.adelaide.edu.au/cies/> or write, email or fax to the above address for our *List of Publications by CIES Researchers, 1989 to 1999* plus updates.

- 0315 Wilson, Patrick J. and Ralf Zurbruegg, "Trends and Spectral Response: An Examination of the US Realty Market", May 2003.
- 0314 Esho, Neil and Anatoly Kirievsky, Damian Ward and Ralf Zurbruegg, "Law and the Demand for Property-Casualty Insurance Consumption", May 2003. (Forthcoming in *Journal of Risk and Insurance*, 2003).
- 0313 Wilson, Patrick J. and Ralf Zurbruegg, "Does it Pay to Diversify Real Estate Assets? - A Literary Perspective", May 2003.
- 0312 Rajan, Ramkishen, "Taxing International Currency Flows: A Financial Safeguard or Financial Bonanza?", April 2003.
- 0311 Rajan, Ramkishen, "Financial Crisis, Capital Outflows and Policy Responses: Simple Analytics and Examples from East Asia", April 2003.
- 0310 Cavoli, Tony and Ramkishen Rajan, "Exchange Rate Arrangements for East Asia Post-Crisis: Examining the Case for Open Economy Inflation Targeting", April 2003.
- 0309 Cavoli, Tony and Ramkishen Rajan, "Designing Appropriate Exchange Rate Regimes for East Asia: Inflation Targeting and Monetary Policy Rules", April 2003.
- 0308 Allsopp, Louise, "Speculative Behaviour, Debt Default and Contagion: An Explanation of the Latin American Crisis 2001-2002", March 2003.
- 0307 Barreto, Raul. A., "A Model of State Infrastructure with Decentralized Public Agents: Theory and Evidence", March 2003.
- 0306 Pardey, Philip G., Julian M. Alston, Connie Chan-Kang, Eduardo C. Magalhães, and Stephen A. Vosti, "Assessing and Attributing the Benefits from Varietal Improvement Research: Evidence from Embrapa, Brazil", March 2003.
- 0305 Allsopp, Louise, "Venezuela: A Nation In Need of Reform", March 2003.
- 0304 Allsopp, Louise and Ralf Zurbruegg, "Purchasing Power Parity in East Asia: Why all the Fuss?", March 2003.
- 0303 Allsopp, Louise and Ralf Zurbruegg, "Purchasing Power Parity and the Impact of the

- East Asian Currency Crisis”, March 2003.
- 0302 Siregar, Reza and Ramkishen Rajan, “Exchange Rate Policy and Foreign Exchange Reserves Management in Indonesia in the Context of East Asian Monetary Regionalism”, March 2003.
- 0301 Jackson, Lee Ann, “Protectionist Harmonization of Food Safety Policies in the Asia-Pacific Region”, January 2003.
- 0236 Damania, Richard, “Protectionist Lobbying and Strategic Investment”, November 2002
- 0235 Damania, Richard and John Hatch, “Protecting Eden: Markets or Government?”, November 2002.
- 0234 Anderson, Kym, “Agricultural Trade Reform and Poverty Reduction in Developing Countries”, November 2002.
- 0233 Wood, Danielle and Kym Anderson, “What Determines the Future Value of an Icon Wine? Evidence from Australia”, November 2002.
- 0232 Kym Anderson and Nielsen, Chantal, “Economic Effects of Agricultural Biotechnology Research in the Presence of Price-distorting Policies”. November 2002.
- 0231 Jackson, Lee Ann, “Who Benefits from Quality Labelling? Segregation Costs, International Trade and Producer Outcomes”. November 2002.
- 0230 Rajan, Ramkishen, “Trade Liberalization and Poverty: Where Do We Stand?”, November 2002.
- 0229 Rajaguru, Gulasekaran and Reza Siregar, “Sources of Variations Between the Inflation Rates of Korea, Thailand and Indonesia During the Post-1997 Crisis”, November 2002.
- 0228 Barbier, Edward B, “Water and Economic Growth”, October 2002.
- 0227 Barbier, Edward B, “The Role of Natural Resources in Economic Development”, October 2002. (The 49<sup>th</sup> Joseph Fisher Lecture.)
- 0226 Rajan, Ramkishen and Rahul Sen, “Liberalisation of Financial Services in Southeast Asia under the ASEAN Framework Agreement on Services (AFAS)”, October 2002. (Forthcoming in *Journal of International Banking Law*).
- 0225 Anderson, Kym “Building an Internationally Competitive Australian Olive Industry: Lessons from the Wine Industry,” October 2002.
- 0224 Bentzen, Jan, Søren Leth-Sørensen and Valdemar Smith, “Prices of French Icon Wines and the Business Cycle: Empirical Evidence from Danish Wine Auctions,” September 2002.
- 0223 Bentzen, Jan and Valdemar Smith, “Wine Prices in the Nordic Countries: Are They Lower Than in the Region of Origin?” September 2002.
- 0222 Rajan, Ramkishen and Graham Bird, “Will Asian Economies Gain from Liberalizing Trade in Services?” September 2002. (Forthcoming in *Journal of World Trade*).
- 0221 Siregar, Reza Y. and Gulasekaran Rajaguru, “Base Money and Exchange Rate: Sources of Inflation in Indonesia during the Post-1997 Financial Crisis” August 2002.
- 0220 Rajan, Ramkishen, “International Financial Liberalisation in Developing Countries: Lessons from Recent Experiences” July 2002. (Published in *Economic and Political Weekly*, 37 (29): 3017-21, July 20-26, 2002).

## ENDNOTES

---

<sup>1</sup> There is also a large amount of research examining linkages between real estate assets and stock markets. Examples include Glascock, Lu and So (2000) and Chaudhry, Myer and Webb (1999).

<sup>2</sup> For example, prior to 1980 less than five funds comprised each of the Australian, Singapore and French series as compiled by Datastream International.

<sup>3</sup> Cointegration parameters and speed of adjustment coefficients are important but extraneous to our need to identify the number of cointegrating equations that may exist.

<sup>4</sup> Columns two and three in table 3 contain two borderline results at the 5% significance level – to marginally exclude and to marginally include four cointegrating vectors. Juselius (1995) argues that if the trace test results are very close to the critical value then the characteristic roots of the companion matrix can provide a useful guide as to the number of cointegrating processes within the system. Doing so we find that there is more evidence for incorporating a fourth cointegrating vector in both columns two and three than not and, accordingly, we decide to settle for four cointegrating vectors within the system.

<sup>5</sup> These two states would also qualify, in terms of economic wealth, to join the OECD. A list of member countries is available from the OECD website.

<sup>6</sup> Sequential tests for exclusion (not presented here) added further support to the important role that the US plays in this system of real estate markets. Without the US not all the countries were part of the cointegrating space. When the US was included all countries formed part of the cointegrating space.

<sup>7</sup> It should be remembered that this tool only tests for an impulse in the driving factor, not a sustained change.

<sup>8</sup> For a consideration of how structural breaks can impact on market integration see Wilson and Zurbruegg (2002).