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Potential Diversification Benefits in the Presence of Unknown Structural Breaks:
An Australian Case Study*

Patrick J. Wilson**
School of Finance and Economics
University of Technology, Sydney

Richard Gerlach
School of Mathematical and
Physical Sciences
University of Newcastle

Ralf Zurbruegg
School of Commerce
University of Adelaide

Abstract

It is reasonable to suggest that a portfolio manager with direct property diversified by sector or region is more interested in strategic than in tactical asset allocation. However, even with strategic allocations of property the portfolio manager needs a regular monitoring of the inter-relationships amongst assets comprising the portfolio to ensure that unexpected events do not 'permanently' alter such relationships. One procedure for ascertaining whether assets are inter-related over the long run (and therefore offer few diversification benefits) is through cointegration analysis. A difficulty with conventional cointegration analysis, however, is that it is unable to accommodate changes in equilibrium relationships amongst assets that might occur due to unexpected structural changes. In this paper we apply the Gregory and Hansen cointegrating procedure to consider how unexpected structural changes might affect the potential long run diversification benefits of assets held in an Australian property portfolio.

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** Contact Author

email: Patrick.Wilson@uts.edu.au

fax: 61(0)295147711

phone: 61(0)295147777

address: PO Box 123, Broadway, NSW, Australia, 2001

Introduction

Either or both sectoral and geographic diversification are generally considered as suitable vehicles to obtain risk reduction benefits in either direct or indirect property portfolios. Preliminary information on potential risk reduction is obtained through examination of simple correlation structures. Recent research has suggested that, since such correlation structures may be temporally unstable, the signals on appropriate combinations of assets to join the portfolio may be difficult to interpret. Another means by which preliminary information on asset combinations can be obtained is through use of the cointegration framework. If assets in the same class, but held in two or more distinct geographic regions, are cointegrated this would indicate that the markets are trending together over the long run. Similarly, if assets in different property sub-classes are cointegrated this would indicate that there are one or more common stochastic trends in the assets. Under such circumstances there would only be limited (if any) opportunity to gain risk reduction benefits through investing in the markets of both regions and/or classes.

There are two broad approaches to testing for cointegrating relationships. One approach is to pursue the Engle-Granger (1987) two-step methodology of applying unit root tests to the residual series of a cointegration equation. An alternative procedure is to apply the Johansen (1991) procedure of testing for a cointegrating relationship in a system of equations.

A potential difficulty in using the cointegration framework arises if one or more of the asset series has been subjected to a structural break or regime shift¹. Such change may come about through relatively infrequent but important events such as changes to the

fiscal treatment of property either in different regions or sub-asset classes, differences in the growth or decline of regional economies - perhaps brought about through the closure of important employment industries (for instance closure of the steelworks in the Newcastle region, downsizing of the steel industry in the Illawarra), and so on... . These events alter the economic performance of regions with consequent flow through to property asset holdings in those regions. Gregory, Nasson and Watt (1994) have shown that conventional Engle-Granger cointegration tests do not perform well in the presence of structural breaks in the series. In particular, they show that the power of a conventional Augmented Dicky-Fuller (ADF) test fails in the presence of a structural break. That is, it may be possible that two or more series are cointegrated with a one time shift in the cointegrating vector, but a conventional ADF test on the residual series may fail to reveal this cointegration. Thus, for example, if a property portfolio manager applied a conventional Engle-Granger methodology to property asset series in two different states or regions or across two property sub-classes and found that these property assets were not cointegrated then, *ceteris paribus*, the manager may decide to add each of the property assets to the portfolio. However, it may be that the existence of an unknown (and unaccounted for) structural break in the cointegrating vector yielded the result of no cointegration. If it turned out that the series were, in fact, cointegrated then the portfolio may fail to attract the expected risk reduction benefits through diversifying across states or asset sub-classes. In this paper we will apply the cointegration methodology to several property portfolios constructed from assets in different Australian states to determine whether there is a long run equilibrium relationship amongst these assets. We will adopt two approaches. In the first instance we will apply the Johansen (1991) methodology to

ascertain whether there appears to be evidence of cointegration amongst the groups of assets held in each portfolio. We will then apply the Gregory and Hansen (1996) procedure on bivariate asset series within each portfolio to ascertain whether there appears to be evidence of cointegration in the presence of a possible structural break in either or both of the series of interest. The remainder of the paper is as follows: in section two we briefly review the literature on geographic diversification; section three presents a statement on the cointegration methodology; in section four we discuss data sources and present the results while section five offers some conclusions.

Section Two: Some Previous Research

While it is reasonable to argue that national economic performance has a strong influence on real estate markets in general it is also reasonable to suppose that local market conditions also have an important bearing. To the extent that this is true, therefore, a portfolio of geographically diverse properties may provide better risk return characteristics than a geographically concentrated portfolio. To examine this notion in the past decade or so several researchers have looked at the potential risk reduction benefits to accrue through geographic diversification of property holdings. A majority of this research has commenced with a study of correlation structures as a means of providing preliminary information on potential portfolios which are then examined for risk-return performance. For instance Mueller and Ziering (1992) and Mueller (1993) examined the real estate diversification benefits of categorizing local economies by 'dominant industry' rather than by political boundary and found that real estate portfolios constructed of regions based on 'economic' characteristic were more efficient. In a

broader context Eichholtz and Lie (1995) found that there were increasing correlations among real estate markets within continents and decreasing correlations between continents, implying a fall in risk reduction benefits from portfolios constructed on a regional basis but improved benefits from globally constructed portfolios. However, correlation analysis is not the only procedure available for initial asset selection. Tarbert (1998) has raised concern over the dangers of using conventional correlation techniques in preliminary portfolio construction due to the temporal instability of such correlations, pointing to earlier work on this by Baum and Schofield (1991). The main difficulty revolves around the idea that, since correlation coefficients are temporally unstable, a well diversified portfolio initially selected through correlation analysis in one period may not hold in subsequent periods. In a move away from correlation analysis Tarbert (1998) applied cointegration techniques for initial property portfolio selection and found that the potential risk reduction benefits of property diversification by region and sector within the UK were more limited than earlier research by Eichholtz et.al. (1994) had indicated. Informal graphical tests can be conducted to assess the temporal stability of the relationship between any two asset series. This can be done via rolling correlations, measuring the association between groups of, say, 20 paired observations. The window is moved forward one point at a time and the correlation is measured again using the last 20 paired data points. These correlations will be highly dependent on each other but can give a graphical assessment of whether relationships are changing over time. Any notions of temporal instability in correlations are then examined by looking at the changes in correlation structure as the sample is rolled through the series. Further, it is straightforward to conduct Monte Carlo tests using the series of correlations obtained to

assess whether changes have occurred just via natural variation or whether a shift in the relationship may have occurred.

For example, figure 1 plots the change in correlation structure for a rolling correlation between the price returns series for All Office and All Retail (described below) for Australia. The dark heavy lines are 95% confidence intervals for the difference in correlations (obtained by simulation and accounting for the variability in the data and the dependence in the rolling correlations) if the data are normal and the correlation between them is stable at the value of the sample correlation when using all the data (in this case the full sample correlation is 0.44 while the rolling values range from -.21 to +0.82)². From figure 1 it is evident that the relationship between the series appears to shift around significantly about the mid nineties and again in the late nineties as it crosses the 95% lines on several occasions.

Section Three: The Cointegration Approach

If two or more property series are cointegrated then this implies that the series are tied together by some common factor or factors and hence the series will not drift too far apart over the long run. If the series in question happen to be assets held in the same portfolio then the fact that these will behave in a similar fashion over the long run implies reduced, or even no, diversification benefits through holding all of these assets simultaneously. It is an important consideration, therefore, for the portfolio manager to ascertain whether there is a cointegrating relationship between/amongst assets held in the portfolio. A preliminary step in testing for cointegration is to determine whether the series are integrated to the same order. Table 1 presents the outcome from

conventional Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) unit root tests. However, a difficulty with these conventional unit root tests is that they lack power in the presence of potential structural breaks in the series – for instance the tests may fail to indicate whether a series is first difference stationary. Several tests have been developed to ascertain whether a series has a unit root in the presence of potential structural breaks, the most popular of which is that by Zivot and Andrews (1992). The Zivot and Andrews (ZA) methodology followed Perron (1989) in considering three possible types of structural break in a series viz. models A (a ‘crash’ model with no change in growth), B (change in growth, but no change in level), and C (the most general model permitting both occurrences). The ZA models test for stationarity subject to structural breaks in the series. The dummy variable DU_t accommodates a one-time level shift in the series and DT_t a one time trend shift. The breakfraction locates each potential break in the series and is the number of observations up to each breakpoint T_B as a proportion of the total sample (T). For example, in the most general model (model C) the breakpoint DU_t is chosen as the minimum t -value on \mathbf{a} for sequential tests of the breakpoint occurring at time $1 < T_B < T^3$:

Equation 1

$$y_t = \hat{\mathbf{m}} + \hat{\mathbf{q}} DU_t + \hat{\mathbf{b}} t + \hat{\mathbf{g}} DT_t^* + \hat{\mathbf{d}} D(T_B)_t + \hat{\mathbf{a}} y_{t-1} + \sum_{j=1}^k \hat{\mathbf{c}}_j \Delta y_{(t-j)} + \hat{\mathbf{e}}_t$$

where $D(T_B)_t = 1$ if $t = T_B + 1$, 0 otherwise; $DU_t = 1$ if $t > T_B$, 0 otherwise and $DT_t^* = t - T_B$ and $DT_t = t$ if $t > T_B$ and 0 otherwise. Because the Zivot-Andrews methodology is not conditional on the prior selection of the breakpoint the critical values are larger (in an absolute sense) than the conventional ADF critical values, consequently it is more difficult to reject the null hypothesis of a unit root. Our procedure was to apply the most

general test (model C) in the first instance. If that test indicated the series was stationary in first differences the testing ceased (i.e. we did not move forward to consider all possible breaks). If model C was inconclusive we moved to test the more restricted models B and A.

The results of this procedure are also shown in table 1. Here we see that conventional ADF and PP tests indicated that most series were I(1) but in those cases not so indicated we see that once the broader ZA tests were applied all series are shown to be I(1).

Since all series are I(1) there is a suitable environment in which to test for the existence of long run equilibrium relationships amongst the assets. In the first instance a standard Johansen (1991, 1995) cointegration test is conducted. The general autoregressive representation for the vector Y , which contains v assets (series), all of which are I(1)⁴, can be expressed as:

$$Y_t = c + \sum_{i=1}^k \mathbf{p}_i Y_{t-i} + \mathbf{e}_t \quad \text{Equation 2}$$

where c is a constant term and \mathbf{p} is a $v \times v$ matrix of parameters. The maximum lag of the system, k , is chosen so as to ensure that the residuals, \mathbf{e}_t , are white noise. This vector autoregression system may also be re-arranged to yield an error correction model (ECM) representation:

$$\Delta Y_t = c + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-k} + \mathbf{e}_t \quad \text{Equation 3}$$

$$\text{with } \Gamma_j = -(I - \sum_{i=1}^j \mathbf{P}_i) \quad \text{and} \quad \Pi = -(I - \sum_{i=1}^k \mathbf{P}_i)$$

where I is the i identity matrix, \mathbf{P} is known as the long-run matrix while \mathbf{G} provides short-run dynamics. Since the variables ΔY_t and ΔY_{t-1} are $I(0)$, while the Y_{t-k} variables are $I(1)$, the system has the same degree of integration on both sides of the equality only if: (i) $\mathbf{P} = 0$, in which case the Y variables are not cointegrated as there is no long-run equilibrium relationship between them; or (ii) if the parameters of \mathbf{P} are such that $\mathbf{P}Y_{t-k}$ is also $I(0)$. This latter case applies when the Y variables are cointegrated and, in turn, implies that the rank, r , of the matrix \mathbf{P} should be less than the number of variables (assets), v , in the vector Y (i.e. the matrix \mathbf{P} should not be full rank, $0 < r < v$). The rank r is also known as the order of cointegration and is equal to the number of distinct cointegration vectors (cointegrating equations) linking the variables in Y . As Dickey, Jansen and Thornton (1991) point out, the number of cointegrating vectors can be thought of as representing constraints that an economic system imposes on the movements of variables within the system over the long run. In essence, the more cointegrating vectors there are the more 'stable' the system, i.e. the less it can wander from its steady-state equilibrium value. So, for instance, if there are $v-1$ cointegrating vectors then the $v-1$ variables must be solved for in terms of the v^{th} variable. There is only one direction in which the system can wander (i.e. there is only one direction in which the variance is infinite). By way of contrast, if there is only one cointegrating vector, then the v^{th} variable must be solved for in terms of the other $v-1$ variables and hence there are $v-1$ independent directions in

which the system can wander – it is stable in only one direction. So, the fewer the number of cointegrating vectors, the less constrained is the long-run relationship and the more directions in which the system can wander from its steady state equilibrium value. A portfolio manager would want to find as few as possible cointegrating vectors amongst the assets comprising the portfolio since the larger the number of cointegrating vectors the less opportunity exists for risk reduction through diversification.

A potential drawback in applying the above test is that the outcome may be biased if a structural break exists in the series. As Inoue (1999) points out, if a break exists then a conventional testing procedure may mislead the analyst into either accepting the null of no cointegration (in the case of a conventional Engle-Granger test) or the null of a cointegrating rank smaller than the true rank (in the case of Johansen's test).

One solution to this problem has been put forward by Gregory and Hansen (1996). Gregory and Hansen (henceforth GH) devised a methodology for determining cointegration in the presence of a single regime-shift. Specifically, they view their technique as an extension of the univariate ZA test, which Fountas and Wu (1999) have shown to be synonymous to a cointegration test with a prior restriction of the value of one being placed on the cointegration parameter. However the GH test is more flexible since the cointegration parameter is estimated and is not restricted to a value of one. Here, as with the conventional Engle and Granger cointegration test (undertaken below for comparative purposes), the null hypothesis is of no cointegration. However, this is tested against the alternative hypothesis of cointegration with a regime shift. This allows the researcher to test whether cointegration holds over some long period of time, but then shifts to a new long run equilibrium relationship. Gregory and Hansen present three

models - what they refer to as the level shift model (c), the level shift with trend model (c/t and the most general regime shift containing both (c/s) viz:

the level shift model (c) ⁵

Equation 4

$$y_{it} = \mathbf{a}_1 + \mathbf{a}_2 \mathbf{j}_{it} + \mathbf{b}x_{it} + \mathbf{e}_{it} \text{ for } t = 1, \dots, T$$

the slope change model (c/t)

Equation 5

$$y_{it} = \mathbf{a} + \mathbf{b}_1 x_{it} + \mathbf{b}_2 x_{it} \mathbf{j}_{it} + \mathbf{e}_{it} \text{ for } t = 1, \dots, T$$

the most general change model (c/s)

Equation 6

$$y_{it} = \mathbf{a}_1 + \mathbf{a}_2 \mathbf{j}_{it} + \mathbf{b}_1 x_{it} + \mathbf{b}_2 x_{it} \mathbf{j}_{it} + \mathbf{e}_{it} \text{ for } t = 1, \dots, T$$

where $\star_{it} = 1$ if $t > \{N\tau\}$ and 0 otherwise; φ_1 and \dagger_1 are the intercept and slope coefficients before the regime shift, and φ_2 and \dagger_2 denote the changes to the intercept and slope coefficients at the time of the shift; \star_{it} is the dummy variable indicating the time of the regime shift, τ . In line with GH we'll call these models c, c/t and c/s.

Although the break point, τ , is test-determined, a start point still needs to be identified. Following GH, iterations of the relevant model are computed for each period between 15% and 85% of the sample, with the residuals reserved from each iteration. These residuals are then utilized to create three test statistics only one of which is reported here viz the ADF statistic:

Equation (7)

$$ADF^* = \inf_{t \in T} ADF(t)$$

where T is any compact subset $(0,1)$, although in our case $T = (0.15, 0.85)$.

Section Four: Data and Results

Data on direct property series was obtained from the Property Council of Australia (PCA). To avoid the possibility that inflation may be a cointegrating factor in the series all were CPI adjusted. The data used were also GST adjusted i.e. the one-off effect of the GST was 'stripped out' and all data were changed to a December, 1994 base⁶. The PCA data series changed frequency from twice yearly to quarterly from June, 1995. This was dealt with by increasing the frequency for early periods using a linear last match method. This uses a simple linear growth to generate an observation for the missing quarter. The procedure was deemed acceptable as it does not change the nature of the relationship between the variables since each variable is treated the same.

Table 2 presents the outcome from the Johansen cointegration tests applied to several different portfolios. Column one indicates the portfolio and the number of assets making up the portfolio. So, for instance, the General portfolio holds office, retail and industrial assets Australia wide. Column two shows the number of cointegrating equations at the 5% level along with the number of common stochastic trends in brackets, while column three indicates the corresponding trace statistic. The first, and most general observation that we can make is that the Johansen test indicates some degree of cointegration within every portfolio of property assets. The most constrained portfolio, and hence the one likely to offer the fewest (if any) benefits over the long run from geographic diversification, is the portfolio holding industrial property in each capital city. Although industrial activity is primarily driven by the state of the economy, and while the three cities represented lie on the eastern seaboard – i.e.

the most industrialized part of the country - the outcome from the test is not entirely expected since one would anticipate local factors and local input by state governments (tax concessions etc) to play an influencing role in bringing some divergence to industrial activity. On the other hand the outcome may well be explained by the relatively small number of observations on a city by city basis – the constraint being set by Melbourne with 26 observations.

On the basis of the Johansen procedure the portfolio having the greatest potential risk reduction benefit is retail holdings spread across the four main states. Retail sales are less influenced by the state of the economy than other areas (motor vehicles, housing etc.) but would certainly be influenced by local demographic factors (population movements in search of employment, lifestyle and so on...) so it seems reasonable to expect more divergence of movement in retail property over the long term.

The apparent strength of the long run relationship amongst the office markets spread over the capital cities is not surprising – either premium grade or general CBD office. Banking, general finance and insurance are the main users of office space and these industries tend to be driven by similar factors and hence one might expect similar general movements in the asset prices, with some tempering due to local conditions.

The broad outcome from the analysis so far is that, while there may exist some risk reduction benefits through geographic (and sectoral) diversification in Australian property portfolios, it is clear that managers may need much greater consideration of the long run implications of their investment choices.

From our earlier discussion it is evident that the complete story on long run equilibrium relationships cannot be presented without consideration of potential breaks in

cointegrating relationships (and subsequent formation of new long run equilibrium relationships). So, let's consider these same portfolio choices in the presence of potential changes (breaks) in the cointegrating relationship. If both the Johansen tests and the GH tests present outcomes suggesting a long run equilibrium relationship then this is strong evidence of the existence of such a relationship, and some care is clearly needed in the construction of a portfolio containing such cointegrated assets. Table 3 presents the GH tests within each portfolio discussed above (along with conventional Engle-Granger ADF tests for comparative purposes). The strategy here is twofold. In the first instance only the most general GH model (c/s) is tested. If the outcome suggests cointegration (with a change in the cointegrating relationship at the indicated date) then the analysis ceases. If no cointegration is indicated then the c/t model is pursued, followed then by the c model. This is a reasonable strategy since the only purpose here is to discover whether there appear to be long run relationships (in the presence of unspecified change) amongst the assets held in the portfolio. The second part of the strategy is to only pursue the tests on a bivariate basis since the aim is to specifically identify those assets within the portfolio that have a long run relationship. To reduce the size of the table the following practice is adopted: if the portfolio contains more than three assets the assumption is made that, since Sydney/NSW is the premier city and NSW the premier state (not only historically but in terms of economic indicators) then managers may prefer to hold the relevant assets from this city/state as a base for the portfolio. Hence the bivariate analysis is restricted to Sydney/NSW along with consideration of the other assets. Since the smallest value of the ADF test statistic is required to identify a rejection of the null hypothesis, table 3 lists this along with the model type and the break point, τ . In the table

significant values are indicated and are based upon the asymptotic critical values given by Gregory and Hansen (1996) (while significant values for the Engle-Granger tests are those from McKinnon (1991)). Like the ZA test the GH test considers each possible point in the series as a potential break candidate and sequentially tests each point with the lowest ADF t-value emerging as the chosen period. In figure two we present a visual impression of one such test for a possible cointegrating relationship between the Sydney and Melbourne office markets. In this instance the GH general model suggests that the markets are cointegrated and that a change in the cointegrating relationship occurred about mid-1988.

Portfolio one is a general sectoral portfolio comprising office, retail and industrial holdings Australia wide. From table 2 we know that Johansen suggested one cointegrating vector. In table 3 conventional Engle-Granger results show that irrespective of which asset is considered the 'driver' there is no cointegrating relationship between any pair of assets. On the other hand the GH results indicate firstly that those factors driving office and industrial markets will also have an influence on retail property, but not vice-versa. This appears reasonable. The office and industrial sectors of the economy are far more dependent on general economic conditions than retail markets and this would have flow through effects to space users. While retail is less susceptible to general movements in the economy it does not mean that this sector is not susceptible at all, hence it seems reasonable to suppose that in a model which carries office and industrial on the RHS there would be flow through effects. On the other hand the retail sector is less driven by general economic conditions, therefore when retail is treated as a RHS variable there may well be few flow through effects to the other sectors since retail

will not move as much with changes in the economy. This raises serious questions on the proportions of each of these assets that should be held.

Portfolio two contains CBD office space in each of the capital cities. Table 2 showed that there was very little scope for independent movement amongst assets in the portfolio (two common stochastic trends) while again the conventional Engle-Granger test indicates no paired cointegrating relationship, implying that all of these assets could potentially be held in the same portfolio. However, once the possibility of a structural break in the cointegrating relationship is accounted for a very different picture emerges. First, the results support Johansen and indicate that there may be very reduced benefits from holding the eastern seaboard office assets in the same portfolio since, for each pair of such assets there is a significant cointegrating relationship. By way of contrast, while all eastern seaboard with other bivariate combinations were not considered, there is evidence to indicate that some such asset combinations may possess long run diversification benefits. In other words, while similar factors appear to drive the eastern seaboard office markets these same factors may be less influential in driving other office markets. For example, there is no cointegrating relationship when Sydney office is combined with Perth office.

The portfolio of premium office space presents a somewhat mixed result compared with the general CBD office portfolio. The Johansen results in table 2 have already indicated a tendency for some of these assets to trend together over the long run (two cointegrating vectors amongst the four assets). In table 3 both the GH test and the conventional Engle-Granger approach suggest that only Sydney and Melbourne do not have a cointegrating relationship. On the other hand, the combinations of holding

Sydney premium office with each of the other cities may be inadvisable since a cointegrating relationship does exist, with a change in the nature of the relationship at the indicated date, mostly mid 1996. In addition, even the Engle-Granger test supported this outcome in the case of Sydney and Brisbane.

The Johansen test suggested that the retail portfolio possessed the greatest potential for diversification benefits in own class asset holdings with three common stochastic trends amongst the four assets and this outcome is certainly supported by the Engle-Granger results in table 3 which indicate no cointegrating relationships. However this picture changes somewhat once the possibility of breaks are taken into account. For example, there are cointegrating relationships between retail assets in NSW and both Victoria and Western Australia. Similarly there is a cointegrating relationship between retail assets in Western Australia and Queensland (here we have expanded our 'rule' of anchoring the portfolio with NSW). So, while the potential still exists for geographical diversification in retail holdings the picture does not appear quite as rosy as the outcomes from the Johansen and Engle-Granger tests indicated.

Summary and Conclusion

Other research had expressed concern that since correlation structures are temporally unstable the use of correlation for initial asset selection for a property portfolio maybe inadvisable. In the present paper a brief example of such instability for Australian real estate was presented to support this notion. Under such circumstances it was suggested that it may be unwise to construct diversified portfolios on the basis of changing correlation structures. Since investors in direct property are likely to take a

long view other research suggested that an alternative approach to initial asset selection may be to use the cointegration methodology. However, in the presence of structural breaks conventional cointegration methodology may not present a true indication of the potential existence of long run relationships. Under such circumstances property portfolios initially constructed on the basis of selection criteria using cointegration analysis may not contain the diversification benefits at first thought. This was shown to be the case in Australia where, using a cointegration methodology that accounts for structural breaks, it was seen that portfolios of property assets diversified by region or sector are likely to be smaller (contain fewer assets) than may have been previously assumed to be appropriate.

Table 1
Unit Root Tests on Series*

Asset Type		Levels		Differences		ZA (Model) Break
		ADF	PP	ADF	PP	
General	Office	-2.94	-1.51	-2.01	-1.71	-5.37 (C) 1994Q2
	Retail	-3.12	-1.92	-2.65	-3.60	-6.33 (C) 1990Q3
	Industrial	-2.62	-0.76	-1.68	-2.28	-5.39 (C) 1992Q4
	Premium Office	-3.11	-1.66	-1.76	-2.02	-5.22 (C) 1994Q4
CBD Office	Syd	-2.92	-1.66	-2.25	-1.95	-5.14 (C) 1994Q2
	Mel	-3.43	-1.33	-1.38	-1.94	-6.07 (C) 1994Q2
	Bris	-2.38	-1.79	-2.02	-3.18	-6.27 (C) 1996Q3
	Adel	-1.95	-2.66	-1.38	-1.89	-5.74 (C) 1995Q1
	Per	-3.23	-1.39	-1.43	-2.17	-5.46 (C) 1994Q4
Premium & A grade	Syd	-2.92	-1.77	-2.30	-2.13	-5.18 (C) 1993Q3
	Mel	-3.19	-2.89	-1.80	-1.76	-5.80 (C) 1999Q4
	Bris	-2.06	-1.40	-2.06	-2.61	-5.28 (C) 1993Q1
	Per	-2.76	-0.86	-1.30	-1.82	-8.36 (C) 1992Q1
Retail	NSW	-2.54	-2.12	-2.92	-3.83	-6.20 (C) 1990Q3
	Vic	-2.48	-2.06	-3.61	-4.25	-6.16 (C) 1992Q1
	Qld	-2.55	-1.66	-2.90	-4.28	-5.59 (C) 1998Q1
	WA	-1.87	-1.53	-2.30	-4.43	-6.38 (C) 1988Q3
Industrial	Syd	-2.55	-0.61	-1.59	-2.33	-5.22 (C) 1992Q4
	Mel	-1.80	-2.08	-2.53	-3.57	insufficient data
	Bris	-0.43	-1.55	-2.53	-4.83	insufficient data
CVs	ADF and PP			ZA		
	Levels			Model A	Model B	Model C
	Diff					
1%	-4.11	-2.60		-5.34	-4.93	-5.57
5%	-3.48	-1.95		-4.80	-4.42	-5.08
10%	-3.17	-1.62		-4.48	-4.11	-4.82

* PP and ADF tests undertaken with the Newey-West suggestion of 3 lags. All ZA tests taken to last significant lag.

Table 2
Johansen Cointegration Tests*

Number	Portfolio Construction	No. of Vectors at 5% level (vs No. Stochastic Trends)	Cointegrating level (vs Stochastic Trends)	Corresponding Trace Statistic
One	General-3 assets Australia wide) – Office, Retail, Industrial	1	(2)	14.82
Two	CBD Office –5 assets (Syd, Mel, Bris, Adel, Perth)	3	(2)	14.15
Three	Premium and A grade Office – 4 assets (Syd, Mel, Bris, Perth)	2	(2)	7.65
Four	Retail – 4 assets (NSW, Vic, Qld, WA)	1	(3)	22.49
Five	Industrial – 3 assets (Syd, Mel, Bris)	2	(1)	0.03

* Test assumption: Linear deterministic trend; lags (in first differences) based on mid-point selection based on AIC and SC criteria.

Table 3
Gregory-Hansen and Engle-Granger Procedures

PORTFOLIO TYPE (from earlier)	GREGORY-HANSEN (Model type) Break Period	ENGLE-GRANGER
ONE – General Property		
RETAIL-OFFICE	-5.19 (c/s) ² 1994 June	-2.68
OFFICE-RETAIL	-3.69 ^a	-2.81
RETAIL-INDUSTRIAL	-5.03 (c/s) ² 2000 June	-2.91
INDUSTRIAL-RETAIL	-3.61 ^a	-2.85
OFFICE-INDUSTRIAL	-4.14 ^a	-2.16
INDUSTRIAL-OFFICE	-5.07 (c/s) ² 1994 Dec.	-1.44
TWO – CBD Office		
SYD-MEL	-6.34 (c/s) ¹ 1988 June	-1.59
MEL-SYD	-5.76 (c/s) ¹ 1988 June	-1.14
SYD-BRIS	-5.33 (c/s) ² 1990 Dec	-2.00
BRIS-SYD	-5.50 (c/s) ¹ 1990 Dec	-3.44
SYD-PER	-4.51 ^a	-2.05
PER-SYD	-4.43 ^a	-1.73
SYD-ADL	-4.91 (c/s) ³ 1986 Dec	-1.61
ADL-SYD	-5.21 (c/s) ² 1986 Dec	-2.62
THREE – Premium Office		
SYD-MEL	-4.20 ^a	-1.61
MEL-SYD	-4.35 ^a	-1.61
SYD-BRIS	-5.16 (c/s) ² 1996 Mar	-3.91 ³
BRIS-SYD	-5.04 (c/s) ² 1996 Mar	-3.87 ³
SYD-PER	-5.17 (c/s) ² 1996 June	-3.47
PER-SYD	-5.02 (c/s) ² 1993 June	-3.35
FOUR – Retail		
NSW-Vic	-4.82(c/s) ³ 1991 Dec	-2.80
Vic-NSW	-5.39 (c/s) ² 1996 Mar	-1.98
NSW-QLD	-4.07 ^a	-2.02
QLD-NSW	-3.96 ^a	-1.61
NSW-WA	-4.62(c) ² 1990 Mar	-2.89
WA-NSW	-5.50 (c/s) ² 1989 Dec	-2.14
QLD-VIC	-3.87 ^a	-2.46
VIC-QLD	-4.0 ^a	-2.06
WA-QLD	-5.11 (c/s) ² 1988 Sept	-1.57
QLD-WA	-4.27 ^a	-3.10

1 – significant at the 1% level; 2 – significant at the 5% level; 3 – significant at the 10% level; a – not significant at any level for any model.

Figure 1

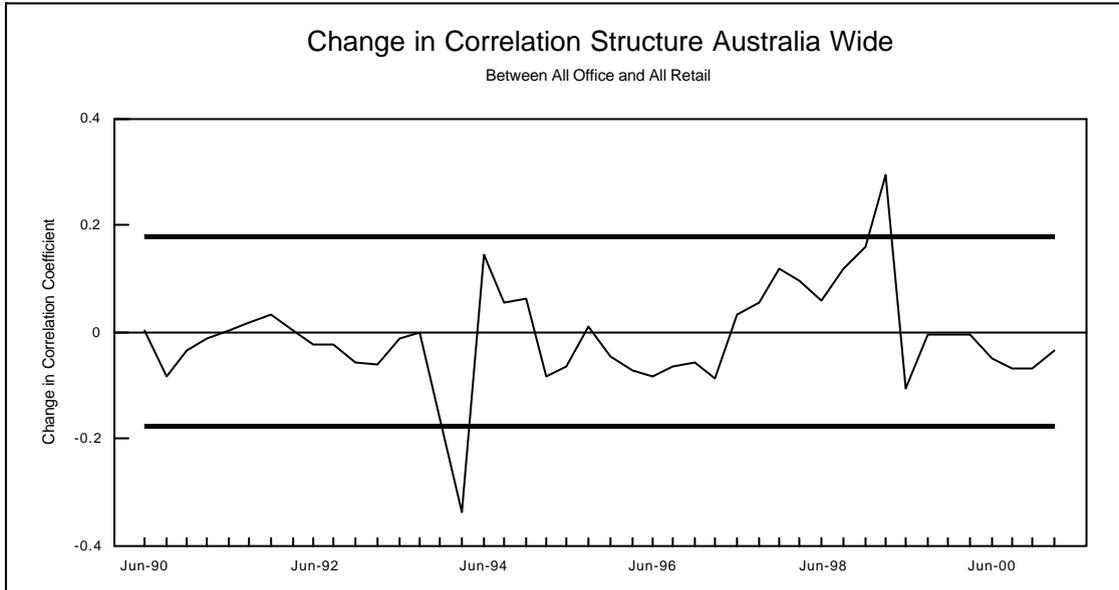
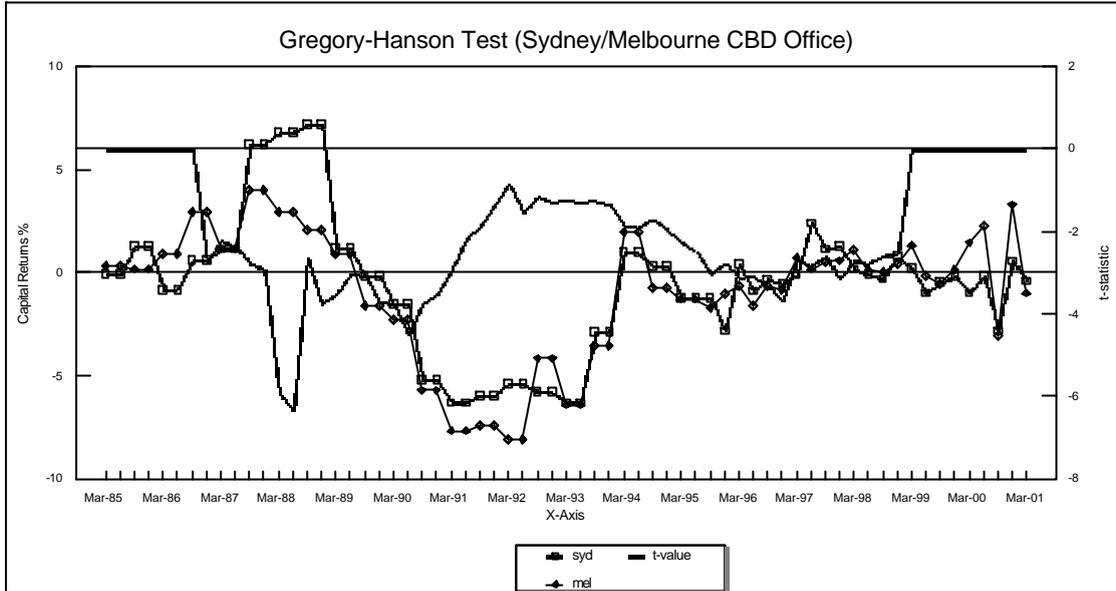


Figure 2



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¹ A structural break refers to a shift in the level and/or slope of a series. The Johansen test may be more robust than the Engle-Granger in the presence of a structural break

² To account for variability we select the overall correlation, mean and variance between the two series and simulate 10,000 sets of observations of the same length with the equivalent correlation structure. For each of the 10,000 series we then undertake rolling correlations.

³ The more restricted models were:

Model A

$$y_t = \hat{\mathbf{m}}^A + \hat{\mathbf{q}}^A DU_t(\hat{\mathbf{I}}) + \hat{\mathbf{b}}^A t + \hat{\mathbf{a}}^A y_{t-1} + \sum_{j=1}^k \hat{\mathbf{c}}_j^A \Delta y_{(t-j)} + \hat{\mathbf{e}}_t$$

Model B

$$y_t = \hat{\mathbf{m}}^B + \hat{\mathbf{b}}^B t + \hat{\mathbf{g}}^B DT_t^*(\hat{\mathbf{I}}) + \hat{\mathbf{a}}^B y_{t-1} + \sum_{j=1}^k \hat{\mathbf{c}}_j^B \Delta y_{(t-j)} + \hat{\mathbf{e}}_t$$

where the superscripts merely refer to models A and B and breakpoint indices etc. have the same interpretation as in the body of the paper.

⁴ Cf. Muscatelli and Hurn (1995)

⁵ Which Gregory and Hansen (1996a) specify both with and without trend.

⁶ The 'stripping out' effect was undertaken by the PCA