The Examination of the Degree of Integration among Art Markets

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Abstract

This paper applies the Johansen Cointegration procedure to test the law of one price (LOOP) for twelve international markets of paintings using semi-annual data for the period 1985-2007. Cointegration test is performed in a pairwise arrangement. Price index for each market is estimated using the repeat sales method. The order of integration of each price series was determined using the augmented Dickey-Fuller and the DF-GLS tests. The results show that only five price index series were I(1). The Johansen bivariate test supports the validity of the LOOP hypothesis only three pairwise systems out of the 66 systems, suggesting weak relationships among international art market.

1 Introduction

There has been empirical research on spatial price linkages and interactions of commodity and equity markets, but despite the importance of the size of fine artworks markets and the growing importance as a component in a mixed-asset diversified portfolio, little is known about the level of integration among international marketplaces of fine art. It is widely acknowledged that the identification of the degree of market integration is beneficial for investors in their

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financial portfolios diversification strategies. The lower levels of correlations among assets in a portfolio, the greater will be the benefits from diversification. The benefits can be further increased by including assets from different markets.

The value of international trade in fine art is estimated to be in excess of $8bn in 2008, which represents more than 100 times the value in 1970. The US market is the leading market place for international fine art sales with about a third of total international market sales. The top houses which experienced most of the world sales are those in USA and UK, and to lesser degree France, Italy and the Netherlands (Artnet, 2009).

An important issue in analysing the international market for fine artworks is whether the market is a single market or a series of geographically distinct markets. In this context, the theory of the Law of One Price (LOOP) suggests that there is a single price for a particular commodity, irrespective of where it is sold. That is, efficient arbitrage and trade activities ensure that prices of commodities sold by different auctioneers in a market tend to uniformity, although deviations from this may occur in the short-run (Jung and Doroodian, 1994). The violation of LOOP may reflect significant segmentation of international markets, as well as it may reflect difference in the auction structure and competitive conditions.

Whether the Law of One Price (LOOP) holds for any set of given prices or not has some implications for the econometric estimation and testing procedures of the prices of commodities. If the LOOP is true, then the prices under consideration are cointegrated, and so the markets involved have to be modelled simultaneously. Otherwise, there may be biased estimation by disregarding price movements in the other markets (Jung and Doroodian, 1994). On the other hand, the failure of the prices of similar goods to equalise between the various markets is a sign that the markets are not completely integrated. Another implication of finding cointegration among price variables is that changes in the prices of lumber in one region will lead to changes in other regions, i.e. the various markets are not independent.

In the literature, many studies have investigated price integration among geographically separated markets by the means of cointegration analysis; Nielsen, Smit, and Guillen (2009) on market integration of fish in Europe; Maloney (1999) on the impact of exchange rate uncertainty on the Law of One Price; Salas-Fumas and Saurina, (2007) on integration in retail banking; Richards (1995) on comovements in national stock returns; Vo (2009) on internationa financial integration in Asian bon markets). In the art market, research has examined the behaviour of art prices by constructing hedonic and repeat sales prices indexes and investigated their financial properties. The degree of integration and internationalisation of international art marketplaces was examined using cointegration analysis and the findings are mixed. The earliest study of co-movements of international art prices is by Ginsburgh & Jeanfils (1995). They estimate hedonic price indexes for the period 1963-1992, for the three categories: Great Masters, Other Painters and US Painters, which were traded in the three key international art markets, London, Paris and New York. Using a VAR (vector

autoregressive) system, they show that art markets indeed move closely together. They also examine art and stock markets' short-run and long-run co-movements. This study finds no support for long-run relation between art and stock markets but confirms the presence of short-term influences of stock markets on art prices.

Another study by Worthington and Higgs (2003) examines the short- and long-run linkages of prices among eight major painting categories and the global equity market for the period 1976-2001. The analysis focuses on the inner dynamics of the international paintings markets and their reactions to general financial market conditions. This study uses multivariate cointegration procedures, Granger non-causality tests, level VARs, and generalised variance decomposition techniques to identify the presence (or lack thereof) and the degree of linkages among these markets. They find strong evidence for the high level of integration of international art markets for short and long-time period spans with significant interrelationships between major stock markets and art markets.

The purpose of this paper is to examine the degree of integration among fine art markets in different countries. In this context, twelve markets are selected, which are selected: US, UK, France, Italy, Germany, Austria, Sweden, Belgium, the Netherlands, Denmark, Canada and Switzerland. These countries are the largest marketplaces for artworks across the globe. Integration is investigated for repeat-sale semi-annual country price indexes in dollar terms covering the period from January 1985 to June 2007 and by the means of cointegration analysis, which measures long-term relationships. We test the validity of the law of one price (LOOP) for paintings across different international markets. Two empirical issues motivate our study of spatial market integration: first, whether or not markets are integrated and; second, the direction of causality between markets and whether one market dominates another. Unit roots tests and the Johansen cointegration test are performed to determine the stability and the presence of cointegration in the data. Pairwise analysis is used to test for which pairs of prices the LOOP is in force.

The paper is organised as follows. The next section describes the data sources and methodologies applied. Empirical results are evaluated in Section 3. The final section concludes.

2 Data and estimation Methodology

2.1 Data sample

The repeat sales data set contains information on 43,069 repeat sales transactions regarding oil painting and works on paper auctioned worldwide between January 1995 and June 2007. The repeat sales observations are derived from the hedonic data set that contained over 2 million transactions. A number of transactions were removed for reasons of validity. Artworks that were sold more than twice in the same time (month, quarter) were excluded. Only artworks sold

twice or more could be used here, pertaining to less than 10% of all transactions. Our data set contains repeat-sales that were occurred within one single market. Twelve international markets are selected due to the availability of data for these markets.

2.2 Construction price indexes using the repeat sales method

The hedonic (Chanel, & Gérard-Varet, and Ginsburgh, 1996; Czujack, 1997) and repeat-sales (Mei and Moses, 2002; Pesando and Shum, 2008) regression models are two main methods that have been used extensively in the literature to construct price indexes for the art markets. The hedonic method constructs a price index that is quality-adjusted for the items' attributes. Sale prices are a modelled as a function of a number of paintings attributes and a constant term for each time period. While the hedonic attributes account for the quality of paintings sold at any given time period, the time intercepts control for any trend in painting prices over the period. Alternatively, the repeat-sales approach restricts the analysis to paintings that have been sold at least twice within the observational period. It ignores the hedonic attributes and assumes that these are unchanged.

To develop price indexes for the art national markets in our sample, we adopt the repeat-sales method. Consider a sample of paintings that are purchased and sold at various time point (t and t+1), the following equation is estimated:

$$\ln\left(\frac{P_{i,t+1}}{P_{i,t}}\right) = \sum_{t=1}^{n} \beta_t \, D_{i,t} + \varepsilon_{i,t} \tag{1}$$

where P_{it} is the price of first sale in period t, and $P_{i,t+1}$ is the price in the second sale at t+1, D_t equals -1, for the first sale in period t, 1 for the second sale in period t+1, and 0 otherwise. *ln* is the natural logarithm.

2.3 Unit root test and order of integration

An cointegrating relationship implies that time series move together so that a stable relationship between them is maintained. Any short-run disturbance away from this relationship induces changes in the prices so that the relationship is maintained in the long run. In this sense, cointegration implies that a long-run equilibrium exists (Engle and Granger, 1987; Granger, 1988). Since a cointegrating relationship cannot exist between two prices which are integrated of a different order, it is necessary to test for their order of integration. That is, a prerequisite in the application of cointegration analysis is to test the unit root properties and determine the order of integration of the time series under observation. The subsequent test for cointegration is a formal test of the long-run equilibrium relationship between pair-wise prices. In our study, two unit root tests are used: the augmented Dickey-Fuller (ADF) and the DF-GLS test.

The augmented Dickey-Fuller test examines whether a time series follows a unit-root-process (a random walk). The null hypothesis is that the time series contains a unit root, and the alternative id that the series was generated by a stationary process (Dickey and Fuller, 1979). The critical values are obtained from (MacKinnon, 1991)). The maximum lag is determined according to the Newsty-Newy procedure, while the optimal lags is obtained using the AIC and SIC values. For the ADF test, three models are considered, with constant, with trend and without constant and trend. The null hypothesis in both tests is the presence of unit root.

The DF-GLS test which was proposed by Elliott, Rothenberg, and Stock (1996) is used to test for unit root in. The test is an augmented Dickey-Fuller test except that the time series is transformed via a generalised least squares (GLS) regression before performing the test. The maximal lag, k_{max}, included in the equation test is determined as proposed by Shwert (1989). The optimal lag length, k, is determined by three methods: the Ng-Perron sequential t, the Schwarz information criterion (SIC) and Ng-Perron modified Akaike Information Criteria (MAIC). The optimal lag length is the one that minimises the two criteria AIC and SIC. The null hypothesis of the test is that y_t is a random walk, possibly with a drift. There are two possible alternative hypotheses: y_t is stationary about a linear time trend or y_t is stationary with a possibly nonzero mean but with no linear trend.

2.4 Cointegration test and Johansen approach

Time series that are referred to as being cointegrated are time series that have the same order of integration and the linear combination of these series is also stationary (Engle and Granger, 1987). Cointegration implies that time series move in the same direction in the long-term. Granger (1986) notes that the error term resulting from a linear combination of the cointegrated time series determines the degree of deviation of the time series from their common long-term relationship, and consequently can be used to forecast their future values.
Accordingly, the existence of a cointegration relationship between time series is equivalent to the consideration of an error correction mechanism (Granger's representation Theorem). Therefore, to test for the existence of a cointegrating relationship, a vector error model (VECM) is estimated:

$$\Delta X_i = \sum \Gamma_i \, \Delta X_{i\text{-}t} + \Pi \, X_{t\text{-}1} + \mu + \varepsilon_t, \tag{2}$$

where $\Gamma_i = -I + \Pi_1 + ... + \Pi i$, with i=1...., k-1 and $\Pi = -(I - \Pi_1 - .... - \Pi_k)$ (Johansen, 1991). The vector X_t contains the set of endogenous variables and has the dimension of p x 1, where p is the number of endogenous variables. μ is a p X 1 vector of deterministic variables. ε_t, is independent and identically distributed error which follow normal distribution with zero mean.

The Johansen method of cointegration determines the rank (r) of the long-term coefficient matrix Π belonging to the error correction term X_{t-1}. If the rank (r) of the matrix Π is greater than zero or less than the number of endogenous variables, the matrix with the dimension p x r can be decomposed into the matrices α and β, so that $\Pi = \alpha\beta'$. The resulting matrix of α contains the adjustment coefficients to the long-term relationship, while the matrix β contains the coefficients of the cointegration relations. Johansen (1988) proposes two test statistics to determine the number of long-term relationships cointegration rank). These are: the "trace statistics" and the "maximum eigenvalue test", which both are based upon a likelihood ratio test

$$\lambda_{trace} = -T \sum_{i=r+1}^{p} \ln\left(1 - \hat{\lambda}_i\right) \tag{3}$$

and

$$\lambda_{max} = -T \sum_{i=r+1}^{p} \ln\left(1 - \hat{\lambda}_{r+1}\right) \tag{4}$$

Both test statistics are distributed asymptotically as Chi-squared with p-r degrees of freedom (Johansen, 1991). The parameters of the system are estimated using the maximum likelihood test.

The failure to reject the null hypothesis of no cointegration between two indexes, e.g., UK and USA, implies that there exists a long-run relationship between these two markets. The relationship, however, may be disturbed by short-term deviations from equilibrium and thus an error correction model (ERM) is used to investigate the flow of information between these markets.

The coefficients $\alpha 1$ and $\alpha 2$ are the speed of adjustment coefficients that help in assessing the lead-lag structure of the markets, if $\alpha 1 > \alpha 2$, this suggests that Market 1 responds more vigorously to short-run disequilibrium that does market 2. Furthermore, at least one if these coefficient must be significant in order for the ECM to hold. If both coefficients are significant, this suggests that both markets exert a long-term relationship that is, there exist a feedback mechanism between these markets. If however, only $\alpha 1$ is found significant and $\alpha 2$ is insignificant, this suggests Market 1 influences Market 2 but not verse versa.

2.5 Market integration and market leaders

A specific restriction of the cointegration vector can be tested if it is linearly restricted so that H_β: $\beta = H\varphi$ where H is a p x s matrix of known parameters with s as the number of unrestricted cointegrating parameters. The corresponding LR-test is asymptotically distributed as X2 with r(p-s) degrees of freedom (Johansen, 1995, p107).

Following Nielsen, Smit and Guillen (2009), we undertake test for the LOOP for the series that are cointegrated. The LOOP is tested by imposing restrictions on the β matrix following. The β matrix is obtained by decomposing

the matrix II into αβ' where α contains the adjustment coefficients and β the cointegrating vectors. To test for the validity of LOOP in a cointegrating relationship; we impose restriction on the β matrix where the sums of the coefficients is equal to zero.

Furthermore, we test whether the Law of One Price (LOOP) holds between the different international fine art markets, which states that prices move in closely in the same direction (perfect or close market integration). The violation of this hypothesis may be a reflection of differences in the quality of artworks, transportation costs, market competitive conditions, etc. We test for the LOOP by imposing the following restriction on the cointegrating vector β = (1, -1). The hypothesis states that the price differences at different markets are rather negligible such that both prices fluctuate around the same level in the long-run, i.e., a cointegrating vector has zero mean.
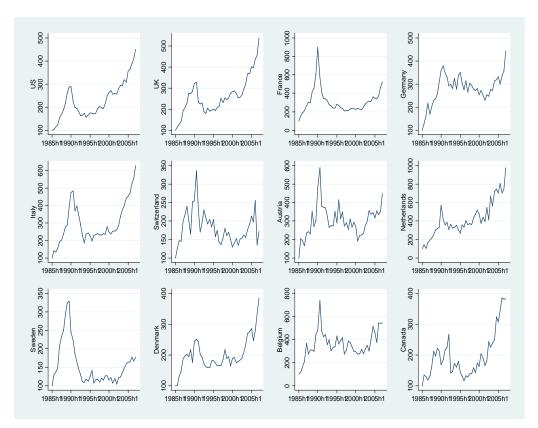
Nielsen, Smit and Guillen (2009) identify three forms of markets integrations that could be applied to the international art market; close, partial and loose. First, when a cointegration test identifies a relationship between two times series, and that the LOOP is valid, the goods which are traded are homogenous, and prices tend to move together and therefore the two markets are closely integrated. Second, if a cointegration is established and that the LOOP is not in force, the analysed goods are heterogeneous (imperfect substitutes) and the two markets are partially integrated. Third, if integration is found between say markets A and B, and another between B and C, but no integration between A and C, the then markets A and C are loosely integrated. The inexistence of a cointegrating relationship between two series indicates that the two markets are separate and therefore are not integrated.

In addition, following cointegration tests, we undertake tests of weak exogeneity of cointegrated times series to identify causal relationships in integrated markets to identify the market leader in each bivariate system. Weak exogeneity is tested by imposing restrictions on α, following Juselius (2006). That is, we separately test the null hypothesis that $\alpha_1 = 0$ and $\alpha_2 = 0$, using sing the LR-statistics. If the lag included (k) is equal to one, this is equivalent to testing Granger non-causality.

3 Empirical results

3.1 Repeat-sale price indexes and returns

Figure 1 provides plots of (log) price art price index for each market over the sample period. The plots show that over the period all markets have been characterised by upward sloping trends in the initial period then a decline in the early 1990s. From the mid-1990s, the plots show an overall upward trend for the markets of Australia, Canada, Italy, Netherlands, UK and US. In other markets, the movements of the art price index have been of mixed trend. Based on Figure 1,

it would appear that there are some aspects of shared art price movements among national art prices.

Figure 1: Repeat sale price indices

Table 1 presents statistics on the sample of returns from art markets for the countries derived from the repeat-sale price indexes. Table 1 shows that the art markets in the US, UK and Italy have mean returns that are significantly different from zero. In other markets, the mean return is not significantly different from zero. Highest mean return is found for the Dutch and Italian markets, whereas the lowest mean returns are exhibited in the Swiss, Swedish and Australian markets. Regarding market risk, measured by coefficient of variance, the Swiss market has the highest risk level, followed by the Swedish and Australian markets. The US and UK markets have the lowest risk levels. The values of the Jarque-Bera statistic in Table 1 indicate that France and the UK are the only markets in our sample that do not have normally distributed returns. In all other markets, the normality hypothesis cannot be rejected.

A preliminary analysis of the relationships among the various markets in the sample can be carried out using the correlation matrix which is reported in Table 2. All correlations are positive overall but with different levels of significance. Higher levels of correlations with statistical significance are observed among the group of US, UK, France, Italy and Sweden. Australia and Canada have no statistically significant coefficients of correlation in any pair under observation. In addition, it seems that the degree of correlation between markets has, on average, been stronger between the UK and other European countries than between the US and other European countries. The Italian, French and Swedish markets are also correlated with other European markets.

3.2 Unit root tests

The cointegration analysis requires that the non-stationary time series which formulate a cointegrating relationship have the same order of integration. Therefore, unit root test are applied to all price indexes under consideration. We expect that the order of integration is one; $I(1)$, as many studies dealing with time series data show a unit root in levels. For this purpose, we carry out two unit root tests: the ADF by Dickey-Fuller (1979) and the DF-GLS by Elliott, Rothenberg, and Stock (1996). The critical values for the tests are obtained from MacKinnon (1991).

The results of the unit root tests are reported in Table 3. Panel 1 reports the results of the DF-GLS test whereas in Panel 2, the ADF results are reported. The test statistic (ADF and DF-GLS) is estimated in the form of the three models (no constant, no trend, trend and constant). For all price series under observation, the null hypothesis that the price indexes had a unit root in levels cannot be rejected at the 5%. However, the results show that the null hypothesis that first differences of the price series are not stationary can be rejected at the 5% critical level. Based upon these results, there is evidence that the price indexes under study are integrated of order one, i.e. $I(1)$. From both tables all time series time series are stationary at first difference in all three models, except for Sweden series which is found to be stationary in levels using the DF-GLS test. It can be inferred that the variable is integrated of order 1. Hence we can process to test for cointegration of the price indexes for the art market under the observational period.

Table 1: Descriptive statistics for returns

Variable	Mean	S.D.	C.V.	Min	Median	Max	Skewness	Kurtosis	J-B
US	0.0342**	0.0870	2.54	-0.2465	0.0417	0.2219	-0.70	1.60	7.19
UK	0.0383**	0.1058	2.76	-0.3392	0.0380	0.3195	-0.81	3.63	5.54**
France	0.0376	0.1658	4.41	-0.4431	0.0136	0.4364	-0.11	1.64	3.48**
Italy	0.0418**	0.1347	3.22	-0.2675	0.0368	0.3492	-0.23	0.26	14.15
Germany	0.0338	0.1267	3.75	-0.2490	0.0330	0.2910	-0.02	-0.68	24.83
Sweden	0.0130	0.1281	9.85	-0.2939	0.0429	0.3374	-0.21	0.47	12.06
Denmark	0.0306	0.1176	3.84	-0.2122	0.0255	0.3290	0.18	0.19	14.71
Belgium	0.0385	0.2186	5.68	-0.4481	0.0264	0.5528	0.04	0.05	15.97
Switzerland	0.0122	0.1963	16.10	-0.6339	0.0594	0.4195	-0.80	1.67	7.94
Canada	0.0305	0.1684	5.52	-0.6411	0.0466	0.3010	-1.35	4.57	17.88
Austria	0.0342	0.2256	6.60	-0.4395	0.0253	0.7195	0.57	1.06	9.28
Netherlands	0.0518	0.2116	4.08	-0.3314	0.0570	0.5389	0.30	-0.23	19.29

Returns are measures as the change in logarithm of the price index
S.D. denotes the standard deviation of the returns and C.V. denotes coefficients of variation calculated as the standard deviation divided by the mean.
J-B is the Jarque-Bera test for normality.
** Statistically significant at the 5% critical level.

Table 2: Correlation estimates between returns

	US	UK	France	Italy	Germany	Sweden	Denmark	Belgium	Switzerland	Canada	Austria
UK	0.626*										
France	0.563*	0.537*									
Italy	0.311**	0.546*	0.545*								
Germany	0.226	0.216	0.395*	0.238							
Sweden	0.515*	0.463*	0.394*	0.353**	0.083						
Denmark	0.278***	0.427*	0.353**	0.107	0.281***	0.184					
Belgium	0.072	0.378**	0.305**	0.421*	0.200	0.298**	0.346**				
Switzerland	0.035	0.354**	0.200	0.344**	0.213	0.218	0.102	0.538*			
Canada	0.146	0.186	0.008	0.150	0.116	0.274***	-0.016	0.041	-0.024		
Austria	0.081	0.408*	0.508*	0.508*	0.173	0.279***	0.110	0.237	0.135	0.128	
Netherlands	0.170	0.212	0.414*	0.404*	0.267***	0.057***	0.069	-0.050	-0.024	-0.199	0.427*

*, ** and *** denote statistical significance at the 1, 5 and 10% critical levels.

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Table 3: Unit root test results

Unit root test	Panel 1: DF-GLS								Panel 2: Augmented Dickey-Fuller (ADF)							
	Levels				First Differences				Levels				First Differences			
	Lag	no trend	Lag	Trend	Lags	no trend	Lags	constant & Trend	lags	No constant/trend	Constant	Constant & Trend	lags	No constant/trend	Constant	Constant & Trend
US	1	0.598	1	-2.948	0	-4.106	0	-4.106	1	1.452	-1.363	0.481	0	-3.697	-4.06	-4.004
UK	1	1.120	1	-2.481	0	-4.598	0	-5.387	1	1.741	-1.235	-1.861	0	-5.142	-5.586	-5.484
France	2	-1.252	2	-2.771	0	-2.76	0	-3.770	2	0.576	-1.999	-1.966	0	-4.803	-4.812	-4.677
Italy	0	0.120	1	-2.306	0	-3.266	0	-4.578	1	1.275	-1.018	-1.386	0	-4.803	-4.812	-4.677
Germany	0	-0.484	1	-1.600	0	-4.552	0	-6.61	2	1.117	-2.399	-2.45	0	-6.896	-7.225	-7.205
Sweden	1	-5.049	1	-3.920	0	-3.731	0	-4.967	1	-0.197	-1.458	-1.517	0	-5.839	-5.777	-5.673
Denmark	1	0.981	1	-1.402	1	-3.416	1	-3.565	1	1.571	-1.813	-2.200	0	-6.040	-6.378	-6.296
Belgium	1	-0.342	1	-1.826	1	-4.077	1	-4.572	4	0.738	-1.592	-1.610	0	-7.482	-7.631	-7.688
Switzerland	3	-1.670	3	-1.784	1	-2.335	1	-3.842	2	0.080	-2.652	-3.120	0	-8.635	-8.547	-8.552
Canada	1	1.376	1	-1.806	1	-2.018	1	-4.178	1	1.134	-0.752	-1.369	0	-7.874	-7.994	-7.955
Austria	1	-0.344	1	-1.545	0	-3.521	0	-6.169	1	0.785	-2.432	-2.393	0	-9.641	-9.649	-9.463
Netherlands	1	1.207	1	-1.949	1	-2.157	1	-3.592	2	1.981	-2.256	-3.152	0	-10.395	-11.196	-11.086

3.3 Bivariate cointegration analysis

Since we have found that the price indexes are integrated of order one, we use the Johansen procedure to identify the number of cointegration relationships across bivariate models. We carry out the cointegration test for each market pairs. As we have 12 market in our sample, the bivariate combination generated 66 country pairs.

Table 4 presents the results of the Johansen cointegration test. The trace and the maximal eigenvalue test statistics are reported for each pair system. The trace statistic is used to test for the null hypothesis of no cointegrating relationship (i.e. r = 0) against the alternative that r > 0. The maximum eigenvalue test is utilised to test the null hypothesis of no cointegration (r = 0) against the alternative that the number of cointegrating vectors is r + 1. In the bivariate combinations presented in Table 4, the trace test shows that the null hypothesis of r=0 is rejected in favour of r=1 in 21 models. This implies that the times series involved in each model of the 21 model are cointegrated, and therefore we conclude that there is cointegrating relationship between them.

Table 4 provides some evidence to support the presence of a long-run relationship across the corresponding countries, in particularly the relationship between the markets in the US, UK, Italy and Belgium. Most European countries exhibit cointegrating relationships with the US, UK and Italian markets. Surprisingly, the results in Table 4 suggest no cointegration with the French market for all the nine European countries. The Canadian market, and to a lesser degree Danish market, seem to be separated from international spatial linkages as both have either no cointegrating relationship or cointegration with one country only. Being the largest market in the world, the US market is countertrade with all countries except for Canada, Denmark and Sweden. The UK market, which is the second largest market in the world, is not cointegrated with the markets in Canada, Denmark, France, Netherlands and Sweden. Surprisingly, the French market is cointegrated with the US only.

The finding of cointegration in 21 pairs suggests that there are long-term relationships among the prices of art in the markets involved in each pair. Now we can proceed to estimate the parameters of the VECM.

Table 4: Johansen's test of cointegration

System	M-l	rma	Eig	λma	p-	System	M-l	rma	Eig	λmax	p-	System	M-l	rma	Eig	λmax	p-
US-UK	C1	0	0.3	18.3	15.41	France-Germany	C1	0	0.4	30.81	15.41	Germany-	T1	0	0.3	31.34	18.17
		1	0.0	1.01	3.76			1	0.1	5.37	3.76			1	0.2	11.73	3.74
US-France	T1	0	0.4	29.6	18.17	France-Sweden	T1	0	0.5	40.04	18.17	Sweden-Denmark	N1	0	0.1	5.20*	12.53
		1	0.0	2.79	3.74			1	0.1	5.39	3.74			1	0.0	0.67	3.84
US-Italy	N1	0	0.4	23.7	12.53	France-Denmark	T1	0	0.2	19.11	18.17	Sweden-Belgium	C1	0	0.3	23.58	15.41
		1	0.0	1.64	3.84			1	0.1	5.27	3.74			1	0.0	3.19*	3.76
US- Germany	C1	0	0.4	24.0	15.41	France-Belgium	C1	0	0.4	34.49	15.41	Sweden-Switzerland	C1	0	0.4	26.05	15.41
		1	0.0	0.40	3.76			1	0.1	5.48	3.76			1	0.0	2.54*	3.76
US-Sweden	T2	0	0.3	22.0	18.17	France-	T1	0	0.5	35.83	18.17	Sweden-Canada	T1	0	0.2	14.31	18.17
		1	0.1	4.90	3.74			1	0.1	5.74	3.74			1	0.0	3.01	3.74
US-Denmark	N1	0	0.1	12.6	12.53	France-Canada	C2	0	0.1	9.29*	15.41	Sweden-Austria	C2	0	0.2	19.89	15.41
		1	0.1	5.13	3.84			1	0.0	0.48	3.76			1	0.1	5.02	3.76
US-Belgium	C1	0	0.4	22.6	15.41	France-Austria	C1	0	0.5	43.61	15.41	Sweden-Netherlands	T1	0	0.5	40.78	18.17
		1	0.0	0.47	3.76			1	0.1	4.59	3.76			1	0.0	4.08	3.74
US-	T1	0	0.4	28.2	18.17	France-	T1	0	0.5	44.02	18.17	Denmark-Belgium	C1	0	0.3	21.73	15.41
		1	0.0	2.15	3.74			1	0.1	6.38	3.74			1	0.0	1.87*	3.76
US-Canada	N1	0	0.2	16.3	12.53	Italy-Germany	C1	0	0.4	27.74	15.41	Denmark-	T1	0	0.4	28.42	18.17
		1	0.1	6.39	3.84			1	0.0	2.05*	3.76			1	0.0	4.16	3.74
US-Austria	C1	0	0.4	28.9	15.41	Italy-Sweden	T1	0	0.4	34.44	18.17	Denmark-Canada	N1	0	0.2	16.95	12.53
		1	0.0	0.54	3.76			1	0.1	7.40	3.74			1	0.0	4.15	3.84
US-	N1	0	0.4	28.5	12.53	Italy-Denmark	C1	0	0.2	18.39	12.53	Denmark-Austria	T1	0	0.4	27.55	18.17
		1	0.0	3.73	3.84			1	0.1	4.50	3.84			1	0.0	4.10	3.74
UK-FR	T9	0	0.3	21.8	18.17	Italy-Belgium	C1	0	0.4	25.09	15.41	Denmark-	T1	0	0.4	29.59	18.17
		1	0.1	4.03	3.74			1	0.0	1.61*	3.76			1	0.0	3.96	3.74
UK-Italy	N1	0	0.2	15.8	12.53	Italy-Switzerland	T1	0	0.4	26.08	18.17	Belgium-Switzerland	T1	0	0.3	34.40	18.17
		1	0.0	2.22	3.84			1	0.0	2.78*	3.74			1	0.2	12.49	3.74
UK-Germany	C1	0	0.3	23.0	15.41	Italy-Canada	C2	0	0.2	13.08	15.41	Belgium-Canada	T1	0	0.2	19.43	18.17
		1	0.0	1.22	3.76			1	0.0	0.23	3.76			1	0.0	4.15	3.74
UK-Sweden	T1	0	0.4	32.5	18.17	Italy-Austria	C1	0	0.4	30.48	15.41	Belgium-Austria	C1	0	0.5	48.15	15.41
		1	0.0	4.30	3.74			1	0.0	1.39*	3.76			1	0.2	13.46	3.76
UK-Denmark	N1	0	0.2	15.4	12.53	Italy-Netherlands	T1	0	0.4	31.72	18.17	Belgium-Netherlands	T1	0	0.5	42.80	18.17
		1	0.1	5.45	3.84			1	0.0	3.49*	3.74			1	0.2	10.13	3.74
UK-Belgium	C1	0	0.3	19.2	15.41	Germany-Sweden	T1	0	0.4	29.28	15.41	Switzerland-Canada	T1	0	0.3	24.35	18.17
		1	0.0	0.87	3.76			1	0.0	4.29	3.76			1	0.0	4.05	3.74
UK-	T1`	0	0.4	25.3	18.17	Germany-	T1	0	0.3	21.21	18.17	Switzerland-Austria	T1	0	0.4	40.83	18.17
		1	0.0	3.01	3.74			1	0.0	3.82	3.74			1	0.2	14.20	3.74

UK-Canada	N1	0	0.2	16.3	12.53	Germany-Belgium	C1	0	0.4	43.19	15.41	Switzerland-	T2	0	0.3	24.94	18.17
		1	0.1	5.29	3.84			1	0.2	14.26	3.76			1	0.1	6.00	3.74
UK-Austria	C1	0	0.4	23.0	15.41	Germany-	T1	0	0.3	32.75	18.17	Canada-Austria	T1	0	0.3	23.75	18.17
		1	0.0	0.90	3.76			1	0.2	13.63	3.74			1	0.0	4.28	3.74
UK-	T1	0	0.5	34.1	18.17	Germany-Canada	T1	0	0.3	23.60	18.17	Canada-Netherlands	N2	0	0.2	16.58	12.53
		1	0.0	4.05	3.74			1	0.1	5.38	3.74			1	0.0	4.21	3.84
France-Italy	T1	0	0.3	22.9	18.17	Germany-Austria	C1	0	0.4	44.00	15.41	Austria-Netherlands	T1	0	0.4	41.90	18.17
		1	0.1	5.17	3.74			1	0.2	15.05	3.76			1	0.2	11.95	3.74

C: constant, T: Trend , N: no trend nor contant

3.4 Vector Error Correction Model

Having established cointegration relations above, we now estimate vector error correction model (VEC) for the cointegrating relations to derive their short-run adjustment coefficients. A vector error correction (VEC) model is a restricted VAR designed for use with nonstationary series that are known to be cointegrated. The VEC has cointegration relations built into the specification so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the error correction term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. In addition, to identify the long-run structure, we restrict each cointegrating vector to contain the coefficient of the price variable of an arbitrarily chosen "central market". The choice of the central market is decided on its size. The US, UK, Italy, Sweden and Denmark are central markets in each pair they appear in. The other markets are referred to as "secondary markets".

Table 5 reports the results the estimates of the relevant cointegration vector in bivariate models and the appropriate tests. Panel 1 presents the cointegration paramter of the non-normalised variable. Panel 2 shows the adjustment coefficients. Panel 3 reports the results of the LOOP test. The LR-test on weak exogeneity is reported in panel 4.

Panel 1 in Table 5 presents the cointegration paramter of the non-normalised variable in each pair, which is the speed of convergence as indicated by β. All points estimates of β are negative as expected and all are significant at the 5% critical levels except for the two systems of Italy-Switzerlands and Sweden-Belgium. It can be seen from Table 4 that the cointegration parameters of the non-normalised variables are not all close to zero indicating that the no-arbitrage condition is not valid for all pairs.

Panel 1 in Table 5 shows that for three relational systems (US-UK, US-Italy and US-Netherlands), the cointegration coefficients are visually close to minus one, suggesting that the no-arbitrage condition is in force. In the first line where the system of US-UK is presented, the value of β is found to be closer to unity (0.917). An increase in the US prices by 1% would lead UK prices to rise by 0.917%. This suggests that the activities of the art markets in the UK are closely linked to the activities of the art market in the US. Similar results are found for the pair of the US-Italy (β=0.933) and US-the Netherlands (β=0.817). Also, the larger and significant values of β are found for the pairs of US-France, UK-Italy and Denmark-Belgium, whereas smaller and significant values of β are found in the six systems where Austria and Germany are pairs with the UK, US and Italian markets.

Panel 2 in Table 5 reports the adjustment coefficients (speed of adjustments) for the cointegrated pairs. These ECM coefficients measure the speed of adjustment of each times series in a system to a shock in the long-run equilibrium described by the cointegration vector. The estimates therefore provide information

on how much of the previous year's disequilibrium is corrected in the following year. In Panel 2 in Table 4, for all cointegration, it seems that all markets in a Bivariate cointegrating vector adjust to the long-run relationship. The signs of the ceofficients (α_1 and α_2) are all negative with different levels of statisticall significance. The magnitude of the coefficients for the Central markets (α_1) is greater than for the coefficients for the Secondary markets (α_2). The coefficients α_1 is statistically significant in all pairs, while α_2 is not statistically significant is in five systems. As α_1 is the error correction coefficient associated with the largest market in each system, our results suggest that a stable long-term relationship achived and guaranteed by the large central market in the system. For example, in the first line where the results for the system US-UK are presented, the coefficient of α_1 (-0.611) is statistically significant and negative, whereas the coefficient α_2 (-0.063) is not significant. This finding implies that the UK market is likely to respond to prices variations in the US, but not virce versa. This result is consistent with the fact that the US is the largest art market in the world. Overall, the largest markets in our sample (US, UK and to some extent Italy) dominate price formation in other markets. The outcome is consistent with the view that smaller markets are likely to react to conditions in larger markets.

Panel 3 in Table 5 shows the results of the LR-test on the validity of LOOP or no-arbitrage condition hypothesis. The null hypothesis that $\beta 1=1$, and $\beta 2=-1$ cannot be rejected in only three of the twenty-one pairs where cointegration is found, which are the US-UK, US-Italy and US-Netherlands. This result implies that close integration in international art market is limited.
Despite the results rejecting full and close market integration of the other pairs of markets, the ECM shows two behavioural characteristics of the markets. First, the response of the price in the secondary market from the change in the price in the central market is thought to be immediate indicating only short-run effect with the hypothesis of $\alpha 1=0$ is rejected for nearly all market pairs. Second, ECM also provides information on the speed at which the prices in the paired markets approach their equilibrium points.

Panel 4 in Table 5 presents identifies market leaders by testing weak exegeneity. As it can be seen, the LR-tests for $\alpha 1= 0$ indicates that all coefficients of central markets (α_1) are statistically significant at the appropriate level, suggesting that the prices in central markets drive the prices in the secondary markets. Prices in the American market dominate price formation in all European markets with a weak influence on prices in the Italian and British markets as the LR-test yileds a statistically significant at the 10% critical level. In addition, the LR-test of weak exogeneity for the coefficients of the secondary markets (α_2) yields insignificant estimates in most pairs except for the pairs where Germany, Austria and Belgium are secondary markets. This result reveals a statistically significant two-way short-term feedback relationship for the systems where the Germanic markets (Germany, Austria and Belgium) constitute pairs with other markets.

Table 5: VECM estimates and hypotheses tests results

Model	Lags	Panel 1: Cointegrating vector		Panel 2: Adjustment coefficients				Panel 3: LOP test	Panel 4: Weak exogeneity test	
	k	β_2	t-stat	α_1	t-stat	α_2	t-stat	$\beta_1=-\beta_2$ (1,-1)	$\alpha_1==0$	$\alpha_2==0$
US-UK	C1	-0.9164	-16.72*	-0.6105	-3.55*	-0.0630	-0.39	2.08	3.71***	0.83
US-France	T1	-1.5048	9.93*	-0.5873	-5.77*	-0.1400	-2.02**	7.17*	3.88**	0.37
US-Italy	C1	-0.9332	-6.96*	-0.4668	-4.24*	-0.1229	-2.09*	0.20	3.39***	0.07
US-Germany	C1	-0.3414	-2.91*	-0.3405	-4.64*	-0.1612	-2.84*	15.70*	10.78*	5.28**
US-Belgium	C1	-0.4584	-2.73*	-0.4167	-4.04*	-0.0926	-2.16**	8.26*	13.98*	2.23
US-Switzerland	C1	-0.5104	-3.16*	-0.6314	-5.27*	-0.1008	-1.49	6.76*	9.56*	0.02
US-Austria	C1	-0.2841	-2.26**	-0.5233	-4.93*	-0.1259	-2.64*	17.10*	3.94**	3.62***
US-Netherlands	T2	-0.8168	-4.38*	-0.5917	-3.35*	-0.0973	-1.00	0.47	5.54**	0.58
UK-Italy	N1	-1.4526	-2.5**	-0.5190	-2.37**	-0.2952	-1.94***	10.14*	9.28*	3.17***
UK-Germany	C1	-0.3584	-2.97*	-0.3643	4.71**	-0.1739	-2.31**	14.82*	12.47*	3.98**
UK-Belgium	C1	-0.4819	-2.68*	-0.4469	-4.37*	-0.1418	-2.55**	7.05*	15.72*	5.50**
UK-Switzerland	T1	-0.4886	-3.14*	-0.6768	-5.06*	-0.1957	-2.24**	7.70*	10.24*	0.77
UK-Austria	C1	-0.2879	-1.98**	-0.5430	-4.83*	-0.1800	-3.02*	7.18*	4.65**	8.01**
Italy-Germany	T1	-0.3947	-3.90**	-0.4468	-5.20*	-0.2390	-2.11**	14.55*	12.64*	0.42
Italy-Belgium	C1	-0.6538	-5.06*	-0.6296	-5.24*	-0.2168	-2.40**	5.72**	16.75*	0.71
Italy-Switzerland	C1	-0.0654	-0.45	-0.4534	-3.85*	-0.1790	-.199**	12.34*	6.64**	0.74
Italy-Austria	C2	-0.3785	-2.31**	-0.3373	-2.23**	-0.2441	-1.96**	5.66**	4.65**	3.65***
Italy-Netherlands	T2	-0.5778	-5.18*	-0.7239	-3.02*	-0.1412	-0.8	6.64**	7.97*	0.63
Sweden-Belgium	C1	-0.2078	-0.94	-0.3318	-4.03*	-0.1648	-3.24*	7.42*	18.36*	3.76***
Sweden-Switzerland	C1	-0.3659	-3.30*	-0.6345	-5.09*	-0.2079	-2.11**	13.28*	14.81*	1.03
Denmark-Belgium	N1	-1.1187	-131.50*	-0.5940	-4.96*	-0.0986	-1.22	14.97*	13.97*	6.74*

4 Conclusion

In this paper, we investigate the degree of integration among fine art markets in twelve international markets (US, UK, France, Italy, Germany, Austria, Sweden, Belgium, the Netherlands, Denmark, Canada and Switzerland). Integration is investigated for repeat-sale semi-annual country price indexes covering the period from January 1985 to June 2007. We test the validity of the law of one price for paintings in different international markets.

Overall, cointegration results indicate that markets are weakly to moderately integrated. Cointegration is found in 21 of the 66 market pairs, which represents a third of total systems. Our results reveal that art prices the US market lead prices in the European market without any feedback, expect from Germany. The UK market leads other markets with feedbacks from Germany and Belgium. Similarly, The Belgian and German market exchange short-term feedback with the Danish and Italian markets, respectively.

The results may provide strong implication for international investors and fund managers in relation to international portfolio diversification using fine art items. To take advantage of the increased international financial integration, it is essential to examine the degrees of correlation and cointegration across art markets, which can indicate considerable diversification benefits.

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