The Manchester School Supplement 2002
1463–6786 87–106

EXPLAINING STOCK MARKET CORRELATION: A GRAVITY MODEL APPROACH

by
THOMAS J. FLAVIN,
MARGARET J. HURLEY
and
*FABRICE ROUSSEAU**
National University of Ireland, Maynooth

A gravity model, frequently used to explain trade patterns, is used to explain stock market correlations. The main result of the trade literature is that geography matters for goods markets. Physical location and trading costs should be less of an issue in asset markets. However, we find that geographical variables still matter when examining equity market linkages. In particular, the number of overlapping opening hours and sharing a common border tends to increase cross-country stock market correlation. These results may stem from asymmetrical information and investor sentiment, lending some empirical support for these explanations of the international diversification puzzle.

1 Introduction

Geographical variables have enjoyed much empirical success in explaining market linkages. These variables have been applied in such diverse areas as trade flows, price differentials, migration flows and foreign direct investment flows. Here, we examine the question of whether geography also matters for asset markets. Asset markets are qualitatively different from other markets in the sense that trade is weightless—there is no physical movement of goods, capital equipment or people. Yet, if habit and convenience play a part in determining connections between goods markets, geographical factors may also be important in financial asset markets.

The particular aspect of asset markets examined here is the correlation between returns in international equity markets. Portfolio

* We are grateful for constructive comments and criticisms from participants at seminars in which earlier versions of this paper were presented, including the Money, Macro and Finance Conference 2001 at Queens University Belfast, the Irish Economic Association Conference 2001 at Portumna and an NUI Maynooth Economics Workshop. We also wish to acknowledge the able research assistance of Elaine Doyle and Anthony Coogan under funding granted by the National Institute for Regional and Spatial Analysis at NUI, Maynooth. We thank Chris Mannion of NIRSA for producing the map. The paper has benefited substantially from comments from two anonymous referees. All errors are our own.

Published by Blackwell Publishers Ltd, 108 Cowley Road, Oxford OX4 1JF, UK, and 350 Main Street, Malden, MA 02148, USA.

selection models, and their success in real-world applications, depend crucially on asset market correlations. In terms of risk reduction, the coefficient of correlation is the most important input into any asset allocation model. There are a number of accepted stylized facts regarding stock market co-movements. First, correlations are generally lower between international than domestic markets. This has been the driving force behind the wealth of literature advocating international diversification from Grubel (1968) to the present day. Second, correlations tend to increase with large shocks to returns such as a stock market crash, e.g. see King and Wadhwani (1990), Longin and Solnik (1995) among others. Despite their importance, little is known about what factors influence co-movement between two markets. Karolyi and Stulz (1996) observe that 'the determinants of the levels and dynamics of these covariances have been little studied from an academic or from a practical perspective'.

This paper makes an initial attempt to fill this void by focusing on the determinants of the level of cross-country stock market correlation using a gravity model. An understanding of the factors underpinning market correlations will have potentially important implications for equity portfolio selection as well as aiding comprehension of some financial puzzles, such as the observed home country bias in asset allocation. While our model does not explicitly address the home bias puzzle, our findings lend some empirical support to potential explanations already offered in the literature.

Gravity models have a long history in economics and have been applied in many different areas. They are predominantly empirical models that examine the determinants of flows and connections between markets. Most of the work is atheoretical; however, in the trade flows applications there have been some recent attempts to provide theoretical underpinnings (Bergstrand, 1985; Feenstra *et al.*, 1998; Anderson and van Wincoop, 2001). The basic idea behind the method is that geography matters. Variables associated with physical geography, such as great circular distances and market size, along with those that emanate from 'psychological geography', e.g. a common border, colonial links, common language etc., enjoy great empirical success in explaining market links.

McCallum (1995) uses the methodology to explain Canadian regional trade patterns, while Engel and Rogers (1996) adapt the model to explain deviations in the law of one price for individual goods. Helliwell (1997) applies a gravity model to migration flows, while Brenton *et al.* (1999) show that distances and borders are significant determinants of foreign direct investment flows. This is a potentially important explanation of the observed 'home bias' in trade patterns, which continues to be a puzzle in open economy macroeconomics (see Obstfeld and Rogoff, 2000). Anderson and van Wincoop (2001) cast doubt on the strength of McCallum's border result. In their specification of the gravity model derived from microeconomic foundations the border has a relatively small, though still significant, impact on trade flows. More recent papers look at the effect of currency unions on trade patterns and international integration (Frankel and Rose, 2000; Rose and Engel, 2000).

Applying this methodology to the analysis of financial markets is a more recent development in the literature. *Ex ante*, one would expect geography to matter less for asset markets, where there is no physical movement of goods or people. The ability of market participants to gather information and to trade instantaneously at low cost should render trader location irrelevant. With the advent of computer-based trading systems, the growth of international equity flows has outpaced that of the goods and services sector. Consequently, it seems reasonable to expect that physical and psychological geographical variables should play less of a role in determining connections between financial markets. However, we know from the international portfolio diversification literature that portfolios are less internationally diversified than asset allocation models would predict. Given investors' reluctance to move funds abroad, which appears to increase as foreign asset markets become less familiar, geography may still play a role in determining financial market co-movements.

Portes and Rey (1999), in a treatment analogous to the trade flows application, look at equity flows between 14 countries. Even for asset trade, which is by definition weightless and transportation costs are not a factor, the distance variable is found to have significant explanatory power. This result suggests that the geography of information is important for equity flows. The distance effect is reduced, though still not eliminated, when information transmission variables such as telephone call traffic and multinational bank branches are included in the specification.

Here, rather than looking at flows, the connection between financial markets as measured by a simple correlation coefficient is examined. We retain the usual explanatory variables found in the standard gravity model but augment them to capture some more specific aspects of asset market behaviour. As well as the physical and psychological geographical variables and market size, we add variables to capture ease of trading, market risk, industrial diversification and corporate governance. Ease of trading is proxied by the number of overlapping opening hours. In practice, this number is primarily due to geographical location (in particular, longitude) and it could be argued that it is also a physical geographical variable.

The paper proceeds as follows. In the next section, we review recent empirical literature on stock market correlation. Section 3 presents our model and describes the data. Results and their implications for the home country bias in portfolio selection are discussed in Section 4 while Section 5 contains our concluding remarks.

2 Stock Market Correlation

In the aftermath of the October 1987 stock market crash, more attention was afforded to stock market correlation and the related concept of equity return covariance. This new higher profile was deemed necessary when markets across the globe fell almost in unison. The goal of the literature was to answer why so many markets all experienced a dramatic adverse shock simultaneously. King and Wadhwani (1990) developed the idea of market contagion whereby shocks in a major market, such as the USA, spill over to other markets. In their model, contagion occurs due to the non-synchronous trading hours by market participants trying to extrapolate information from price changes in earlier opening markets. This 'news' may be contaminated because market-specific information that should have no bearing on the domestic market is incorrectly incorporated into domestic prices. Contagion was found to increase with market volatility. They also provide empirical evidence that London stock prices tend to jump when the New York stock exchange opens, establishing a leader–follower pattern from bigger to smaller market. King *et al.* (1994) show that little of stock market co-movement can be accounted for by observable economic factors and the majority is due to unobservable factors such as investor sentiment. Karolyi and Stulz (1996) analyse return co-movements on Japanese and US stock markets, but fail to find a statistically significant relationship between asset returns and US macroeconomic announcements, shocks to the exchange rate, Treasury bill returns or industry effects. Ammer and Mei (1996) find that equity risk premia rather than fundamental variables account for most co-movements across national indices.

Longin and Solnik (1995) use a bivariate generalized autoregressive conditional heteroscedasticity (GARCH) model to capture the conditional covariance structure. They find that correlations are unstable over time and covariances even more so. Furthermore, they provide empirical evidence that conditional correlations may be influenced by dividend yields and short-term interest rates. In a similar exercise, Ramchand and Susmel (1998) use a SW-ARCH model to show that correlations are both time and state dependent. Correlation tends to increase when markets become more volatile. Bodart and Reding (1999) also use a bivariate GARCH model to examine the impact of exchange rate variability on international correlation. Their main empirical result is that a reduction in exchange rate variability leads to an increase in international correlation of bond and stock market returns.

Groenen and Franses (2000) use a graphing technique to investigate stock market correlations and their evolution over time. They do not observe a world market portfolio but rather three clusters of markets that break down along geographical lines, namely Europe, Asia and the USA.

These clusters have become more pronounced over time. Using clustering analysis, Heaney *et al.* (2000) report similar findings.

3 Gravity Model

3.1 The Model

We investigate the sources of stock market correlation by adapting a gravity model, akin to that found in the trade literature, to capture financial asset market behaviour. The variables allowed to influence the degree of stock market correlation include the standard geographical and historical variables such as distance, borders, language and colonial links, while country size is replaced with stock market capitalization. The augmented model aims to capture features that are unique to asset markets. Some of these 'new variables' are geographical in nature and others are more financially oriented. Our main innovation is to include a measure of trading synchronicity, namely overlapping opening hours. We have not seen this used in other studies; King and Wadhwani (1990) use a dummy variable capturing whether markets are open at the same time whereas here we use the number of hours of common trading. We also incorporate a measure of risk, a variable that captures similarities in industrial composition, a variable that captures the effects of corporate governance on inward investment and a currency dummy variable. The posited model is as follows:

$$\begin{aligned} \mathrm{corr}_{ij,t} = {} & \beta_0 + \beta_1 \ln(\mathrm{GCD})_{ij} + \beta_2 \mathrm{OLOH}_{ij} + \beta_3 \ln(\mathrm{size}_i * \mathrm{size}_j)_t \\ & + \beta_4 \mathrm{Ind}_{ij,t} + \beta_5 \mathrm{conc}_{ij,t} + \beta_6 \mathrm{border}_{ij} + \beta_7 \mathrm{lang}_{ij} \\ & + \beta_8 (\mathrm{law}_i/\mathrm{law}_j) + \beta_9 \mathrm{col}_{ij} + \beta_{10} \mathrm{currency}_{ij,t} + u_{ij,t} \end{aligned} \tag{1}$$

The dependent variable is the unconditional correlation between stock markets i and j, GCD refers to the great circular distance between the main financial centres in countries i and j, and market size is measured by the average annual market capitalization in each year of the panel for that market. The variable labelled border is a dummy variable, which takes the value one if the two countries share a common land border and zero otherwise. Language, colonial links and currency are similarly defined dummy variables. Note that some variables have a time subscript which captures the panel nature of the data; variables such as great circle distance and colonial links do not, as they are constant over time.

Our measure of synchronicity, OLOH, is simply the number of overlapping opening hours between each pair of markets. Given the geographical nature of this variable, it might be expected to be closely related to the distance measure, but they have a relatively low correlation. This is due to the fact that cities that are far apart may still be in the same time zone, e.g. London and Johannesburg. This is further underlined by some markets (mostly Far Eastern) having morning and afternoon trading sessions, reducing the number of hours of common trading, despite some of these markets being geographically close. The coefficient on this variable should give us some insight into market participant behaviour. For example, a positive sign may be indicative of markets reacting to global news or indeed market contagion, while a negative sign may be supportive of the view that trade causes noise in the return process.

The industrial composition of a market may be an important source of co-movement. For example, Germany (a market with many industrial stocks) may be expected to be more highly correlated with another market in which industrial stocks are dominant, such as Taiwan, rather than its European neighbours Denmark and the UK where service and financial stocks are more important. Our measure Ind is a (crude, yet simple) one–zero dummy variable, which takes the value one if two markets share a common largest industrial sector or if both have a common sector that accounts for at least 25 per cent of the index value, and zero otherwise.

Given that much of financial economics is founded on the principle of a risk–return trade-off, it seems appropriate to include some measure of stock market risk. It is not as obvious as one might think to choose an appropriate proxy for risk given that the standard measures of standard deviation, variance and beta are all related to our dependent variable. Bearing this in mind, we have opted for a simple market concentration measure, the idea being that poorly diversified markets should be more risky than broad-based indices. Conc is the proportion of the market accounted for by the five largest companies.

The inclusion of the law variable stems from the study of La Porta *et al.* (1998) who show that there are four major families of law which influence corporate governance. The nature of the law system in a country seems to be related to its colonial past and exerts an important influence on current law practices and, more importantly for our study, the protections afforded to international investors under these regimes. The investment climates nurtured by these can vary quite considerably.[1]

3.2 Data

We use national stock market data for 27 countries (see Table 1 for a complete list of countries and their relative importance to the world portfolio). These 27 countries represent more than 98 per cent of world market capitalization. Figure 1 presents a map of global financial markets,

[1]We are grateful to Peter Spencer for bringing our attention to this strand of literature.

TABLE 1
DISTRIBUTION OF COUNTRIES AND THEIR RELATIVE IMPORTANCE TO WORLD MARKET PORTFOLIO

Country	*Proportion of world market (%)*
USA	47.48
Japan	12.50
UK	8.9
France	4.19
Germany	3.79
Switzerland	2.46
Holland	2.31
Italy	2.27
Canada	2.21
Hong Kong	1.77
Australia	1.34
Spain	1.24
Sweden	1.01
Taiwan	0.89
Finland	0.83
Brazil	0.63
Korea	0.62
Belgium	0.56
Singapore	0.46
Mexico	0.44
South Africa	0.41
India	0.39
Denmark	0.33
Malaysia	0.32
Greece	0.29
Ireland	0.25
Portugal	0.23
Total	98.15

Notes: All data were sourced from Datastream.

with market capitalization being represented by the size of the marker. We form a panel data set by computing the annual correlation for each pair of markets for 1999–2001. The 27 markets give rise to 351 annual cross-country correlations. Stock market correlations are calculated from realized daily returns (with dividends included) on each market. Correlations are calculated using both local and common currency (US dollar) returns. Stock price indices, market capitalization, along with the data required to construct the industrial sector dummy (see Table 2) and the concentration ratios were computed using Datastream constructed indices.

Information for the geographical variables was gathered from the CIA World Fact Book and other sources. Great circular distance is computed between the main financial centres, rather than country capitals.

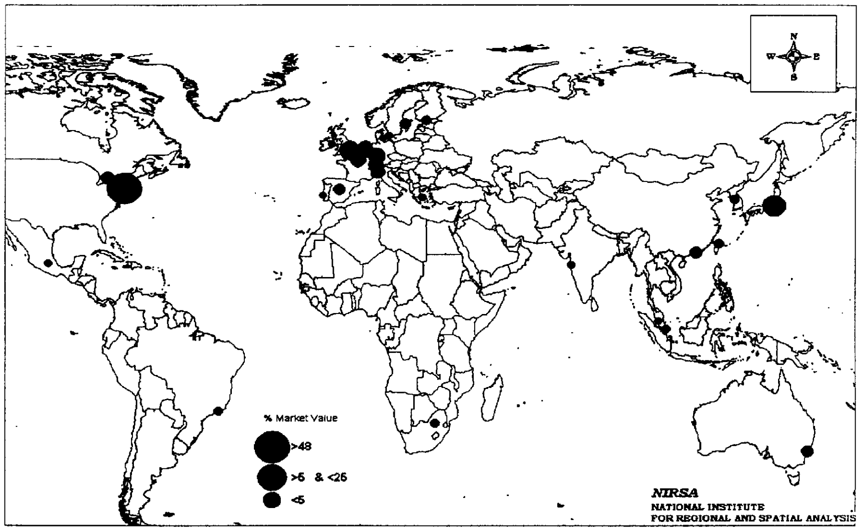

FIG. 1 Stock Markets by Market Size

As emphasized by Fig. 1, physical distance between markets is much larger in the Far East than for European markets. Data on overlapping opening hours were collected from the Websites of the individual stock markets.

Our law variable is constructed from data presented in Table 5 of La Porta *et al.* (1998). They present an index for each of five measures of law enforcement (efficiency of judicial system, rule of law, corruption, risk of expropriation, and risk of contract repudiation) that are designed to measure the friendliness of a market to inward investors. From these measures, we construct an equally weighted index of the corporate governance climate that exists in each jurisdiction (details are supplied in Table 3). The index values range from 0 (adverse investment conditions) to 10 (very favourable conditions). Switzerland has the highest score, and the Scandinavian countries as well as the traditional markets do well. On the other hand, Mexico, India and South Africa fare worst and as such are regimes that add to the overall investment risk.

Our model includes a number of dummy variables. The border dummy is simply a signal of whether there is a common (physical) border between each pair of countries. As is standard in gravity models, countries connected by a bridge (Denmark and Sweden) or tunnel (France and the UK) or those separated by a narrow strait of water (Malaysia and Singapore) are considered to have a border. The common currency dummy shows that there are two main currency blocks in our sample. The larger of these is the Euro zone, which accounts for nine of the financial markets

TABLE 2
IMPORTANCE OF INDUSTRIAL SECTORS TO NATIONAL INDICES

Country	*Industrial*	*Financial*	*Services*	*Consumer*	*Utils*	*Itech*	*Resor*
USA	0.11	0.17	**0.23**	0.19	0.03	0.22	0.04
Japan	0.19	0.18	**0.28**	0.20	0.03	0.11	0.01
UK	0.08	**0.26**	**0.31**	0.17	0.05	0.02	0.12
Germany	**0.26**	**0.26**	0.24	0.18	0.02	0.04	0.00
France	0.23	0.16	**0.26**	0.19	0.00	0.08	0.09
Switzerland	0.11	**0.32**	0.07	**0.49**	0.01	0.00	0.00
Holland	0.10	**0.33**	0.20	0.13	0.00	0.03	0.21
Italy	0.05	**0.41**	0.32	0.07	0.04	0.00	0.10
Canada	0.15	**0.22**	0.17	0.09	0.04	0.20	0.13
Hong Kong	0.19	**0.49**	**0.24**	0.01	0.06	0.01	0.00
Australia	0.06	**0.32**	**0.42**	0.06	0.01	0.00	0.13
Spain	0.10	**0.36**	0.24	0.03	0.20	0.00	0.07
Sweden	0.24	0.19	0.15	0.10	0.02	**0.29**	0.02
Taiwan	**0.47**	**0.25**	0.03	0.06	0.00	0.19	0.00
Finland	0.14	0.05	0.14	0.03	0.00	**0.61**	0.02
Korea	**0.36**	0.20	0.24	0.04	0.12	0.02	0.02
Belgium	0.14	**0.44**	0.11	0.06	0.24	0.01	0.00
Brazil	0.06	0.17	**0.42**	0.04	0.07	0.00	0.24
Singapore	0.16	**0.39**	**0.42**	0.03	0.00	0.00	0.00
South Africa	0.13	**0.36**	0.14	0.06	0.00	0.03	0.27
Mexico	0.19	0.09	**0.60**	0.12	0.00	0.00	0.00
India	**0.30**	0.06	0.08	**0.26**	0.02	0.15	0.13
Greece	0.09	**0.43**	**0.28**	0.08	0.00	0.07	0.05
Denmark	0.08	0.21	**0.52**	0.19	0.00	0.00	0.00
Malaysia	0.19	0.23	**0.28**	0.15	0.14	0.00	0.01
Portugal	0.11	**0.36**	**0.35**	0.01	0.17	0.00	0.00
Ireland	0.21	**0.47**	0.07	0.24	0.00	0.00	0.01

Notes: This table gives the relative importance of seven industrial sectors (Industrial, Financial, Services, Consumer Goods, Utilities, Information Technology and Resources) in each of the 27 markets in the analysis. Numbers in bold denote the dominant sector in each index along with sectors that account for at least 25 per cent of the market. All data were sourced from Datastream.

in our sample. The other is the USA–Mexico–Hong Kong foreign exchange agreement whereby the currencies of the two smaller partners are linked to the US dollar. Colonial links refer to historic linkages between countries with the most important of these being the Commonwealth countries. We also consider that South Africa has links with Holland. For the language dummy, ten countries use English as their main language. Spain and Mexico share a common language, as do Portugal and Brazil.

4 RESULTS

4.1 General Discussion

We estimate the gravity model, as specified in equation (1), and present

TABLE 3
INDEX OF CORPORATE GOVERNANCE FOR 27 COUNTRIES

Country	*Efficiency of the judicial system*	*Rule of law*	*Corruption*	*Risk of expropriation*	*Risk of contract repudiation*	*Index*
USA	10.00	10.00	8.63	9.98	9.00	9.52
Japan	10.00	8.98	8.52	9.67	9.69	9.37
UK	10.00	8.57	9.10	9.71	9.63	9.40
Germany	9.00	9.23	8.93	9.90	9.77	9.37
France	8.00	8.98	9.05	9.65	9.19	8.97
Switzerland	10.00	10.00	10.00	9.98	9.98	9.99
Holland	10.00	10.00	10.00	9.98	9.35	9.87
Italy	6.75	8.33	6.13	9.35	9.17	7.95
Canada	9.25	10.00	10.00	9.67	8.71	9.53
Hong Kong	10.00	8.22	8.52	8.29	8.82	8.77
Australia	10.00	10.00	8.52	9.27	8.71	9.30
Spain	6.25	7.80	7.38	9.52	8.40	7.87
Sweden	10.00	10.00	10.00	9.40	9.58	9.80
Taiwan	6.75	8.52	6.85	9.12	9.16	8.08
Finland	10.00	10.00	10.00	9.67	9.15	9.76
Korea	6.00	5.35	5.30	8.31	8.59	6.71
Belgium	9.50	10.00	8.82	9.63	9.48	9.49
Brazil	5.75	6.32	6.32	7.62	6.30	6.46
Singapore	10.00	8.57	8.22	9.30	8.86	8.99
South Africa	6.00	4.42	8.92	6.88	7.27	6.70
Mexico	6.00	5.35	4.77	7.29	6.55	5.99
India	8.00	4.17	4.58	7.75	6.11	6.12
Greece	7.00	6.18	7.27	7.12	6.62	6.84
Denmark	10.00	10.00	10.00	9.67	9.31	9.80
Malaysia	9.00	6.78	7.38	7.95	7.43	7.71
Portugal	5.50	8.68	7.38	8.90	8.57	7.81
Ireland	8.75	7.80	8.52	9.67	8.96	8.74

Notes: Numbers in the second to sixth columns are taken from Table 5 of La Porta *et al.* (1998). The index (seventh column) is an equally weighted average of these. The numbers range from 0 to 10, with 0 representing the worst investor conditions, i.e. poor judicial system, high corruption etc., while 10 denotes the most favourable conditions.

our results in Table 4.[2] We correct for the presence of heteroscedasticity in our ordinary least squares estimates by using a random effects estimator to allow for time-varying variances. This approach decomposes the error into a purely random effect and a time effect and is estimated using generalized least squares. In our case, a random effects estimator is more appropriate than a fixed effects estimator since many of our explanatory

[2]In principle, there may be a problem with using correlation as our dependent variable since by definition it can only take values between −1 and 1. This may be overcome by using the Fisher A–Z transformation to construct a variable, $z = \ln(1+\mathrm{corr}) - \ln(1-\mathrm{corr})$. Using this constructed variable, we find that exactly the same variables are statistically significant. For ease of interpretation, we revert to the unconditional correlation and correct for the presence of heteroscedasticity.

TABLE 4
RESULTS OF THE GRAVITY MODEL—CORRELATION OF DAILY RETURNS

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}
Panel A											
Estimate	−0.50	−0.01	0.039	0.046	0.024	0.305	0.12	−0.01	0.055	−0.01	0.017
t statistic	4.82	0.84	16.48	11.5	3.11	6.1	5.94	1.11	2.66	0.38	1.23
	$R^2 = 0.62$		H_0	$\beta_1 = \beta_2 = \beta_6 = 0$		$\chi^2(3) = 859.9$					
			H_0	$\beta_1 = \beta_6 = 0$		$\chi^2(2) = 45.5$					
Panel B											
Estimate	−1.33	−0.02	0.034	0.09	0.027	0.363	0.155	0.046	0.046	0.005	−0.01
t statistic	7.4	2.38	11.87	7.71	2.68	5.52	4.04	3.18	2.07	0.19	0.57
	$R^2 = 0.55$										
Panel C											
Estimate	−0.19	−0.01	0.04	0.028	0.036	0.19	0.11	−0.01	0.01	−0.02	0.056
t statistic	1.86	1.70	17.8	7.42	4.80	3.91	5.68	0.22	0.03	0.93	4.08
	$R^2 = 0.65$		H_0	$\beta_1 = \beta_2 = \beta_6 = 0$		$\chi^2(3) = 1011.4$					
			H_0	$\beta_1 = \beta_6 = 0$		$\chi^2(2) = 48.5$					
Panel D											
Estimate	−1.05	0.006	0.036	0.085	0.045	0.219	0.123	0.031	−0.02	−0.03	0.02
t statistic	5.65	0.67	12.26	6.94	4.35	3.20	3.09	2.07	0.80	1.12	0.91
	$R^2 = 0.56$										

Notes: Panels A and B present the results of our model with the dependent variable measured in local currency. Panel A covers the entire sample, while B covers only the 'small' markets. These are defined as those who have contributed less than 2 per cent of world capitalization. Panels C (entire sample) and D (small markets only) contain the estimated results for the correlation computed from common currency (US dollar) returns.

variables are time invariant and would thus be 'swept out' by the latter approach.

We conduct the analysis for both local currency and common currency (US dollar) correlation. We prefer to focus on the local currency return correlation as this measure of market co-movement is uncontaminated by exchange rate movements. As the results are similar, we concentrate our discussion on local currency results and highlight the areas of difference at the end of this section.

The results are supportive of our approach, suggesting that our gravity model has some explanatory power over cross-country equity return correlation. All of the estimated coefficients are statistically significant at conventional levels with the exception of the distance variable and the language, colonial links and currency dummy variables. This finding for the aforementioned dummy variables is unsurprising given that most developed financial markets are comfortable with using English and, of course, there is no real reason to expect that colonial links should play a role in the determination of equity price co-movement. The insignificance of the currency variable is consistent with other studies (e.g. Eun and Resnick, 1988; Bodart and Reding, 1999) which show that currency risk is a more important consideration for bond rather than equity portfolio managers. Currency risk generally accounts for a small proportion of total equity risk.

The geographical variables have different degrees of success in explaining cross-country stock market co-movement. Unlike the literature dealing with physical goods trade, great circular distance, though of the expected sign, is not a significant determinant of stock market co-movement. For equity markets, it appears that another measure of market proximity, namely the number of overlapping opening hours, is a more influential determinant of price co-movements. This hypothesis is strongly supported by the data. The more hours of common trading, the greater is the degree of equity price co-movement. For an advocate of the efficient market hypothesis, this may indicate that markets are reacting to 'global news' simultaneously (or at least with shorter time lags) and immediate price changes lead to increased correlation. Alternatively, it could be evidence of stock market contagion or herd behaviour among market participants. King and Wadhwani (1990) provide evidence of contagion between the London and New York stock markets that results from non-synchronous trading. This contagion occurs due to investors' attempts to infer information from price changes in the other market. Of course, another more practical explanation may be that traders just find it easier to conduct business with other financial market participants who are active at the same time. Common opening hours may facilitate the dissemination of information among investors, thereby reducing the aforementioned asymmetries.

TABLE 5
RESULTS OF THE GRAVITY MODEL—CORRELATION OF WEEKLY RETURNS

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}
Panel A											
Estimate	−0.83	−0.01	0.026	0.066	0.016	0.365	0.114	0.023	0.078	−0.01	0.009
t statistic	5.58	1.53	8.35	12.32	1.56	5.42	4.22	1.38	2.79	0.26	0.52
	$R^2 = 0.41$										
Panel B											
Estimate	−0.50	−0.01	0.03	0.045	0.023	0.282	0.12	0.038	0.02	−0.001	0.03
t statistic	3.22	0.98	9.61	8.39	2.21	4.15	4.39	0.21	0.73	0.05	1.37
	$R^2 = 0.43$										

Notes: Panel A presents the results from estimating equation (1) with the dependent variable being the correlation of weekly stock market returns measured in local currency. Panel B presents the corresponding results for returns measured in US dollars.

In an effort to eliminate spurious correlation due to non-synchronous returns, we re-estimate the equation using correlations calculated from weekly returns and present the results in Table 5. The overlapping opening hours continues to be a significant explanatory variable. This strengthens the hypothesis that the geographical variables are acting as a proxy for informational asymmetries and leads us to believe that differences in investors' information rather than ease of trading are driving this result.

The border dummy exerts a positive and significant impact on the level of the correlation. This means that stock markets in countries with a common border move together, even though the financial capitals may be relatively far apart. This finding is consistent with the results of Groenen and Franses (2000), who observe clusters of markets moving together which are broadly divided along geographical lines, and Heaney *et al.* (2000), who suggest that stock markets cluster on a regional basis. Consequently, two of our geographical variables—overlapping opening hours and the common border dummy—contain important explanatory power over cross-country equity co-movements.

We conducted tests of joint significance on the geographical variables, and the null hypothesis that $\beta_1 = \beta_2 = \beta_6 = 0$ was resoundingly rejected, as was $\beta_1 = \beta_6 = 0$. Therefore, geography appears to matter in determining stock market correlation.

Correlation and size exhibit a positive and statistically significant relationship, i.e. the larger the markets, the more correlated they are. Larger markets being more liquid and displaying more price movement than smaller counterparts may potentially explain this. Smaller or thinly traded markets may not react as quickly to relevant information because some stocks may be traded infrequently. Larger markets may also be more diversified across industrial sectors and consequently are influenced by more common 'news'. Another possible explanation may be that the larger markets are driving this result. However, restricting the sample to 'small' markets (those with a market capitalization less than Canada) and repeating our estimation confirms that market size is a significant determinant of correlation. The result is just as strong for our sample of small markets as for the whole set (see Table 4, panel B).

The dummy variable that captures similarities in industrial composition is also highly statistically significant. However, the estimated coefficient of 0.024 is quite low, but consistent with the studies of Heston and Rouwenhorst (1994, 1995), Rouwenhorst (1999) and Griffin and Karolyi (1998). These studies show that industrial composition accounts for a low proportion of stock return covariance, about 4 per cent in most studies.

The risk measure is highly statistically significant and has a positive relationship with cross-country equity correlation. *A priori*, one might expect that this concentration variable would be negatively related to our dependent variable. Since a high concentration ratio is indicative of a poorly diversified market, it is reasonable to assume that information relevant to that sector would tend to cause greater price movement in this financial centre than in a large diversified exchange. This would give rise to low levels of co-movement. Two poorly diversified markets that specialize in different industries should also have low correlation. However, closer inspection of the individual stock markets reveals that it is the importance of the telecommunications sector that is driving our result. Figure 2 shows the proportion of market capitalization of each index that is accounted for by telecom stocks as at 31 December 1999.[3] Almost half of the markets in our sample have at least 20 per cent of the index in telecom stocks. Consequently, 'news' relevant to this sector appears to be causing the observed positive co-movement.

Also, our measure of corporate governance turns out to be a significant determinant of stock market correlation. This variable is entered as a ratio. The positive coefficient tells us that the closer markets are in terms of 'investor friendliness' then the more likely they are to move together. Of course, we would expect two 'highly protected' markets to follow this pattern. However, in the case of two 'poorly protected' markets, this may be indicative of market segmentation. According to Bartram and Dufey (2001) market segmentation is 'caused by barriers that are difficult for investors to overcome, such as legal restrictions on international investment . . .'. Without explicit bans on inward investment, market segmentation may arise due to the lack of appropriate investor protections in certain countries. This could be reflected in little (or slower) movement in asset prices in these indices due to a lack of international investment.

[3]These concentration ratios also contain some 'high-tech' stocks which specialize in manufacturing telecommunications equipment.

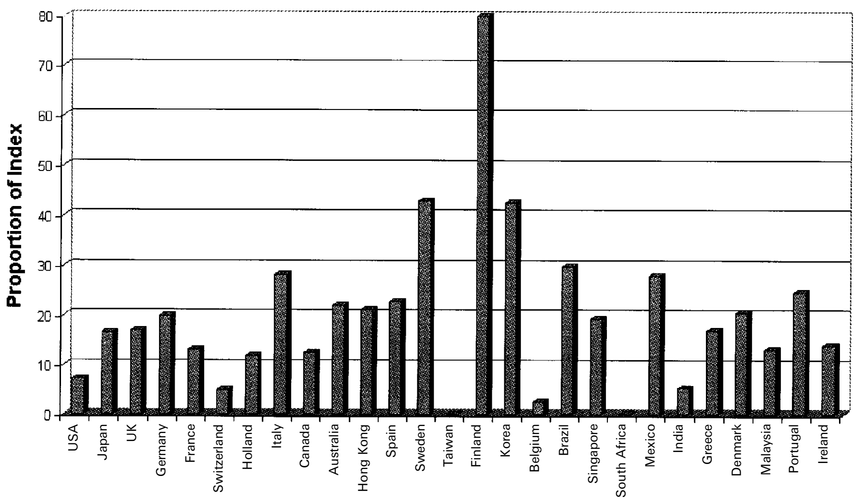

FIG. 2 Telecom Sector as a Proportion of the Total Index

Two such markets would also have a ratio close to unity. Pairs of markets with a ratio far from one are likely to involve one market that attracts large inward financial investment and consequently displays more price movement and a more segmented market. It is reasonable to expect such markets to have lower correlation.

We also examine the driving forces behind correlations measured in US dollars. These measures are not a pure measure of stock market co-movements but are also influenced by the variability of exchange rates with the dollar and co-variation between returns and the exchange rate.[4] The results are quite similar with the main difference being the statistical significance of the currency dummy in this formulation. It is likely that this result is being driven by the currency fluctuations of other countries against the dollar.

4.2 Implications for the Home Bias Puzzle

One of the least controversial puzzles in the finance literature is that of 'home bias' in asset allocation. This refers to the fact that investors tend to over-weight their portfolios in favour of domestic assets and fail to take opportunity of international diversification benefits. Many potential

[4]The correlation depends on the standard deviation of each market's dollar return which is given by $\sigma(R_{i\$}) = [\sigma^2(R_i) + \sigma^2(e_i) + 2\,\mathrm{cov}(R_{i\$}, e_i) + \Delta\mathrm{var}]^{1/2}$. The final term on the right-hand side represents the contribution of the cross-product term, R_i, e_i, to the risk of the dollar-denominated investment.

explanations have been proffered,[5] including hedging domestic inflation, tax differences and transactions costs, informational asymmetries between domestic and foreign investors, investor sentiment and most recently corporate governance. Our results provide empirical support for some of the aforementioned explanations. Not only do investors have a greater propensity to invest at home, but connections between markets are strongest for countries with geographical links, suggesting that when investors do invest abroad, they are most likely to do so in nearby markets.

In particular, the statistical significance of the geographical variables may reveal important insights into asset allocation and the lack of potentially beneficial portfolio diversification across international markets. One potential explanation for the home bias is that there is an asymmetry of information between domestic and foreign investors. In our analysis, these variables may be acting as a proxy for informational asymmetries. Portes and Rey (1999) offer a similar explanation in their study on equity flows. The inability of investors to gather or process information from 'far-away' financial centres leads to portfolios that are concentrated in home or nearby markets. This regional behaviour among market participants will lead to stronger correlation between nearby markets. Hence, contagion effects between neighbouring countries may be stronger. Merton (1987) argues that investors are most likely to invest in securities that they are familiar with. Kang and Stulz (1997) support this argument when they observe that inward foreign investment in Japanese stocks is primarily concentrated in large domestic companies that have a higher international profile. Frankel and Schmukler (1996) provide empirical evidence that it was Mexican investors and not 'fickle foreigners' who fled the markets and precipitated the Mexican crisis of 1994.

Alternatively, these geographical variables may capture investor sentiment to which King *et al.* (1994) attribute a key role in determining asset market co-movements. French and Poterba (1991) suggest that home bias could result from investors feeling safer with domestic assets and feeling more optimistic than foreign investors about the prospects of domestic securities. The former argument is given credence by Tversky and Heath (1991) who present evidence that households perceive an unfamiliar gamble to have greater risk than a familiar one, even when both gambles have identical probability distributions. Also Shiller *et al.* (1991) present survey evidence consistent with the fact that investors are often more optimistic about the domestic market than foreign markets.

A recent contribution to the literature on home bias comes from Pinkowitz *et al.* (2001) who attribute a considerable part of the bias to

[5]Excellent reviews of the puzzle and potential explanations are provided by Lewis (1999) and Karolyi and Stulz (2001).

corporate governance or investor protections. They show that a large bias is created by the desires of individuals to maintain a majority shareholding in firms. They argue that 'investors are more reluctant to invest in countries with poorer rights and that our estimate of shares held by controlling shareholders serves as a proxy for investor rights' (p. 4). This is consistent with the significance of our 'law' variable. Markets with better protection for investors will attract more inward investment and will thus react more uniformly and quickly to relevant news. At the other end of the scale, markets with a poor record of corporate governance will not be as sensitive to international capital flows.

Consequently, our results offer empirical support for the arguments that home bias is caused by informational asymmetries, investor sentiment, corporate governance or a combination of all.

5 Conclusion

Geographical variables have long been known to explain linkages between goods markets. Our analysis shows that this result is also applicable to financial asset markets. Gravity models can explain cross-country equity return correlation. We find that measures of stock market proximity as well as sharing a common border are important explanatory variables for stock market correlation. These geographical measures may be acting as a proxy for informational asymmetries across the investment community. It could be argued that overlapping opening hours could be capturing many effects, from markets reacting to global news to market contagion to the ease of trading with another market participant at another location. However, given that measuring the correlation of weekly returns (rather than daily) does not reduce its significance, we are led more towards the asymmetry of information explanation. This finding has important implications for the international diversification (or home bias) puzzle as it gives more credibility to the proponents of asymmetric information as a potential explanation. Investors may be more comfortable with portfolios that are concentrated in their region, hence amplifying the effects of an adverse shock in that area.

Likewise, the colonial past seems to have left an important legacy in terms of its influence upon the legal regimes and in particular the laws of corporate governance in various countries. La Porta *et al.* (1998) document this effect and our model finds empirical support for its significance in determining stock price co-movements. Furthermore, this lends empirical support to the argument of Pinkowitz *et al.* (2001) that the degree of investor protection (or corporate governance) is a potential explanation of the home bias puzzle.

We also find that more conventional financial variables such as market size and risk (level of concentration) influence cross-country correlation. In particular, larger markets tend to be more correlated. This result may be due, at least in part, to market liquidity, with larger more liquid markets exhibiting stronger co-movements than thinly traded markets. Such markets will react more quickly and to a greater range of information than a thin market dominated by one sector and consequently exhibit higher correlation. Our risk measure tells us that more concentrated markets tend to move together but this result may be driven by the global importance of telecom stocks. The industrial composition of markets also helps to explain stock market correlation. This is intuitive, as we would expect markets with a common dominant industry to exhibit higher co-movement.

The main contribution of this paper is to show that results found in the literature explaining goods trade extend to financial asset markets. Even for financial markets, geography and borders matter. Market participant behaviour and informational asymmetries may explain the large and statistically significant influence exerted on the level of stock market co-movement by these variables.

References

Ammer, J. and Mei, J. (1996). 'Measuring International Economic Linkages with Stock Market Data', *Journal of Finance*, Vol. 51, pp. 1743–1763.

Anderson, J. E. and van Wincoop, E. (2001). 'Gravity with Gravitas: a Solution to the Border Puzzle', *NBER Working Paper 8079*.

Bartram, S. and Dufey, G. (2001). 'International Portfolio Investment: Theory, Evidence and Institutional Framework', *Financial Markets, Institutions and Instruments*, Vol. 10, pp. 85–155.

Bergstrand, J. H. (1985). 'The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence', *Review of Economics and Statistics*, Vol. 67, pp. 474–481.

Bodart, V. and Reding, P. (1999). 'Exchange Rate Regime, Volatility and International Correlations on Bond and Stock Markets', *Journal of International Money and Finance*, Vol. 18, pp. 133–151.

Engel, C. and Rogers, J. H. (1996). 'How Wide is the Border', *American Economic Review*, Vol. 86, pp. 1112–1125.

Eun, C. and Resnick, B. (1988). 'Exchange Rate Uncertainty, Forward Contracts and International Portfolio Selection', *Journal of Finance*, Vol. 43, pp. 197–215.

Feenstra, R. C., Markusen, J. A. and Rose, A. K. (1998). 'Understanding the Home Market Effect and the Gravity Equation: The Role of Differentiating Goods', *NBER Working Paper 6804*.

Frankel, J. A. and Rose, A. K. (2000). 'Estimating the Effect of Currency Unions on Trade and Output', *NBER Working Paper 7857*.

Frankel, J. A. and Schmukler, S. L. (1996). 'Country Fund Discounts, Asymmetric Information and the Mexican Crisis of 1994: Did Local Residents turn Pessimistic before International Investors?', *NBER Working Paper 5714*.

French, K. R. and Poterba, J. M. (1991). 'Investor Diversification and International Equity Markets', *American Economic Review*, Vol. 81, pp. 222–226.

Griffin, J. M. and Karolyi, G. A. (1998). 'Another Look at the Role of the Industrial Structure of Markets for International Diversification Strategies', *Journal of Financial Economics*, Vol. 50, pp. 351–373.

Groenen, P. J. F. and Franses, P. H. (2000). 'Visualizing Time-varying Correlations across Stock Markets', *Journal of Empirical Finance*, Vol. 7, pp. 155–172.

Grubel, H. (1968). 'Internationally Diversified Portfolios: Welfare Gains and Capital Flows', *American Economic Review*, Vol. 58, pp. 1299–1314.

Heaney, R., Hooper, V. and Jagietis, M. (2000). 'Regional Integration of National Stock Markets', *Asian Review of Accounting*, Vol. 8, pp. 55–65.

Helliwell, J. F. (1997). 'National Borders, Trade and Migration', *Pacific Economic Review*, Vol. 3, pp. 165–185.

Heston, S. L. and Rouwenhorst, K. G. (1994). 'Does Industrial Structure Explain the Benefits of International Diversification?', *Journal of Financial Economics*, Vol. 36, pp. 3–27.

Heston, S. L. and Rouwenhorst, K. G. (1995). 'Industry and Country Effects in International Stock Returns', *Journal of Portfolio Management*, pp. 53–58.

Kang, J. K. and Stulz, R. M. (1997). 'Why Is There a Home Bias? An Analysis of Foreign Portfolio Equity Ownership in Japan', *Journal of Financial Economics*, Vol. 46, pp. 3–28.

Karolyi, G. A. and Stulz, R. M. (1996). 'Why Do Markets Move Together? An Investigation of the U.S.–Japan Stock Return Comovements', *Journal of Finance*, Vol. 51, pp. 951–986.

Karolyi, G. A. and Stulz, R. M. (2001). 'Are Financial Assets Priced Locally or Globally?', in G. Constantinides, M. Harris and R. M. Stulz (eds), *Handbook of Economics of Finance*, Amsterdam, North-Holland, forthcoming.

King, M. A. and Wadhwani, S. (1990). 'Transmission of Volatility between Stock Markets', *Review of Financial Studies*, Vol. 3, pp. 5–33.

King, M. A., Sentana, E. and Wadhwani, S. (1994). 'Volatility and Links Between National Stock Markets', *Econometrica*, Vol. 62, pp. 901–933.

La Porta, R., Lopez-de-Silanes, F., Shleifer, A. and Vishny, R. (1998). 'Law and Finance', *Journal of Political Economy*, Vol. 106, pp. 1113–1155.

Lewis, K. K. (1999). 'Trying to Explain Home Bias in Equities and Consumption', *Journal of Economic Literature*, Vol. 37, pp. 571–608.

Longin, F. and Solnik, B. (1995). 'Is the Correlation in International Equity Returns Constant: 1960–1990?', *Journal of International Money and Finance*, Vol. 14, pp. 3–26.

McCallum, J. (1995). 'National Borders Matter: Canada–U.S. Regional Trade Patterns', *American Economic Review*, Vol. 85, pp. 615–623.

Merton, R. C. (1987). 'A Simple Model of Capital Market Equilibrium with Incomplete Information', *Journal of Finance*, Vol. 42, pp. 483–510.

Obstfeld, M. and Rogoff, K. (2000). 'The Six Major Puzzles in International Macroeconomics. Is There a Common Cause?', *NBER Working Paper 7777*.

Pinkowitz, L., Stulz, R. M. and Williamson, R. (2001). 'Corporate Governance and the Home Bias', *NBER Working Paper 8680*.

Portes, R. and Rey, H. (1999). 'The Determinants of Cross-border Equity Flows', *NBER Working Paper 7336*.

Ramchand, L. and Susmel, R. (1998). 'Volatility and Cross Correlation across Major Stock Markets', *Journal of Empirical Finance*, Vol. 5, pp. 397–416.

Rose, A. K. and Engel, C. (2000). 'Currency Unions and International Integration', *NBER Working Paper 7872*.

Rouwenhorst, K. G. (1999). 'European Equity Markets and the EMU', *Financial Analyst Journal*, Vol. 48, pp. 57–64.

Shiller, R. J., Kon-ya, F. and Tsutsui, Y. (1991). 'Speculative Behaviour in the Stock Markets: Evidence from the US and Japan', *NBER Working Paper 3613*.

Tversky, A. and Heath, C. (1991). 'Preferences and Beliefs: Ambiguity and Competence in Choice under Uncertainty', *Journal of Risk and Uncertainty*, Vol. 4, pp. 5–28.