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THE CO-MOVEMENT OF THE IRISH, UK, AND US STOCK MARKETS, 1869-1925

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This paper studies the co-movements of the Irish stock markets with those in the UK and the US using monthly data between 1869 and 1925. The time-varying correlation of the markets are estimated in a tri-variate DCC-GARCH framework. Spillovers from the UK market to the Irish market are evident in increasing correlation during periods of crisis. The correlation between the Irish and UK markets is much higher than that between the US and either market, suggesting that there was an unusually strong relationship between the Irish and UK markets during the sample period.

Introduction

In this paper, I consider the co-movement of the Irish stock market with those in the UK and the US over the period 1869-1925. The international co-movement and integration of the Irish stock exchanges has been little studied, and what comparisons exist tend to focus on the co-movements with those in the UK. It is easy to see why this may be: by dint of relative size, geographic location and political links, these two economies were bound to have strong ties during the sample period.

A question that arises in this context is, what does a certain level of co-movement mean? Since this period includes the 'first era of globalization,' some co-movement of the series would be expected.[1] But was this level of co-movement exceptional? To address this question, I compare the level of co-movement between Ireland and the UK with that between the US and the UK and the US and Ireland. During much of this period, the US and the UK markets were the largest in the world.[2] Thus, conclusions about the broader global integration of the Irish market can be drawn by comparing its co-movements with those in the UK and the US. Furthermore, these countries are natural comparators: all three were

[1] See Michael D. Bordo and Christopher M. Meissner (2015).
[2] See, for instance, Gareth Campbell and Meeghan Rogers (2017).

Anglophone, practicing common law and with strong links in labor and goods markets.

As a result, the paper addresses not just whether the Irish and UK markets co-moved, but the relative degree of this co-movement. It answers questions such as, was there particularly strong co-movement between the Irish and UK stock markets? Was the Irish market so small and provincial that it was dominated by this relationship? Or did it co-move with other global markets?

These are important questions for understanding the position of the Irish exchanges during this period of global financial integration. The Irish Free State was established in 1922, and had aspirations to industrialize and reduce its reliance on the UK. A well-functioning stock market could play a central role in helping to finance such a transformation. But if the Irish stock market dominated by the vagaries of the UK market, breaking the link between the business cycles of the two countries would likely be more difficult.

In addressing these questions, this paper adds to the relatively sparse literature on the Irish stock market. William A. Thomas (1986) provides a narrative history of the Irish stock exchanges from their inception in the eighteenth century, through to the second half of the twentieth century. Gareth Campbell et al., (2016) examine the integration of the London stock market with 'provincial' stock markets in the UK, including the Irish exchanges. They find that integration of the provincial markets with the London market increases over time, although the number of listings on provincial markets concurrently declines. However, the individual relationships of each provincial exchange, including the Irish exchanges, with London are not reported in the paper.

Two papers have compiled Irish equity indices over different sample periods. Richard S. Grossman et al., (2014) develop a monthly Irish stock market index over the period 1864-1930. Charles R. Hickson and John D. Turner (2005) compile stock market data for Ireland over the period 1865-1913. In both papers, descriptive statistics are provided for the final series, and a comparison is drawn with a UK series; however, this is not a central part of the papers.

To study co-movements in the data, I use monthly capital gains (referred to as 'returns') in the London, New York (here referred to as UK

and US, respectively) and Irish (Dublin, Belfast and Cork) stock markets over a 55-year period. Descriptive statistics show the relative performance of the markets. I then estimate a tri-variate DCC-GARCH model to study the co-movement of returns in these markets over the sample period. The DCC-GARCH is chosen since it enables the estimation of time-varying correlations between the returns. Thus, I can benchmark the level of co-movement between the UK and Irish markets against the correlations of these two markets with the US market through time.

As a result, this paper also adds to the broader literature on international stock market integration. There are studies that examine co-movement of stock prices across a number of countries, however these often use annual data that do not capture short-term market volatility.[3] There are also a number of studies using monthly data of the relationship between two markets, often the UK and one other market.[4] Still, these bilateral studies cannot provide any sense of whether the level of integration is high or low compared with that of other markets at the time. As such, this is one of the first studies using monthly data to provide a cross-country analysis of stock market co-movements.

There are two main findings in the paper. First, the UK market had significant influence on the Irish market during this period. This is evident from the fact that shocks originating in the UK were transmitted to Ireland, in contrast to those originating in the US. In particular, the correlation between the returns in the Irish and UK markets rises around periods of crisis or heightened tensions in London. Similar periods in New York are not reflected in particularly heightened correlation with the Irish market.

Second, the level of co-movement between Ireland and the UK is always higher than that between the UK and US, and much higher than that between Ireland and the US. Thus, it appears that the Irish market did not co-move much with the US market, but that developments in the UK dominate the Irish market. This suggests a particularly high level of co-movement between the Irish and UK markets.

[3] See, for instance, Elroy Dimson *et al.*, (2002) and Richard Baldwin and Philippe Martin (1999).

[4] See, for example, Richard Sylla *et al.*, (2006), Christopher Hoag (2006), Campbell and Rogers (2017), Kenneth D. Garbade and William L. Silber (1978) and Larry Neal (1987).

The paper is structured as follows: the next section outlines why co-movements in stock returns might be expected, considers the specific cases of the UK, Ireland and the US, and discusses some methods used in the literature to estimate co-movements. Thereafter the compilation of the data is described, and some descriptive statistics are discussed. I then present the GARCH specification and results, and follow with some conclusions.

Co-Movements in Stock Returns

Why might there be International Co-movements in Equity Returns?

For simplicity, consider the Myron J. Gordon (1959) dividend growth model, according to which the price of a stock is determined as follows:

$$p_t = \frac{D_t}{r - g}$$

Here, the price, p_t, is determined by the dividend today, D_t; the growth rate of dividends (which is assumed constant), g; and the required rate of return, r, which can be thought of as the sum of the risk-free rate and the risk premium required for holding equities. This simple model suggests that co-movements in stock prices across markets can occur for three reasons. First, the risk-free rate in a number of countries could change at the same time. This could happen, for example, if there is a change in the outlook across a number of countries. Second, co-movements in economic growth across countries could lead the expected growth rate of dividends to be correlated across countries. Third, there could be a reappraisal of risk premia across countries at the same time. Such a shift could happen following a shock to one, or several, countries.

Co-movement between Irish, UK and US Markets

Were similar co-movements of shocks possible between the countries under review during the sample period? Undoubtedly, they were. Maurice Obstfeld and Alan M. Taylor (2005, 25), argue that between 1870 to the First World War "the first age of globalization sprang forth."[5] The UK

[5] They point to the role of the gold standard in driving a convergence in interest rates across countries and the consequent increase in capital flows.

and Ireland shared the same currency–-pound Sterling–-throughout the period.[6] Furthermore, but for the period around the First World War, the gold standard was in place, linking the currencies of all three markets.

This led to a high level of capital mobility during the period. Sylla, et al., (2006) note that as early as 1803 to 1804 almost half of US securities were owned by foreigners.[7] Thomas (1986, 102) states that as early as the 1840s, Irish shares were placed with subscribers in the UK (and that Irish money funded companies listed overseas[8]). These investments were initially in Irish railways, as were the UK companies these investors were also likely funding.[9]

Indeed, this similarity in the types of companies listed in the different indices probably drove some of the co-movement over time. For instance, the slow demise of railways as a force on the stock exchanges is consistent across the series. Likewise, industrial shares became more important through time. However, the timing of the initial surge in industrials was not consistent across exchanges. For instance, Grossman et al., (2014) note a surge in share of market capitalization of the industrials on the Irish exchanges in the 1880s. However, in the US the process was slower; indeed initially, a number of industrials incorporated in the UK and listed on the London exchange due to a lack of domestic investors.[10] It was not until the 1890s that there was a surge of industrial listings on the New York exchange.[11] However, the importance of these sectors varied across indices; in particular, despite the surge in the 1880s, industrials were not a

Similarly, Baldwin and Martin (1999) argue that capital mobility was perhaps higher during parts of the sample review than in more recent decades. Nonetheless, such capital flows halted abruptly when the gold standard was abandoned (temporarily) during the First World War.

[6] Despite being independent from 1922, the Saorstát currency was not introduced until after the passing of an Act in 1927.

[7] This is based on the inclusion of stocks of export-oriented companies, rather than just domestically-oriented companies

[8] Thomas (1986, 150).

[9] Early railway shares attracted funds from Lancashire, while funds from London only became important later.

[10] See Mary A. O'Sullivan (2016) Chapter 2 for a discussion.

[11] Ibid, 109.

large part of the Irish exchanges which were dominated by railways and banks.

There were also strong links between these countries in both goods and labor markets. Since Ireland was part of the UK during most of this period it is unsurprising that the economic relationship between the two was very close.[12] The labor market was fully integrated, with emigration to the UK from Ireland common.[13] Furthermore, as late as 1924, two years after Irish independence, the UK still accounted for over 98 percent of Irish exports, and 81 percent of imports. Indeed, the UK continued to account for the majority of Ireland's external trade for several decades after independence.[14]

On the other hand, the relative size of the two countries meant that Ireland was less important for the UK. Ireland accounted for just over 5 percent of UK imports and exports in 1924. In contrast, the US was the UK's main trading partner throughout this period, accounting for 18 percent of UK imports, and almost 7 percent of exports in 1924.[15]

Irish trade was so overwhelmingly dominated by the UK that there were very weak links with other countries, including the US.[16] However, there was a significant flow of emigration from Ireland to the US, both before and during the sample period, which created strong cultural bonds between the two countries.[17] Indeed, cultural ties existed between all three countries through language (English speaking) and institutions (all used common law).[18]

Institutional factors also linked the UK and Irish exchanges, at least. Thomas (1986, 158-159) notes several instances in which the rules of the

[12] See Raghurum G. Rajan and Luigi Zingales (2003) for a discussion of the role of trade links in financial development.

[13] See for instance, Cormac Ó Gráda (1973) and (1975).

[14] See Ella Kavanagh (1997).

[15] Data taken from Brian R. Mitchell (1981).

[16] Nonetheless, Mitchell (1981) reports that the US accounted for over 5 percent of Irish imports, although it accounted for less than 0.5 percent of Irish exports.

[17] Kerby A. Miller (1987, 3) reports that 7 million Irish emigrated to the US from the 16th century up to Irish independence in 1922.

[18] See Rafael La Porta *et al.,* (1997) for a discussion of the importance of common law in financial development.

Irish exchanges were modelled on those of the London exchange, and that changes to rules in London were often transposed to the Irish exchanges.[19] Interestingly, the prevailing wisdom on the differences in rules governing listing in London and New York has recently been challenged. Previously, it was understood that the New York exchange maintained stricter listing rules than London[20], however, O'Sullivan (2016) disputes this, arguing that, if anything, it may have been easier to list in New York.[21]

Finally, the three countries were linked by modern communications. The trans-Atlantic telegraph cable, which was completed in 1866 and made landfall on the west coast of Ireland, reduced the amount of time it took to communicate across the Atlantic from over a week to just a few minutes.[22] The importance of this to stockbrokers is illustrated by Michie (1987, 46) who notes that by 1871 New York brokers were spending $0.8 million per annum on telegrams to London and that transatlantic cable companies deliberately located offices near to stock exchanges in order to provide express services to traders.[23]

Measuring Stock Market Co-Movements

Stock market co-movements have been measured in the literature using several different methods. One is to calculate the correlation of stock

[19] Rules designed to prevent 'shunting' or arbitraging across the provincial and London exchanges were introduced in 1909 and 1912. This would have reduced correlation across cross-listed firms, however, these are excluded from the analysis here.

[20] Ranald C. Michie (1987, 198).

[21] O'Sullivan (2016), for instance Table 2.3 on page 92.

[22] By 1868, transmission speeds had increased to 8 words per minute. See A.J. Litton (1961) for a discussion of the development of telephone communication in Ireland.

[23] Similarly, Hoag (2006) shows that the trans-Atlantic cable reduced the information lag between the London and New York exchanges from 10 days to almost zero. A modern comparison is high frequency traders locating their servers close to exchanges. Communications allowed investors respond quickly to news from other jurisdictions. Gail D. Triner and Kristen Wandschneider (2005) argue that the behaviour of markets during the Brazilian financial crisis of 1890/91 is a precedent for the contagious financial crises in emerging markets more recently.

returns. William N. Goetzmann et al., (2005) do this for stock returns in Europe, Asia, the Americas, Africa and Australasia over extended samples, mainly beginning in the first half of the twentieth century. They argue that markets were well integrated in the pre-First World War period, even compared to more recent periods. In a similar style, Campbell and Rogers (2017) and Campbell et al., (2016), focus on the r-squared from a rolling regression of two returns on each other since. Since the r-squared takes values between zero and one, it is used as an indicator of integration.[24]

Other studies focus on estimating the timing of when markets begin to co-move. Using modern data, Geert Bekaert and Campbell R. Harvey (1995) use a conditional regime-switching model in which periods of greater and lesser integration between modern capital markets are identified. An alternative approach is that in Geert Bekaert et al., (2002), who run regressions of financial and macroeconomic data for 20 emerging market countries. They then test for breaks in the regressions, which are interpreted as reflecting changes in the level of integration.

Co-movements can also be thought of as reflecting common shocks. For instance, studies of modern data by Kuntara Pukthuanthong and Richard Roll (2009) attempt to estimate common shocks affecting all markets in their samples, and then estimate the co-movement of each index with this shock. Those markets that move more strongly with the common shock are considered to be more integrated. While many recent studies use such methods[25], few historical studies have employed them.[26] An exception is Rebecca Stuart (2016) who identifies a common shock across six equity markets during the classical gold standard era using principal component analysis and estimates the impact of this shock on each market in a VAR.

[24] See Peter C. Schotman and Ania Zalewska (2006) for a similar study of the integration of emerging European economies and developed economies using modern data.

[25] See also Anthony Chambet and Rajna Gibson (2008) and Geert Bekaert, *et al.,* (2009).

[26] Michael Edelstein (1982) employed such methods to examine co-movements of rates of return across industries and countries over the period 1850 to 1914.

Another approach uses generalized autoregressive conditional heteroscedasticity (GARCH) methods to estimate the co-movement of the returns and volatility across markets. GARCH models allow for the heteroskedasticity which is often present in financial data, and explicitly model how it evolves over time. GARCH frameworks thus enable the estimation of time varying covariances and correlations between markets. In a historical setting, Taufiq Choudhry (1995) estimates an integrated GARCH model of the persistence of stock return volatility of European indices in the 1920s and 1930s. The author shows that shocks to volatility are permanent for most of the indices studies. A similar GARCH approach is adopted in this paper.

The Data

Data Sources

This section outlines the data used in the analysis. The data for the UK are provided by Campbell and Rogers (2017), those for the US are compiled from the database of William N. Goetzmann et al., (2000), while those for Ireland are compiled from the underlying data in Grossman et al. (2014). Although the data are from different sources, they are compiled in a consistent manner. Specifically, they are for capital gains (exclusive of dividends) in common equities (preference shares, bonds, and other instruments are excluded), price-weighted and end-month.[27] Furthermore, there is no cross listing of stocks.[28] The Campbell and Rogers (2017) data pertain to the London Stock Exchange, the Goetzmann et al., (2000) data

[27] The data presented in Campbell and Rogers (2017) includes dividends, however, the authors kindly provided a series exclusive of dividends. The Grossman *et al.*, (2014) series are presented in unweighted and market capitalisation weighted averages, however, the authors kindly provided the underlying data so that a price-weighted series could be calculated.

[28] Listings in the Irish index compiled by Grossman *et al.*, (2014) are all of domestically oriented firms. Nonetheless, seven companies of these companies were also listed in London; these are removed from the Irish index for the current study. All listings included in the UK index are domestically oriented. Stocks on the NYSE listed in London were removed using the list provided in Table 10 of Campbell and Rogers (2017) (who also use the Goetzmann *et al.*, (2000) database to compile a US series).

pertain to the New York Stock Exchange, while the Grossman et al., (2014) data are composed of listings on the three Irish exchanges, Dublin, Belfast and Cork.

Following Campbell and Rogers (2017), the data series are windsorized to lessen the impact of outliers. Thus, the most extreme negative values of the series are set to the level of returns at the 2.5th percentile, and the most extreme positive values of the series are set to the level of returns at the 97.5th percentile.

Finally, the exchange rate needs to be considered. The UK and Irish data are in pounds Sterling, so no adjustment is required. However, even though the gold standard was in operation for much of the sample, the Dollar-Sterling exchange rate floated for periods. Therefore, US returns are converted to Sterling using exchange rate data from William D. Craighead (2010). Interestingly, the Dollar-Sterling exchange rate does not seem to have a large impact on returns: the correlation between US returns denominated in Dollars and those denominated in Sterling is 0.99.

A Look at the Data

The final series are presented in the three panels of Figure 1 (note that the scales differ). Although the econometric analysis below uses monthly returns, here I present a 12-month moving average, for ease of interpretation. All series are presented on the same scale, and are missing for the months at the beginning of the First World War. The UK series in panel (a), has four notable episodes. First, the series declines markedly in the late-1870s, coinciding with the failure of the City of Glasgow Bank.[29] Although it did not precipitate a systemic crisis, this failure did have broad effects on other banks, credit access and, in the medium term, the regulatory landscape. Second, in the mid-1890s, the series grows strongly, in line with the period of strong growth in the London Stock Exchange noted in Richard S. Grossman (2002). The period of the First World War is marked by increased volatility. The outbreak of the War resulted in a financial crisis in the UK, which prompted the closing of the exchange. As

[29] See John D. Turner (2014), Graeme G. Acheson and John D. Turner (2008) and Richard Button *et al.,* (2015).

the centre of international finance at the time, the financial system in the UK ground to a halt when the prospect of European war led foreign counterparts to withdraw funding from the system.[30] The effect is evident in the immediate decline in the series upon the reopening of the exchange. However, it recovers towards the end of the War and during the immediate post-War boom. The economic vicissitudes of the early 1920s, including rising unemployment and falling prices and the return to the gold standard, led to large swings in returns.

Some of these shocks are evident in the other two series. The Irish returns, in panel 1(b), also decline around the time of the City of Glasgow Bank failure. However, the decline begins earlier, coinciding with the agricultural depression which began in 1877. The invention in 1888 in Ireland of the pneumatic tire resulted in a 'bicycle boom', which was coupled by strong performance of railways in the early 1890s.[31] Railways grew strongly again in the late 1910s; thereafter they declined almost continuously.[32] Finally, towards the end of the sample, the Irish market experienced similar shocks to those in the UK; the First World War, and the difficulties of the post-War period are associated with greater volatility in the series. However, the lower level of returns during this period compared to the UK is also striking, and this has often been attributed to the disruptive effect of the Irish independence struggle and the establishment of the Irish Free State in its immediate aftermath.[33]

The shocks of the First World War and the 1920s are also evident in the US data, however, they are not outliers (panel 1(c)). Instead, the US series exhibits many large shocks throughout the period. In particular, panics in 1873, 1884, 1893, 1901 are all evident in the data. The crisis triggered by the failure of the Knickerbocker Trust in 1907 generated the largest decline of all over the period.[34] The only other similar decline occurred in 1917, coinciding with the US joining the First World War. In

[30] See Richard Roberts (2013) for a discussion of the origins and resolution of this crisis.

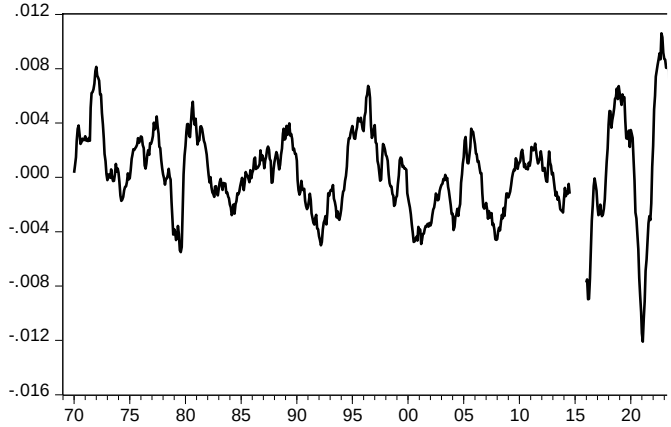
[31] See Thomas (1986).

[32] See Grossman *et al.,* (2014).

[33] See Grossman *et al.,* (2014) and Hickson and Turner (2005).

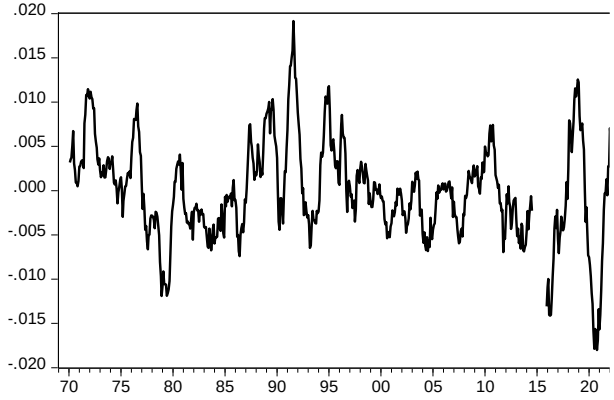
[34] See Library of Congress business reference service and NYSE.com for a chronology of the exchange.

the post-War period, although the series display volatility in the post-War period similar to that in the other series, overall, it picked up more strongly during the 1920s.[35]



Source: See text

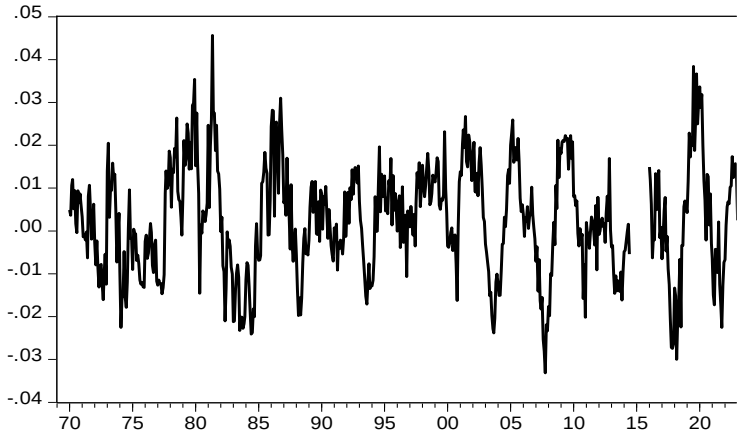
Figure 1(a)
UK Returns, 12-Month Moving Average, 1869-1925



Source: See text

Figure 1(b)
Irish Returns, 12-Month Moving Average, 1869-1925

[35] By 1921, 171 million shares were traded on the NYSE, a new record (Michie (198 7)).



Source: See text

Figure 1(c)
US Returns, 12-Month Moving Average, 1869-1925

Table 1 contains descriptive statistics for the three series. The Table presents the mean monthly return and variance for the three series over the full sample and three subsamples: the period up to the failure of the City of Glasgow Bank, the period between that and the outbreak of the First World War, and the period thereafter. Turning to the mean monthly return, the US series grows most strongly over the entire sample, followed by the UK and then Ireland, which records a negative average return over the sample period. This result is not surprising and is compatible with findings in Philippe Jorion and William N. Goetzmann (1999) that US equity returns were higher than those in other developed economies in the twentieth century.[36] However, looking across the subsamples, the stronger overall growth in the US is driven by the final two subsamples. Indeed, in the first subsample, the average US return is markedly lower than that in either Ireland or the UK. In contrast, the UK and Irish average returns are both negative in the second subsample, but the US average return was strongly positive, while the average return in the US in the 1920s is particularly high, reflecting the boom in stock markets preceding the 1929 crash.

[36] Jorion and Goetzman (1999) use real data, while the data here is nominal.

Looking at the right-hand side of Table 1, perhaps unsurprisingly given the volatility evident in Figure 1, the US displays the highest variance over the sample period, followed by Ireland and then the UK. This is a pattern repeated throughout the subsamples. Furthermore, it increases through the subsamples, and is highest in the final subsample for all three series.

Table 1

Descriptive Statistics, Monthly Returns, 1871-1925

	Average Return			**Variances**		
	UK	IE	US	UK	IE	US
Full sample	0.050	-0.005	0.264	0.445	2.098	41.374
1869M1-1878M9	0.177	0.201	0.048	0.277	1.302	39.403
1878M10-1914M8	-0.020	-0.015	0.273	0.322	1.786	37.508
1914M9-1925M12	0.162	-0.154	0.426	0.935	3.750	55.710

Source: See text

Estimating the Co-movement of Equity Returns

The GARCH Framework

To understand the co-movements of the three markets better, I next turn to the econometric evidence. Since financial data such as those used here often display volatility that is predictable through time, I estimate the joint behavior of stock returns in a dynamic conditional correlation (DCC) multivariate GARCH (1, 1) model framework as set out in Robert Engle (2002). [37] Unlike other specifications, such as constant conditional correlation models, DCC models assume that the correlations between series vary through time. This is an important feature of the model as it will allow an examination of how the correlations of the three markets changed over the 55-year sample period.

[37] Testing for ARCH effects requires regressing each return series on its own lags and retrieving the residuals series. The residuals series is squared, and then regressed on its own squared lags. The null hypothesis is that ARCH effects are not present, and therefore that the parameters on the squared lagged terms are equal to zero. The test indicates that the null of no ARCH effects can be rejected for all three series (all have p-values of 0.00).

The DCC framework can be written as:

$$y_t = Cx_t + \epsilon_t$$
$$\epsilon_t = {H_t}^{1/2} v_t$$
$$H_t = D_t^{1/2} R_t D_t^{1/2}$$
$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}$$
$$Q_t = (1 - \lambda_1 - \lambda_2)R + \lambda_1(\tilde{\epsilon}_{t-1}\tilde{\epsilon}'_{t-1}) + \lambda_2 Q_{t-1}$$

Where y_t is a vector of dependent variables (the returns), C is a matrix of coefficients, x_t is a vector of independent variables (in our case, lagged returns), $H_t^{1/2}$ is the Cholesky factor of the time-varying conditional covariance matrix, H_t, v_t is a vector of normally, independently and identically distributed innovations, and D_t is a diagonal matrix of conditional variances,

$$D_t = \begin{bmatrix} \sigma_{1,t}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{2,t}^2 & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & \sigma_{2,t}^2 \end{bmatrix}$$

in which each of $\sigma_{i,t}^2$ evolves according to a univariate GARCH model of the form:

$$\sigma_{i,t}^2 = s_i + \sum_{j=1}^{p_i} \alpha_j \epsilon_{i,t-j}^2 + \sum_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2$$

In addition, R_t is a matrix of conditional correlations[38]:

$$R_t = \begin{bmatrix} 1 & \rho_{21,t} & \cdots & \rho_{1m,t} \\ \rho_{12,t} & 1 & \ldots & \rho_{2m,t} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1m,t} & \rho_{2m,t} & \ldots & 1 \end{bmatrix}$$

$\tilde{\epsilon}_{t-1}$ is a vector of standardized residuals, $D_t^{-1/2}\epsilon_t$. λ_1 and λ_2 are non-negative and satisfy $0 \leq \lambda_1 + \lambda_2 < 1$. When Q_t is stationary, the R

[38] Or more technically, quasi-correlations. See Robert Engle (2009) for a discussion.

matrix is a weighted average of the unconditional covariance matrix of the standardized residuals $\tilde{\epsilon}_t$.

Before continuing it is useful to discuss the role of λ_1 and λ_2 further. These are adjustment parameters that govern the dynamics of conditional correlations. If $\lambda_1 + \lambda_2 = 0$ then the model collapses to one with constant, rather than dynamic, conditional correlation (the matrix R). Conversely, the importance of this matrix declines as the sum of the two parameters approaches one, with the result that the estimated correlations become increasingly dynamic. In particular, as λ_1 increases, the lagged squared residuals (the ARCH terms) play an increasingly important role in estimates of the correlations. Finally, when λ_2 increases, the conditional correlations become more persistent.

In estimating the model, the missing data during the first five months of the First World War are treated as a gap during which the unconditional expectations are substituted for the dynamic components that cannot be computed.[39] This method is appropriate when T/g goes to zero as T goes to infinity, where T is the sample size, and g is the number of missing observations; a reasonable assumption in this instance.

I estimate the model using a standard GARCH (1,1) specification. One lag of the dependent variable is included in the mean equations to capture any autocorrelation in the returns. The results are presented in Table 2, two of which are of particular note. First, the ARCH and GARCH terms are significant in all equations, implying that a GARCH specification is appropriate. [40] Second, a Wald test rejects the hypothesis that the adjustment parameters, $\lambda_1$and λ_2, are both equal to zero, indicating that the dynamic correlation specification of the GARCH model is appropriate (p-value = 0.00).[41]

[39] In addition, data are missing from the Goetzmann *et al.*, (2000) database in five non-consecutive months during the sample period. For these gaps, it is assumed that half the change in the index between the preceding and following months occurs in the missing month.

[40] This is in addition to the ARCH test results.

[41] If the adjustment variables are both equal to zero the DCC model collapses to a constant conditional correlation model, implying that the underlying assumption that there are dynamics in the correlation is incorrect.

Table 2

Trivariate GARCH Results For Monthly Returns, 1869M3-1925M12

	Mean Equations		
	UK Returns	**Irish Returns**	**US Returns**
Lagged UK Returns	0.342***		
Lagged IE Returns		0.088**	
Lagged US Returns			-0.295***
Constant	0.000	-0.000	0.003
	Variance Equations		
Lagged ARCH Term	0.042**	0.046*	0.074***
Lagged GARCH Term	0.932***	0.926***	0.849***
Constant	0.000	0.000	0.000
	Adjustment		
Alpha		0.012	
Beta		0.931***	

Notes: ***, ** and * indicate significance at the 1%, 2.5% and 5% levels respectively.

Correlation of the UK and Irish Markets

The estimated correlation of the UK and Irish market is presented in Figure 2 (solid line). The correlation averages 0.34 over the sample period, however, it is evident that the correlation is much higher and lower than this at various points in the sample. For instance, in the period around 1878, the correlation rises markedly following the failure of the City of Glasgow Bank. In the early 1890s, when the Irish market experienced the bicycle boom, the correlation declines. However, the correlation rises as both markets grow strongly in the late 1890s, reaching its highest point of 0.48 in 1896. The strong performance of Irish railways in the 1910s, leads to a decline in the correlation to 0.26, while the run up to the First World War, and the early-War years, see a rise in the correlation. Through the 1920s, the correlation is somewhat volatile as the economic difficulties of the period affect both indices.

Thus, it appears that the Irish market was to a large extent influenced by events in the UK. That the correlation rises during the failure of the City of Glasgow, the First World War and the economic crises of the 1920s, all points to spillovers occurring from London to the Irish markets. However, it is also notable that a number of idiosyncratic Irish shocks are also evident in the correlation, such as the bicycle boom in the early-1890s,

and the strong performance of Irish railways in the 1910s. Thus, it appears that while the Irish market and UK markets co-moved strongly, there were still shocks occurring in the Irish market only.

Overall, it appears that the correlation rises marginally over time. This is compatible with findings in Campbell et al., (2016) who examine the co-movement of provincial stock exchanges, including the Irish exchanges, with London. They argue that this upward trend might reflect improving communications technology. Furthermore, it is recognized that provincial exchanges originally catered to regional industrial needs, but that over time the number of listings on provincial exchanges declined due to mergers and acquisitions, particularly among banks and railways.[42] The new, larger firms tended to list on the London exchange only. The appearance of more 'regional', albeit large, industries on the London exchange may have increased its co-movement with the Irish exchanges.

Comparison with US Market Correlations

To understand the relative level of co-movement between the Irish and UK markets, Figure 2 also presents the time-varying correlations between the US and the UK markets and the US and Irish markets (dashed lines).

The correlation of the US and UK markets declines around the time of banking panics in the US, most markedly around the panic of 1901, however, also for instance around the panic in 1884, and to a certain extent in 1907. The First World War results in a gradual decline in the correlation of the two markets, and while the correlation rises in the immediate post-War period, it declines again through the 1920s, as the US market recovers more strongly.

Interestingly, despite the gradual rise of correlations, it declines during the final years of the sample. This is the period during which Ireland gained independence from the UK (the Irish Free State was established in 1922), and shows the start of a divergence between these markets. However, it is difficult to draw firm conclusions given the small number of observations covering this period.

In some degree, the correlation between the US and Irish markets follows the pattern of the US and UK through much of the early sample.

[42] Campbell *et al.,* (2016).

A large decline in the correlation is evident in the 1910s, around the time that Irish railways were performing strongly. Also, the correlation between the Irish and US markets rises during the First World War, a period during which the correlation between the Irish and UK markets is falling. The correlation then declines through the 1920s.

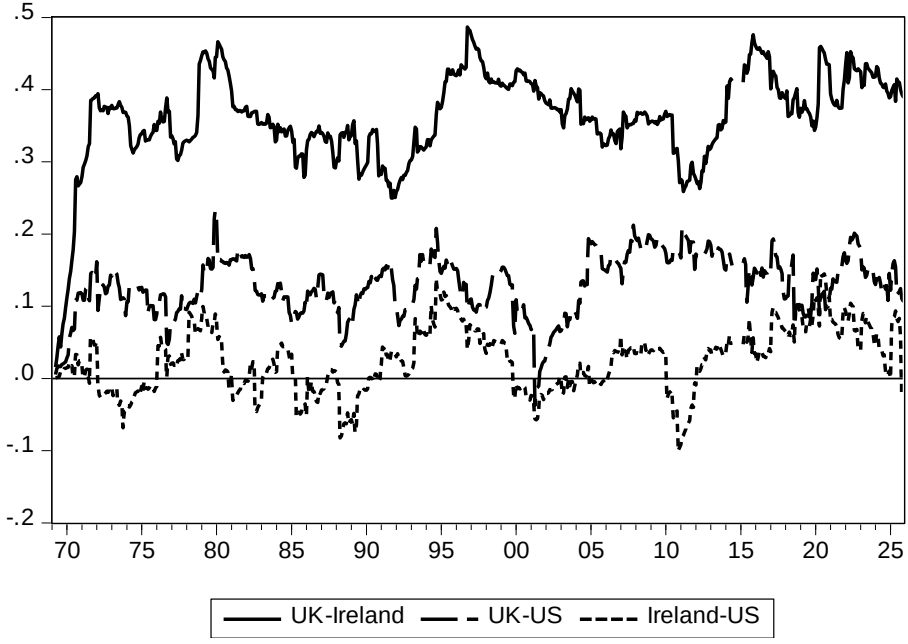


Figure 2
Estimated Correlations Between UK, Irish and US Stock Returns

However, our interest also lies in the comparison of the correlation of the UK and Irish markets with those for the US market. It is clear from Figure 2 that the correlation of the Irish and UK markets is higher than that of the UK and US markets, throughout the entire sample period. Furthermore, the correlation of the Irish and US markets is lower still, and very often negative. This suggests that the Irish market did not co-move with the US market to any significant extent.

As such, it seems that the co-movement between the Irish and UK market was exceptionally high; the Irish market was not particularly

integrated with the other main global market of the day in the US. Therefore, it appears that the UK market dominated that in Ireland during this period, most likely due to the relative size of the UK economy and its geographical proximity.

Conclusions

This paper has studied the co-movements between the Irish stock markets with those in the UK and the US over the period 1869-1925. In doing so, this is one of the first papers to formally examine Irish markets in an international context. By studying three markets, the paper is able to compare the levels of the pair-wise correlations to understand whether some markets are more highly correlated than others. This adds to the literature which examines bi-lateral relationships between markets, by asking not just 'whether' markets co-move, but by 'how much'.

To accomplish this, this paper estimated a tri-variate DCC GARCH model of monthly capital gains in equity prices in London, Ireland and New York. Because the model structure assumes that the conditional correlation of the series is dynamic, the time-varying correlations between the markets can be calculated. The two main findings are as follows.

First, the UK market had considerable impact on the Irish market. This is evident from the fact that shocks that originate in the UK, such as the failure of the City of Glasgow Bank, appear to raise the correlation between the UK and Irish indices, suggesting the shock is transmitted to Ireland. In contrast, similar stress periods in the US do not appear to coincide with increased correlation with the Irish market.

Second, the level of co-movement between the Irish and UK markets is always higher than that between the UK and US markets, and much higher than that between the Irish and US markets. Thus, it appears that the Irish market did not co-move with the US market to any significant degree, but that developments in the UK market dominate the Irish market.

Overall, the findings suggest that there was a particularly close relationship between the UK and Irish markets over the period. Intuitively, this seems unsurprising given the close economic and political links between the two countries during this period. Nonetheless, it raises several questions, including whether the historical co-movement of returns was closer in other countries with similarly strong links, whether Irish and UK

markets moved more or less closely with other European markets than with that in the US, and whether this close relationship between the Irish and UK markets continued in the post-1925 period as Ireland established itself fully as an independent country. I leave these questions to future research.

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WORKS CITED

Acheson, Graeme G. and John D. Turner. 2008. "The Death Blow to Unlimited Liability in Victorian Britain: The City of Glasgow Failure." *Explorations in Economic History* 45 (3): 235-253.

Baldwin, Richard and Philippe Martin. 1999. "Two Waves of Globalisation: Superficial Similarities, Fundamental Differences." NBER Working Papers Series, Working Paper 6904, January.

Bekaert, Geert and Campbell R. Harvey. 1995. "Time-Varying World Market Integration." *The Journal of Finance* 50(2): 403-444. Bekaert, Geert, Campbell R. Harvey and Robin L. Lumsdaine. 2002. "Dating the Integration of World Equity Markets." *Journal of Financial Economics* 65(2): 203-247.

Bekaert, Geert, Robert J. Hodrick and Xiaoyan Zhang. 2009. "International Stock Return Comovements." *The Journal of Finance* 63(6): 2591-2626.

Bordo, Michael D. and Christopher M. Meissner. 2015. "Financial Globalisation, Financial Development and Financial Crises in the

Golden Age, 1870-1914." Paper Prepared for the Conference "Financial Systems and Economic Growth: Conference in Honor of Richard Sylla" Stern School of Business, New York University March 27-28.

Button, Richard, Samuel Knott, MacManus, Conor and Matthew Willison. 2015. "Desperate Adventurers and Men of Straw: The Failure of City of Glasgow Bank and Its Enduring Impact on the UK Banking System." *Bank of England, Quarterly Bulletin 2015* Q1: 23-35.

Campbell, Gareth and Meeghan Rogers. 2017. "Integration Between the London and New York Stock Exchanges, 1825-1925." *The Economic History Review* DOI 10.1111/ehr.12423.

Campbell, Gareth, Meeghan Rogers and John D. Turner. 2016. "The Rise and Decline of the UK's Provincial Stock Market, 1869-1929." *QUCEH Working Paper Series*, 2016-3, May.

Chambet, Anthony and Rajna Gibson. 2008. "Financial Integration, Economic Integration and Trade Structure in Emerging Markets." *Journal of International Money and Finance* 27(4): 654-675.

Choudhry, Taufiq. 1995. "Integrated-GARCH and Non-Stationary Variances: Evidence from European Stock Markets During the 1920s and 1930s." *Economics Letters* 48: 55-59. N

Craighead, William D. 2010. "Across Time and Regimes: 212 Years of the US-UK Real Exchange Rate." *Economic Inquiry* 48(4): 951-964.

Didier, T., I. Love, M. Soledad Martinez Peria. 2012. "What Explains Co-Movement in Stock Market Returns During the 2007–2008 Crisis?" *International Journal of Finance and Economics* 17(2): 182-202.

Dimson, Elroy, Paul Marsh and Mike Staunton. 2002. *Triumph of the Optimists: 101 Years of Global Investment Returns*. New Jersey: Princeton University Press.

Edelstein, Michael. 1982. *Overseas Investment in the Age of High Imperialism: The United Kingdom, 1850-1914*. London: Columbia University Press.

Engle, Robert. 2002. "Dynamic Conditional Correlation – A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* 20(3): 339-350.

Engle, Robert. 2009. *Anticipating Correlations: A New Paradigm for Risk Management*. New Jersey: Princeton University Press.

Garbade, Kenneth D. and William L. Silber. 1978. "Technology, Communication and the Performance of Financial Markets: 1840–1975." *The Journal of Finance* 33(3): 819-832.

Goetzmann, William. N., Roger G. Ibbotson and Liang Peng. 2000. "A New Historical Database for the NYSE 1815 to 1925: Performance and Predictability." Yale International Center for Finance.

Goetzmann, William N., Lingfeng Li and K. Geert Rouwenhorst. 2005. "Long-Term Global Market Correlations." *The Journal of Business* 78(1):1-38.

Gordon, Myron J. 1959. "Dividends, Earnings and Stock Prices." *The Review of Economics and Statistics* 41(2): 99-105.

Grossman, Richard. 2002. "New Indices of British Equity Prices, 1870-1913." *The Journal of Economic History*. 62 (1): 121-146.

Grossman, Richard S., Ronan C. Lyons, Kevin H. O'Rourke and Madeleine A. Ursu. 2014. "A Monthly Stock Exchange for Ireland, 1864-1930." *European Review of Economic History* 18(3): 248-276.

Hickson, Charles, R., and John D. Tuner. 2005. "The Rise and Decline of the Irish Stock Market, 1865-1913." *European Review of Economic History* 9: 2-33.

Hoag, Christopher. 2006. "The Atlantic Telegraph Cable and Capital Market Information Flows." *The Journal of Economic History* 66(2): 342-353.

Hwang, Eugene, Hong-ghi Min, Bong-Han Kim and Hyeongwoo Kim. 2013. "Determinants of Stock Market Co-Movements Among US and Emerging Economies During the US Financial Crisis." *Economic Modelling* 35: 338-348.

Jorion, Philippe and William N. Goetzmann. 1999. "Global Stock Markets in the Twentieth Century." *Journal of Finance* 54(3): 953-980.

Kavanagh, Ella. 1997. "Irish Macroeconomic Performance Under Different Exchange Rate Regimes." *Journal of Economic Studies* 24(1/2): 10-42.

La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer and Robert W. Vishny. 1997. "Legal Determinants of External Finance." *The Journal of Finance* 52(3): 1131-1150.

Litton, A. J. 1961. "The Growth and Development of the Irish Telephone System." *Journal of the Statistical and Social Inquiry Society of Ireland* 10(5): 79-115.

McLaughlin, Eoin. 2015. "Economic Impact of the Irish Revolution." In *Atlas of the Irish Revolution*, edited by John Crowley, Donal Drisceoil and Mike Murphy John Borgonovo (forthcoming), University of St. Andrews Discussion paper in Environmental Economics, 2015-13.

Michie, Ranald C. 1987. *The London and New York Stock Exchanges 1850-1914*. London: Unwin Hyman Ltd.

Miller, Kerby A. 1985. *Emigrants and Exiles: Ireland and the Irish Exodus to North America*. Oxford: Oxford University Press.

Mitchell, B. R. 1981 *European Historical Statistics, 1750-1975*. London: Macmillan Press.

Neal, Larry. 1987. "The Integration and Efficiency of the London and Amsterdam Stock Markets in the Eighteenth Century." *The Journal of Economic History* 47(1): 97-115.

Obstfeld, Maurice and Alan M. Taylor. 2005. *Global Capital Markets: Integration, Crisis, and Growth*. Cambridge: Cambridge University Press.

Ó Gráda, Cormac. 1973. " Seasonal Migration and Post-Famine Adjustment in the West of Ireland." *Studia Hibernia*, 13: 48-76.

Ó Gráda, Cormac. 1975. "A Note on Nineteenth-Century Irish Emigration Statistics." *Population Studies*, 29(1): 143-149.

O'Sullivan, Mary A. 2016. *Dividends of Development: Securities Markets in the History of US Capitalism*. Oxford: Oxford University Press.

Pukthuanthong, Kuntara and Richard Roll. 2009. "Global Market Integration: An Alternative Measure and Its Application." *Journal of Financial Economics* 94(2): 214-232.

Rajan, Raghurum G. and Luigi Zingales. 2003. "The Great Reversals: The Politics of Financial Development in the Twentieth Century." *Journal of Financial Economics* 69: 5-50.

Roberts, Richard. 2013. *Saving the City: The Great Financial Crisis of 1914*. Oxford: Oxford University Press.

Schotman, Peter C. and Ania Zalewska. 2006. "Non-Synchronous Trading and Testing for Market Integration in Central European Emerging Markets." *Journal of Empirical Finance* 13 (4-5): 462-494.

Stuart, Rebecca. 2016. "International Stock Market Integration during the Gold Standard." Unpublished manuscript.

Sylla, Richard, Jack W. Wilson and Robert E. Wright. 2006. "Integration of Trans-Atlantic Capital Markets, 1790–1845." *Review of Finance* 10(4): 613-644.

Thomas, William A. 1986. *The Stock Exchanges of Ireland*. Liverpool: Francis Cairns Publications.

Triner, Gail D. and Kristen Wandschneider. 2005. "The Baring Crisis and the Brazilian Encilhamento, 1889–1891: An Early Example of Contagion Among Emerging Capital Markets." *Financial History Review* 12(2): 199-225.

Turner, John D. 2014. *Banking in Crisis: The Rise and Fall of British Banking Stability, 1800 to the Present*. Cambridge: Cambridge University Press.