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THE G-7 GOVERNMENT BOND MARKETS: A COINTEGRATION STUDY

by

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ABSTRACT

This thesis examines the long-run relationship among government bond total return indexes for the G-7 nations using weekly observations from 1993 to 2022. Using cointegration and error correction models, this study finds long-run relationships for the G-7 government bond markets as a group and evidence for pairwise cointegration between the US government bond market and many of the other G-7 government bond markets. The results imply that diversification benefits by investing across these markets are limited, with hedged US investors having more opportunities than non-hedged investors. Evidence for short-term arbitrage opportunities was also found for the hedged US investor investing in the French and Italian markets. Weak evidence for progressive cointegration between the G-7 government bond markets was also discovered using a backward recursive cointegration test.

Contents

1. INTRODUCTION

In general, investors in the bond market will try to diversify their portfolios to include bonds from other international markets. For a long time, international diversification has been strongly argued to be a valid strategy to minimize portfolio risk for the investor, with studies such as Grubel (1968) and Solnik (1974) segmenting it in the academic sphere. If international bond markets are correlated, this strategy's benefits in terms of risk reduction will be limited. An important indication to investors whether global bond markets are correlated in the long term is to determine if the markets are cointegrated (Granger 1987). This thesis will examine the government bond weekly total return indexes of the G-7 nations (USA, UK, Japan, Germany, France, Canada, and Italy) between 1993 to 2022 and determine if cointegrating relationships exist between these markets. Is it possible for investors to use international diversification when investing in the G-7 government bond markets to reduce their portfolio risk, or are the markets cointegrated and therefore share a common trend or risk factor that renders this strategy ineffective?

For many decades, the cointegration between international interest rates and international stock markets has been studied. Both Kanas (1998) and Gerrits & Yuce (1999) examine the long-run relationship between the US and several other countries (UK, Germany, France, Switzerland, Italy, and the Netherlands) stock markets by observing the daily closing prices of the countries stock indexes. The authors came to different conclusions regarding the evidence for cointegration between these markets. Kanas's study found no long-run relationship between the markets, while Gerrits & Yuce found evidence for cointegration between the stock markets of the USA, Germany, Netherlands, and the UK.

Khan (2011) examined opening daily prices for 22 different stock markets to find the least integrated markets. This was to see if some markets provided US investors with better diversification opportunities. Khan found that after 2010, 16 out of the 22 markets in the sample were cointegrated with the US stock market. Khan concluded that stock markets have become more cointegrated as the world economy and trade have become more globalized.

Although international interest rates and stock markets have been extensively researched using cointegration methods, government bond markets were, for a very long time, a subject lacking

any significant literature even though the government bond market is the largest bond market in the world and is a crucial instrument for government financing.

There has been some literature using cointegration methods to study international government bond markets in recent times. Mills and Mills (1991) examined the long-run relationships between four international government bond markets, the UK, Germany, Japan, and the US. Mills and Mills used daily closing observations on redemption yields of the four markets from 1986 to 1989. To estimate if there existed a long-run relationship between these four markets, they performed a multivariate Johansen cointegration trace tests. They found no evidence for cointegrating relationships in these markets. They conclude that diversification between these markets is a viable strategy for investors to reduce portfolio risk. Clare et al. (1995) study used monthly total return data instead of daily redemption yields for the same four government bond markets as in Mills and Mills (1991). The authors applied the Engle-Granger cointegration method to investigate if there existed pairwise cointegrating relationships between the four markets. As Mills and Mills (1991) four years earlier, Clare et al.(1995) found no significant evidence of cointegration between these markets.

Using monthly government bond index data from 1985 to 1999, Smith (2002) investigated if the markets in the US, Canada, UK, France, Germany, and Japan were cointegrated. The cointegration test for the entire group of markets indicated cointegration. Smith found three cointegrating relationships between the six markets, which goes against the famous "efficient market hypothesis." If a market is efficient, no price information from other markets should be able to forecast the future price of another market. Cointegration between two markets allows for this type of forecast.

Kelly et al. (2008) (from now on, abbreviated KRR) examined the possibility of pairwise and group cointegration relationships between the G-7 nations. The study used total return on the government bond indexes denoted in local currency and USD from 1993 to 2000. The study's result should be interpreted from a US investor's point of view as the pairwise cointegration test is performed with regard to the US. The denotation of the seven indexes in both local currency and USD enables a comparison between investors who hedge currency risk and investors who do not. However, there was no evidence of pairwise cointegration between the US and the other markets regardless of hedging. The authors argued that US investors could diversify their portfolios by investing in these markets. Some evidence of cointegration was found when testing the G-7 government bond markets as a group. The author hypothesized that

market cointegration increased over time, but their results only reported periods of increase but no progressive increase over time.

In a similar fashion to KRR, this paper will examine the G-7 countries and the possibility of cointegrating relationships between the nation's government bond markets. This paper differs by examining a larger period covering 1993 to 2022. Not many studies have examined data from 2000 and beyond. If, as Khan (2011) points out, the globalization of the economy and trade leads to market cointegration, there is a high possibility for the markets to show more evidence regarding cointegration relationships than in the previous studies. The larger period of data covered in this thesis might also allow it to find evidence of progressive cointegration as KRR hypothesized.

This thesis aims to study if there are any cointegrating relationships pairwise between the US government bond market and the other G-7 countries' markets and if the G-7 markets as a group share a cointegration relationship. The results will be used to draw conclusions about the relationships and how US investors should use the information to diversify their bond portfolios.

The rest of the thesis is structured as follows. Section two provides a brief background regarding economic integration, international diversification, and cointegrations implication for the effective market hypothesis. The data used will be described in section three, and in section four, the methods used to study the data will be explained. The empirical results are reported in section five. Section six will discuss the implications of the results for the US investor, international government bond market integration, and the ramification of cointegration for the effective market.

2. BACKGROUND

2.1 Economic integration

Due to advancements in information technology, economic integration has increased between the world's advanced economies. This increase in economic integration implies that economic shocks spread quickly between the country's different markets. An economy's vulnerability to

shocks originating from another country or in the global capital markets depends on the level of integration the country's economy has with the rest of the world (Aysun, 2022).

Aysun (2022) looks at the G-7 countries and tries to estimate the level of integration. He concludes that Canada and the UK are less integrated with the others countries in the group, while Japan and France are more integrated.

Yang et al. (2003) studied whether stock market cointegration had increased from 1970 to 2001, particularly after the economic crash of 1987 and the abolishment of capital controls. They found no evidence of a long-running relationship between the US stock market and other major economies like Japan and Germany. However, the authors found evidence of several smaller nations, such as Norway, Sweden, and Belgium, increasingly sharing long-run relationships with the US after the introduction of the EMU.

2.2 International diversification

The bulk of the literature on international diversification focuses on equity. However, some studies, such as Levy and Lerman (1988), argue for potentially large diversification benefits for the US investors in portfolios consisting of bonds in developed markets. The gains made from international diversification have been argued due to increased correlation between developed markets, see Goetzmann et al. (2005). Glen and Jorion (1993) found significant benefits by investing in international government bond indexes, especially for investors who choose to hedge currency risk. Fletcher et al. (2019) similarly found possible diversification gains by investing in the G-7 government bond markets, although the gains were naturally smaller if the portfolio was restricted (no short-selling). By contrast, Hansson et al. (2009) found no benefit in regards to diversification by investing in developed market government bond portfolios regardless of currency hedging.

Tahai et al. (2004) investigated the financial cointegration of the G-7 countries' stock markets. Using monthly stock indexes from 1978 to 1997, Tahai et al. (2004) found common trends in the market's returns when doing a joint cointegration test. The authors conclude that these findings imply that the literature on international diversification gains made from investing in the different international markets could be overstated.

2.3 Effective market hypothesis and cointegration

The effective market hypothesis, in which prices always "fully reflect" available information, is called "efficient" and has long been debated. Furthermore, scholars have discussed over many years whether cointegration disproves the efficient market or not.

Granger (1986) argues that if two prices are shown to be cointegrated, the price of one asset can be used to forecast the other assets' future price. This is in direct violation of the principles of the effective market hypothesis. During the 1990s, many counteracted this assumption. Engle (1996) claims that cointegration and market efficiency have nothing to do with each other. Wilson & Marashdehm (2007, p.88) argues that co-movements or cointegration between stock prices is consistent with efficient markets in the long run but not in the short run.

3. DATA

The indexes used in this study are from the FTSE Russel World Government bond index (WGBI), where the seven indexes were obtained using a Bloomberg terminal. These indexes measure the performance of fixed-rate, local currency investment-grade sovereign government bonds.

Only bonds which fulfill specific criteria, such as fixed-rate coupons, minimum maturity of at least one year, and minimum market size of at least 50 billion USD, 40 billion EUR, or 5 trillion JPY (outstanding amount of markets eligible issues), have been included in the indexes. Furthermore, the indexes are weighted by market capitalization. For more details on the indexes used, see FTSE Fixed income Index Guide (2021).

The data are the weekly total return indexes of the G-7 countries expressed as prices (the price performances of the indexes, accounting for price appreciation and reinvesting interest and coupon payments but disregarding potential fees and taxes the investor might pay) spanning from January 8^{th,} 1993, to April 22^{th,} 2022. Some series had data dating back to 1985. However, this data was not complete and was missing many observations. As stated in the introduction, this thesis focuses primarily on the data available after the turn of the century (2000 and beyond), as this period has not been studied as extensively as the second half of the 20th century. Hence, the data dating back to 1985 was therefore not used.

This study examines the G-7 nations, consisting of the US, Japan, UK, Germany, France, Canada, and Italy. Individual indexes for each country's government bond markets' weekly total return were gathered in local currency and USD. As the indexes are stated in both local currency and USD, the comparison can be made for the US investor that chooses to hedge their currency risk or leave it open. The indexes denoted in local currency consider the return the investor would have made from currency fluctuations. The international diversification implications of the results obtained will be from the US investors' point of view.

The data set has 1529 weekly observations for each of the seven indexes. The weekly total return of the seven countries was converted into natural logs to combat any skewness in the sample.

This study focuses on cointegration and the long-term relationships between these government bond markets. However, it is interesting to first look at the short-term findings and correlations between the seven markets to see if the short-term can provide hints for long-term relationships. Table 1 displays the average weekly returns, standard deviations, and coefficient of variation for each of the seven countries. This is the average returns in percentages week to week, not to be confused with the total return price indexes used when testing for cointegration.

Table 1: Average weekly returns (AWR), standard deviations (SD), and coefficient of variation (CV)

	Local Currencies			USD		
	AWR	SD	CV	AWR	SD	CV
US	0,09%	0,62%	7,19	0,09%	0,62%	7,19
Japan	0,05%	0,38%	7,80	0,06%	1,58%	26,88
UK	0,11%	0,89%	7,88	0,11%	1,48%	13,62
Germany	0,08%	0,54%	6,45	0,09%	1,36%	15,70
France	0,09%	0,59%	6,33	0,09%	1,39%	14,83
Canada	0,10%	0,62%	6,39	0,10%	1,21%	11,67
Italy	0,12%	0,75%	6,18	0,12%	1,51%	12,42

From this table, Italy seems to have the most favorable risk to return ratio of the Indexes, while Japan, for the hedged investor, has arguably, compared to the other markets, an inferior risk to return ratio. This representation does not consider the possible diversification gains the investor can make as it only assumes the investor invests in one of the indexes.

Table 2 displays the correlation between the seven government bond markets' weekly returns in local currencies and USD.

When considering short-term relationships, the US and Canada have the highest correlation between local currencies, which is expected as they share geographical, cultural, and economic similarities. Japan's bond market has the lowest correlation with the US and could be an arguable good short-term diversification opportunity for the US investor not hedging.

If the US investor hedges their currency risk, they would, in the short-term, be best off investing in the Italian market, which has a very low correlation with the US market, while the UK market is arguably the worst of the markets with a correlation of 0.44.

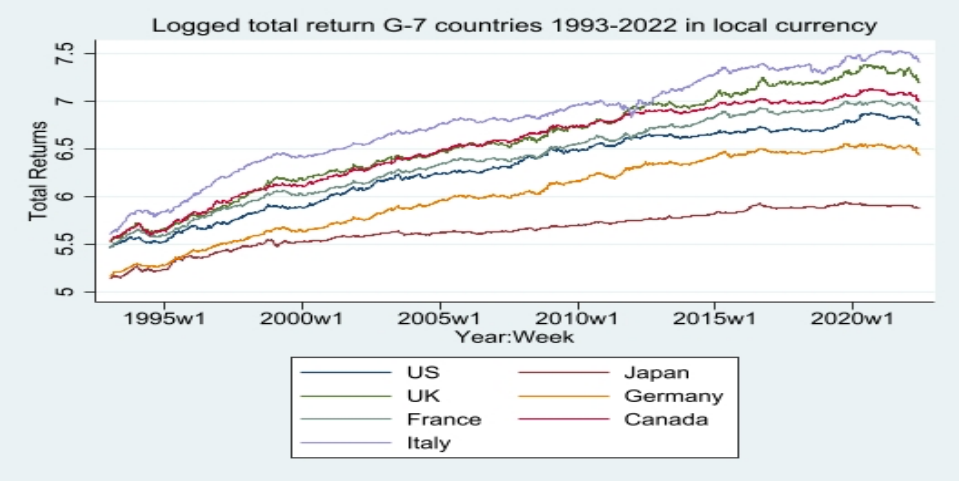
Table 2: Correlation Coefficients for weekly returns: January 1993-April 2022							
Local Currencies							
	US	Japan	UK	Germany	France	Canada	Italy
US	1						
Japan	0,32	1,00					
UK	0,68	0,32	1,00				
Germany	0,71	0,37	0,77	1,00			
France	0,64	0,34	0,71	0,88	1,00		
Canada	0,82	0,30	0,65	0,67	0,60	1,00	
Italy	0,32	0,17	0,37	0,39	0,59	0,32	1,00
USD							
	US	Japan	UK	Germany	France	Canada	Italy
US	1,00						
Japan	0,32	1,00					
UK	0,44	0,26	1,00				
Germany	0,23	0,28	0,44	1,00			
France	0,37	0,39	0,67	0,58	1,00		
Canada	0,34	0,14	0,45	0,26	0,43	1,00	
Italy	0,25	0,29	0,59	0,51	0,91	0,42	1,00

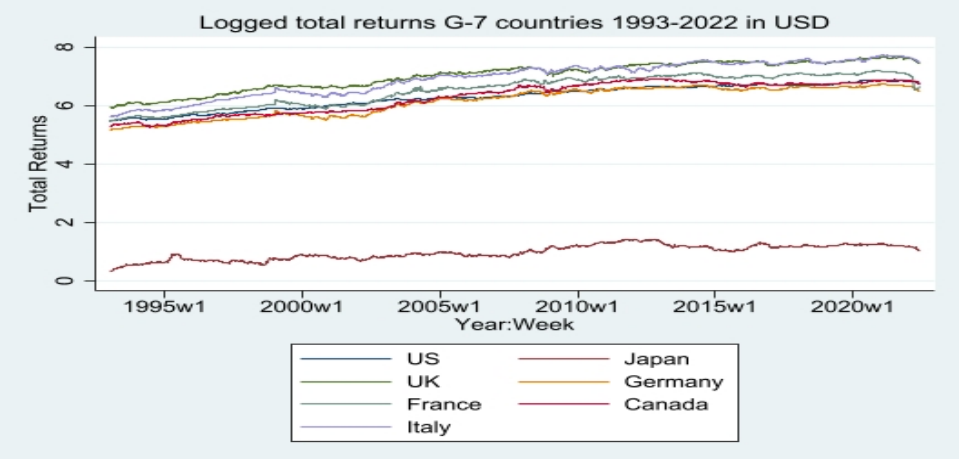
4. METHOD

Two or more nonstationary variables are considered cointegrated when a linear combination of the variables is stationary. This means the variables display long-run relationships. The variables can drift apart in the short run, but economic systems will, in the long run, bring their values back to the same path (Johansen 1988, 1991)

To determine if the G-7 government bond markets are cointegrated, the first step is to test if the different series on their own are nonstationary. This will be done using the Augmented Dickey-Fuller (ADF) test. If the series are nonstationary, as would be expected from observing the graphs in Figure 1, the first difference of each series is taken and again tested using the ADF test. If the variables are first difference stationary, they are all integrated by order one or I (1). This allows for tests of cointegration.

Figure 1: Logged total returns G-7 countries 1993-2022 denoted in local currency and USD





The first test is the pairwise Johanssen cointegration trace test. The test will be performed between the US government bond market and the other six countries' markets. This is to estimate if there is a cointegration relationship between the US market and the other countries. This test will be performed separately for the local currency and USD denominated series. The result is interesting from the view of a US investor. Suppose there is evidence for cointegration between the US market and another G-7 market. In that case, this implies they share a common trend or risk factor, and trying to diversify your investment portfolio by investing in the other markets is not effective. All cointegration tests are methods described by Johansen (1988, 1991) and Johansen & Juselius (1990).

The second Johanssen cointegration trace test will be performed for the entire group of nations. This is done to see if there is any long-run relationship within the entire group.

Two more tests will be performed after the multivariate cointegration test on the group of G-7 nations. The first one is a recursive cointegration test. This is to see if the G-7 markets have become more or less integrated over time. The test procedure outlined by Bremnes, Gjerde & Saettem (1997) is a backward recursive test. The test is used to combat the fact that in time series data, there is overtime, often shifts in the means and the trends of the variables. The test involves testing for cointegration with the Johannsen cointegration trace test but with a decreasing number of observations until the end of time, keeping the end date fixed. The first trace statistic is observed by performing the Johannsen cointegration test on observations 1 to 1529. The second trace statistic uses observations 2 to 1529, the third 3 to 1529. The last trace statistic will be on observations 1504 to 1529. The test results will be displayed with graphs. The graphs show the trace test statistic over time with a 5% critical horizontal value-line added to determine significance. The results from the recursive cointegration test will display how stable the cointegrating relationship between the markets has been across the time period of the sample. When reading the result, the observer must keep in mind that as the degrees of freedom diminishes towards the end of the period (2022) due to the smaller sample size, the test statistic will likely become distorted. Therefore, the reader needs to be critical of any significant results towards the very end of the period.

A parameter exclusion test will be performed if signs of cointegration are found. The test discussed in Johansen & Juselius (1990) is a likelihood ratio test. The Vector Error Correction Model (VECM) is used with the lags selected for the underlying VAR model and tested for if a variable can be set to zero. The test statistic is chi-square with 1 degree of freedom, as only

one of the variables is restricted. If the parameter restriction test fails to reject the null, the restricted variable does not belong in the cointegration relationship. If the null is rejected, the variable in question is statistically significant for the cointegration vector. After the test, an Error Correction Model (ECM) will be estimated for the countries found significant to the cointegration relationship. This estimates how the long-run relationship between the markets is upheld in the short-run. The ECM model will specify which market corrects the long-run relationship and which markets diverges. The ECM will also show if one market's return can be predicted with the lagged return of another market.

5. EMPIRICAL RESULTS

Table 3 displays the results of the ADF unit root test. All the ADF tests included a trend. The inclusion of a trend was determined after inspecting the graphical representation of the series. The lag lengths were chosen by using the lag lengths that minimized the Akaike information criterion (AIC).

All countries are, as expected, nonstationary unit root processes. After the first difference, all the variables are stationary. This result implies that all variables are integrated by order one or I (1) (Table 3).

Table 3: Augmented Dickey-Fuller Unit root test

Level variable					First difference variable				
	Local Currency		USD			Local Currency		USD	
Variable	Lag	ADF	Lag	ADF	Variable	Lag	ADF	Lag	ADF
US	6	-0.30	6	-0.30	US	6	-14.00*	6	-14.00*
Japan	5	-2.30	9	-2.40	Japan	5	-13.53*	9	-14.41*
UK	3	-1.18	3	-1.40	UK	3	-18.88*	3	-20.31*
Germany	2	0.40	2	-0.43	Germany	2	-22.24*	1	-10.86*
France	1	-0.33	11	0.34	France	7	-12.73*	10	-11.68*
Canada	6	-0.05	11	-0.19	Canada	6	-14.30*	11	-14.90*
Italy	4	-2.36	1	-1.52	Italy	4	-16.35*	1	-16.23*

H0: series contains unit root * indicates significance at a 5% level

The model used for the cointegration test allows for a linear deterministic trend and a constant. In table 4, the results of the bivariate or pairwise Johansen cointegration trace tests are displayed. Lag lengths were again chosen by the lag that minimized AIC for each pairwise regression.

Table 4: Johansen cointegration test

	Local Currency		USD	
	Lag	Trace test stat.	Lag	Trace test stat.
US & Japan	6	15.88*	6	14.80
US & UK	5	10.58	3	16.22*
US & Germany	5	16.17*	2	12.69
US & France	7	15.65*	12	7.32
US & Canada	5	20.00*	9	11.28
US & Italy	3	22.26*	5	18.39*

* indicates significance at 5% level.

The results indicate that pairwise cointegration exists for the US government bond market with the markets in Japan, Germany, France, Canada, and Italy when the indexes are denoted in their local currency. Only the UK market showed no statistically significant cointegration relationship with the US government bond market when the indexes were denoted in local currency. For the test conducted on the indexes denoted in USD, only UK and Italy are shown to have cointegration relationships with the US. This result would imply that the US investor hedging their currency risk has more choices regarding which markets to purchase bonds in to diversify their portfolio. In KRR, no pairwise cointegration relationships were found. The results would indicate that these six markets have become more cointegrated in the years after 2000 with the US market.

The pairwise cointegration test can overlook more complex relationships between the countries. Testing for cointegration in the markets as a group provides a complete image of the long-run relationships. The result of the group test is reported in table 5. The interpretation is that the higher the number of cointegrating vectors, the more stable the cointegrating relationship between the variables (Stock & Watson 1988). For the G-7 markets, the existence of only one cointegration vector at the 5% level is rejected, implying two or more cointegrating vectors. This is a more stable relationship than that previously found by KRR, who could only reject the null hypothesis of zero (none) cointegrating vectors. This would imply that the theory

they propose in their study of cointegration increasing over time between these government bond markets might hold. To determine if there have been periods of increased stability in the relationship among the G-7 markets. The recursive cointegration test was performed. The results imply no more than four cointegration vectors for the local currency-denominated indexes and three for the USD-denominated indexes. Since the evidence of a fourth vector was arguable weak, it could be argued that this result is in line with the findings of KRR, indicating that the markets have experienced periods of increased integration, but there is no evidence of progressive integration. The recursive cointegration test results are found in figures 2 through 7 in Appendix A.

Table 5: Multivariate Johansen cointegration test for all G-7 countries		
	Local currency Lag(2)	USD Lag(13)
Possible number of cointegrating vectors	Trace test stat.	Trace test stat.
None	152.44*	138.97*
One	100.86*	79.10
Two	67.79	48.59
Three	41.27	31.17
Four	23.00	16.25
Five	9.77	7.8
Six	3.40	1.72

The test includes a linear trend and a constant. * indicates significance at a 5% level

For these seven markets, there can be as many as six cointegrating vectors (7-1). However, it is impossible to specify between which of the markets these vectors exist. A test for parameter restrictions needs to be performed to define the relationship more accurately. This test is done to check if any of the markets does not belong in the cointegration equation. Table 6 reports the results of the parameter exclusion test. The US and Canada can be excluded from the model for the local currency test. In the USD denominated test, UK and Germany can be excluded from the cointegrating relationship.

Table 6: Likelihood ratio test for exclusion of variables in cointegration vector		
	Local currency	USD
	$\chi 2$ statistic	$\chi 2$ statistic
US	2.664	19.73*
Japan	6.632*	23.65*
UK	10.32*	0.005
Germany	4.22*	0.02
France	7.635*	13.01*
Canada	0.3876	1.193
Italy	10.17*	23.23*

H0: The variable can be restricted to zero and does not belong in the cointegration equation. * indicates significance at a 5% level

Tables 7 and 8 show the corresponding error correction models for the countries denoted in local currency and USD, respectively (removing the countries found insignificant in the parameter exclusion test). Except for France in the USD denoted ECM, all error correction terms are significant.

Some of the lagged returns in the USD denoted ECM significantly impacted other markets' returns, such as France with the first lag of the US and the third lag of Italy. The first lag of France also showed a significant impact on Italy's returns. These significant relationships imply that the French market returns are influenced by the previous returns from the US and the Italian markets. This would suggest that investors can, in the short-run, partly predict the French market's return by observing the past returns of the Italian and US market and the Italian market returns by observing past returns of the French market.

Table 7: Error correction model Japan, UK, Germany, France, and Italy (Local currency)					
Regressor	Regressand				
	Japan	UK	Germany	France	Italy
Correction term	-0.00	-0.01*	-0.01*	-0.01*	-0.01*
Cointegration term	1	-0.53*	-1.79*	-3.17*	-1.19*
Constant	0.00	0.00	0.00	0.00	0.00
Japan_{-1}	0.340	0.049	0.047	0.036	-0.032
UK_{-1}	-0.010	-0.150	-0.031	-0.039	0.062
$Germany_{-1}$	0.085	-0.003	-0.100	-0.017	-0.293
$France_{-1}$	-0.039	0.067	0.070	0.002	0.127
$Italy_{-1}$	0.011	0.000	0.007	0.001	-0.023
R^2	0.030	0.037	0.039	0.044	0.014

* indicates significance at a 5% level

Table 8: Error correction model US, Japan, France, and Italy (USD)				
Regressor	Regressand			
	US	Japan	France	Italy
Correction-term	0.00*	0.01*	-0.01	-0.02*
Cointegration term	1	-1.06*	2.01 *	-2.18*
Constant	0.00*	0.00	0.00	0.00
US_{-1}	-0.08*	0.15	0.20*	-0.01
US_{-2}	0.06*	-0.01	-0.04	0.05
US_{-3}	0.04	0.10	-0.04	-0.02
Japan_{-1}	0.00	-0.07*	-0.03	-0.03
Japan_{-2}	0.00	0.02	0.05	0.02
Japan_{-3}	-0.01	-0.03	0.00	-0.01
$France_{-1}$	0.00	-0.02	-0.28*	-0.07*
$France_{-2}$	0.01	0.00	0.19*	-0.01
$France_{-3}$	0.00	-0.01	-0.15*	0.00
$Italy_{-1}$	0.01	0.03	0.07	0.01
$Italy_{-2}$	-0.01	-0.01	0.01	0.03
$Italy_{-3}$	-0.01	-0.05	0.10*	0.04
R^2	0.04	0.03	0.22	0.05

* indicates significance at the 5% level

6. DISCUSSION

The results for the pairwise cointegration test between the US market and the other G-7 markets show that several markets share a long-run relationship with the US market. Japan, Germany, France, Canada, and Italy were cointegrated with the US market when the indexes were denoted in local currency. The arguable implication is that for the US investor that does not hedge their currency risk, investing in these markets will be suboptimal for diversification purposes (this assuming the investor is also investing in his/her market). Only the UK and Italy showed any cointegrating relationships with the US market for the investor that chooses to hedge their currency risk. The pairwise result suggests that the hedged investor has greater diversification opportunities than the unhedged investor, with fewer cointegrating relationships with the other G-7 nation's markets. This result is in line with Glen and Jorion's (1993) study, which also found evidence of hedged investors receiving greater diversification possibilities over unhedged investors.

The group cointegration analysis of the G-7 countries implies at least two cointegrating vectors. There was only evidence for at least one cointegrating vector in KRR. This finding would imply that the cointegrating relationship between the markets has become more stable in later years. This is in line with the overall increase in economic integration mainly due to information technology advancements. The results from this thesis imply that the diversification possibilities regarding government bond markets in developed countries such as the G-7 are limited, especially if the investor does not hedge their currency risk. The literature on international diversification benefits might be overstated. However, when observing the recursive cointegration test results, there was arguably only weak new evidence for cointegration stability increasing over time in these markets. The results point to a maximum of four cointegrating vectors for the markets in local currency, and three for the USD denoted markets. The possible fourth vector for the local denominated markets could be evidence of increasing stability over time as KRR only found a possible third vector. This evidence was, however, arguably weak. This result gives more power to the hypothesis that these seven markets experience periods of increased integration, but there is still no strong evidence for progressive integration.

The group Johannsen trace test results for the markets in local currency (after testing for significance of the variables using the Johansen parameter restriction test) imply that Germany,

France, Italy, the UK, and Japan share a cointegrating relationship while Canada and the US were excluded. The US, Japan, France, and Canada were part of the cointegrating relationship for the USD denoted markets. These results suggest several of these markets are cointegrated; therefore, international diversification possibilities are limited regardless of whether the investor hedges their currency risk. The implication for the US investor is that trying to diversify in more than one of the markets part of the cointegration relationship would be ineffective.

As the USD ECM shows, the French and Italian markets have a lagged relationship with previous returns of the US and Italian markets and the French market, respectively. This result implies that US investors who hedge their currency risk can predict future movement in the French and Italian markets by observing past values of the US and Italian markets (the French market in Italy's case). This lagged relationship is not coherent with the effective market hypothesis. Prediction of another variable's future movement by another variable's past movement should not be possible if the markets are efficient.

7. CONCLUSION

This study examines possible cointegrating relationships between the G-7 government bond markets. The examination of the entire group shows there is more than one cointegrating relationship. After testing for parameter restrictions, the markets of Japan, the UK, Germany, France, and Italy were shown to share a long-run relationship when denoted in local currency. For the USD denoted markets, the US, Japan, France, and Italy were shown to have a cointegrating relationship. There is weak evidence of a progressive increase in cointegration between these markets. The results from the error correction models implied that the returns of the French and Italian markets are influenced by the previous returns of the US and Italian markets (the French market in Italy's case). This result implies potential arbitrage opportunities for the hedged US investor in the short run.

The pairwise test suggests the US market, in particular, has become more cointegrated with the other markets in recent years compared to findings in previous studies such as KRR, finding evidence of cointegration between the US and all other markets except for the UK when indexes were denoted in local currency. The US investor who chooses to hedge currency risk

has more opportunities to diversify in these markets as fewer cointegrating relationships with the other markets were found when this was considered, as only Italy and the UK displayed long-run relationships with the US market when the market indexes were denoted in USD.

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9. APPENDIX A

9.1 Results recursive cointegration tests

Figure 2: Backwards recursive cointegration test for G-7 countries: Zero cointegrating vectors

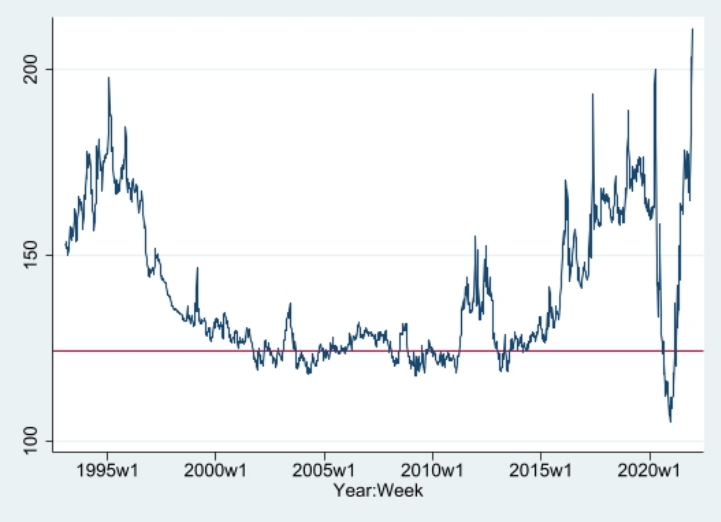

Figure 1 displays the trace test statistic for the hypothesis of zero cointegrating vectors for the G-7 government bond markets denominated in local currency. The results imply at least one cointegrating vector between the markets for most periods of the sample.

Figure 3: Backwards recursive cointegration test for G-7 countries: One cointegrating vector

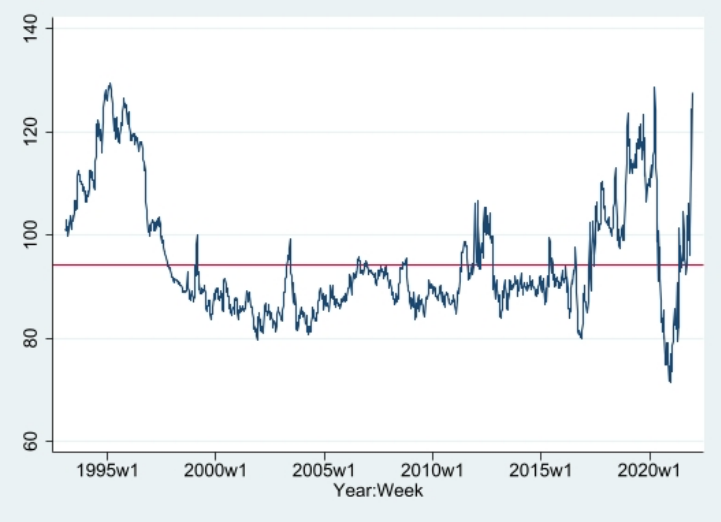

Figure 3 displays the trace test statistic for the hypothesis of only one cointegrating vector for the G-7 government bond markets denominated in local currency. The figure implies that the null hypothesis of only one cointegrating vector can be rejected for some periods, indicating the existence of two or more cointegrating vectors.

Figure 4: Backwards recursive Cointegration test for G-7 countries: Two cointegrating vectors

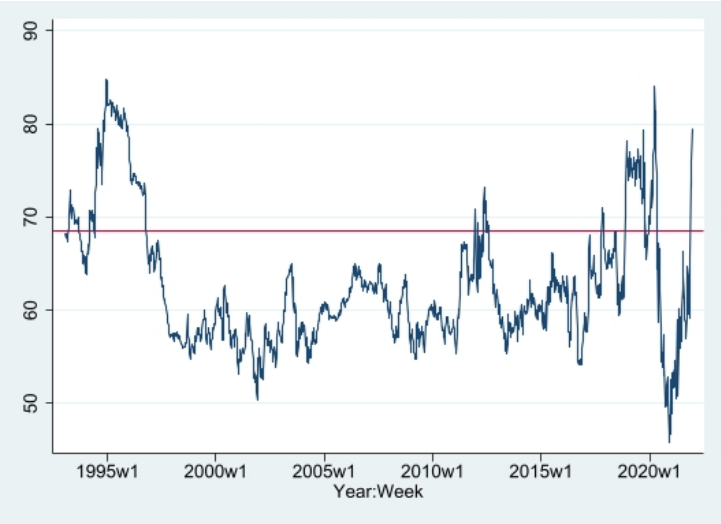

Figure 4 displays the trace test statistic for the hypothesis of only two cointegrating vectors for the G-7 government bond markets denominated in local currency. The results show that the null hypothesis of two cointegration vectors is rejected for some periods, indicating the existence of at least three cointegrating vectors.

Figure 5: Backwards recursive Cointegration test for G-7 countries: Three cointegrating vectors

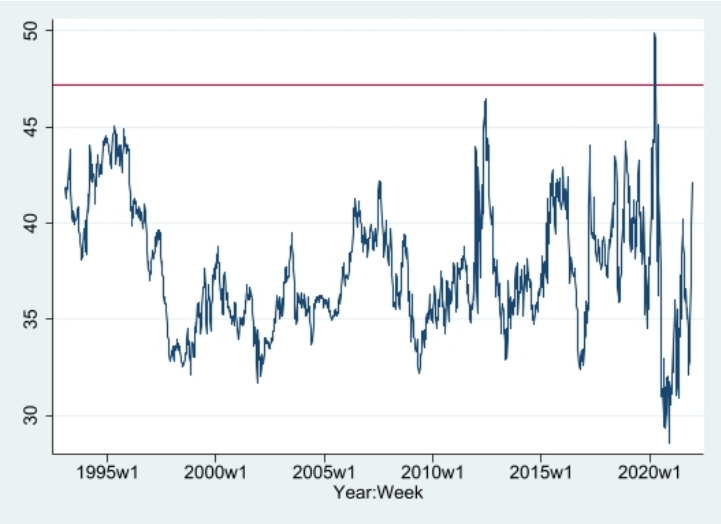

Figure 5 displays the trace test statistic for the hypothesis of only three cointegrating vectors for the G-7 government bond markets denominated in local currency. The results show that the null hypothesis of three cointegration vectors is not rejected for most periods. However, from 2019 to 2020, there is a short period where the null is rejected. This result could indicate the existence of four cointegration vectors. However, the evidence could be argued as weak. No evidence was found for a potential fifth cointegrating vector.

Figure 5: Backwards recursive Cointegration test for G-7 countries (USD denoted): Zero cointegrating vectors

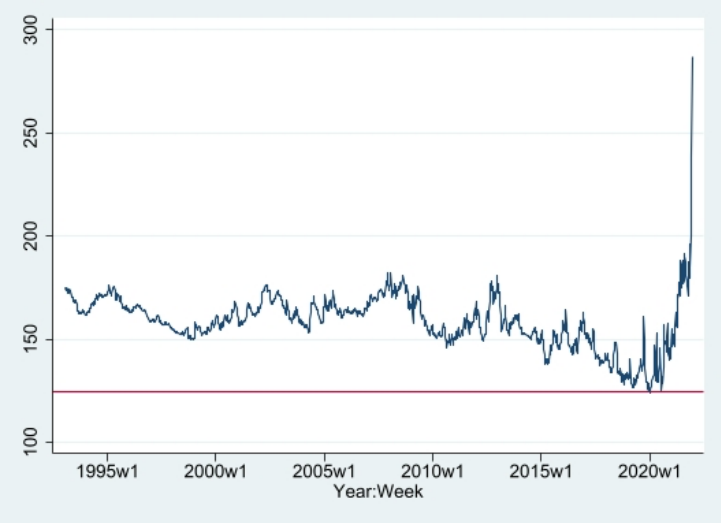

Figure 5 displays the trace test statistic for the hypothesis of only two cointegrating vectors for the G-7 government bond markets denominated in USD. The results show that the null hypothesis of zero cointegration vectors is rejected for all periods indicating the existence of at least one cointegrating vectors

Figure 6: Backwards recursive Cointegration test for G-7 countries (USD denoted): One cointegrating vector

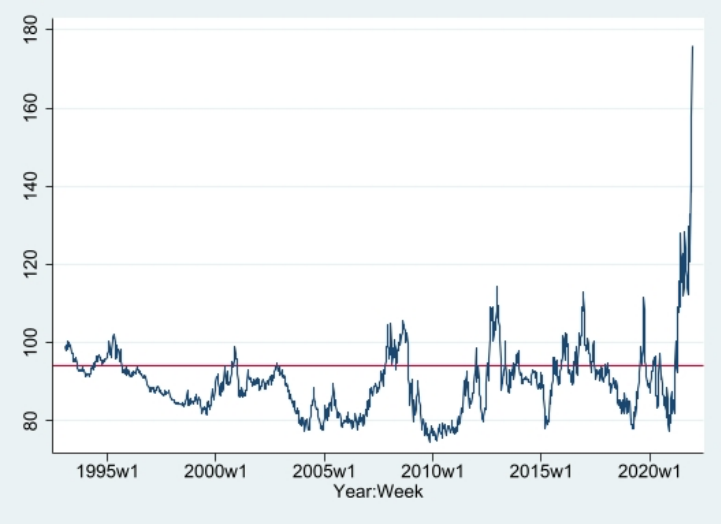

Figure 6 displays the trace test statistic for the hypothesis of only one cointegrating vector for the G-7 government bond markets denominated in USD. The results show that the null hypothesis of only one cointegration vector is rejected for some periods indicating the existence of at least two cointegrating vectors

Figure 7: Backwards recursive Cointegration test for G-7 countries (USD denoted): Two cointegrating vectors

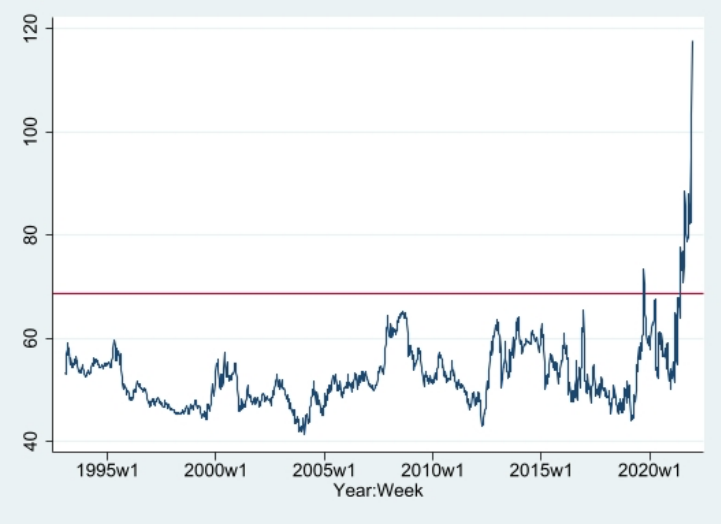

Figure 7 displays the trace test statistic for the hypothesis of only two cointegrating vectors for the G-7 government bond markets denominated in USD. The results show that the null hypothesis of only two cointegration vectors can be rejected for a short period. Weak evidence

for a possible third cointegration vector is implied. No evidence for a possible fourth vector was found.