Sovereign Risk, Cross-Currency Basis and Equity Markets: A Cross-Market Dynamic Interaction

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Abstract

To explore the propagation of shocks across markets, this paper examines the dynamic connections between three distinct markets: credit default swaps (CDS), equities, and cross-currency basis swaps (CCBS) of four major individual economies: Eurozone, UK, Australia, and Japan. We use CDS spreads, CCBS spreads and stock market returns to capture sovereign credit risk, dollar funding liquidity and stock market performance, respectively. Our results show there is a feedback mechanism connecting these markets, for most of these economies. We document that higher CDS spreads induce wider CCBS spreads and declines in stock market returns. We equally show that positive shocks to CCBS spreads lessen CDS spreads and enhance stock market returns. Finally, we show that positive shocks to the stock market are associated with lower CDS spreads and tighter CCBS spreads. These findings are supported by Granger-causality analysis and are robust across subperiods and empirical specifications. Underpinning the feedback mechanism is the role of CDS as an indicator of potential default on obligations in the financial markets.

Keywords: Credit derivatives, dollar funding shortages, credit default and cross-currency swaps, equities performance, dynamic interdependence,

JEL: F30, G15

1. Introduction

How do equities, sovereign credit default swap (CDS) and cross-currency basis swap (CCBS) markets interact dynamically? Several studies have examined the links between equity and credit markets using either bond spreads or corporate CDS spreads to capture events in the credit markets (Longstaff, Mithal & Neis, 2005; Acharya & Johnson, 2007; Blanco, Brennan & Marsh, 2005; Norden & Weber, 2009; Trutwein & Schiereck, 2011). However, since the advent of persistent deviations from covered interest parity (CIP), which have led to significantly wider CCBS spreads, and the subsequent commencement of active trading and hedging activities using CCBS, studies on the dynamic interdependence between sovereign CDS, a gauge of sovereign default risk, and CCBS are scarce. A few theoretical and empirical attempts have recently been made to study the joint dynamics of CDS and CCBS. However, most of them have concentrated on corporate and financial institutions' CDS as a measure of counterparty risk, default likelihood and credit worthiness. For example, in the literature, two such attempts include Iida et al. (2018) & Baba and Packer (2009a). Iida et al. (2018) develop a theoretical equilibrium model and argues that, until more recently, CIP deviations are linked to a rise in non-U.S. banks' default probability, where default likelihood is measured by CDS in their robustness analysis. By developing and testing their equilibrium model of the FX swap market, they underpin the historical importance of default likelihood for understanding CIP deviations, but document that the influence of global banks' credit worthiness (or likelihood of default) in CIP deviations has been weakened by global interest rate differentials.

Baba and Packer (2009a) propose the counterparty-risk hypothesis. Measuring counterparty risk by the size of European and US financial institutions' CDS, they propose that counterparty risk asymmetry between European and US financial institutions are linked with deviations from CIP: If European financial institutions facing US dollar shortages are riskier than their US counterparts, then such a high counterparty risk for European financial institutions would limit dollar flows from their US counterparts (i.e. risk-off sentiment) and increase the premium required for European financial institutions to obtain dollars in the swap market, which worsens the deviations from CIP (i.e. wider CCBS spread). Conversely, increased counterparty risk for US financial institutions relative to their European counterparts works in the opposite direction: dollars flow from US financial institutions (higher counterparty risk) to their European counterparts (lower counterparty risk). Such flows occur when dollar shortages are localized in European financial institutions and do not extend to the US. When the shortages, however, become a global phenomenon (and impact the US), such as during the Lehman failure, then US financial institutions would face increased constraints or barriers to obtaining dollars in the cash market, which would limit their ability to provide dollars to the swap market. In this instance, increased US financial institutions' counterparty risk, together with general dollar shortages, means increased difficulty for these institutions to raise dollars. Thus, when US financial institutions face a higher counterparty risk than their European counterparts, the dollar shortages impair their ability to obtain and provide dollars to the markets, thereby worsening CIP deviations. In extreme cases of shortages, some US institutions could possibly issue in European currencies and swap to dollars, putting further worsening pressure on CIP deviations.

Why is sovereign CDS important? In any country, it is rarely the case that corporates or financial institutions function in isolation from the overall macroeconomy. In this sense, sovereign CDS provides a more general, holistic measure of default likelihood or counterparty risk at the sovereign level; that is, from a macroeconomic point of view, not just for specific institutions within an economy, but for the whole economy and thus it provides a better macro picture of the overall credit risk of an economy on an ongoing basis. For instance, to highlight the importance of sovereign CDS, Bedendo and Colla (2015) argue that credit risks often spillover from sovereign to corporates. Their results reveal that a rise in sovereign CDS leads to a statistically and economically significant increase in corporate CDS and, hence, higher firm borrowing costs. Also, as noted in Kanlı and Aydoğuş (2017), CDS are rational indicators that measure countries' ongoing risks since they are determined on prevailing market conditions and do not only depend on aggregate economic data which are often reported at a lower frequency. Akdoğan and Chadwick (2012) identify sovereign CDS as a direct measure of country risk while Heinz and Sun (2014) argue that CDS spreads reflect financial markets' perception of a country's default risk. Lee et al. (2019) show that CDS prices contain unique credit risk information that is not captured by the prices of other related securities.

Thus, since sovereign CDS provides a central gauge of overall default risk, it is important to understand its dynamic links with other markets within an economy. In view of the foregoing, one objective of this paper is to investigate how hedging activity responds to variations in the likelihood of sovereign default. This is done by examining the dynamic connections between CCBS and sovereign CDS. One insight this analysis will offer is an understanding of whether a positive shock to the likelihood of sovereign default (i.e. higher sovereign CDS spreads) leads to lower risk-taking by global dollar entities and, in turn, reduces hedging activities leading to wider CCBS spreads via diminished dollar supply or liquidity in the swap market.

Additionally, empirical finance literature has been rather silent on potential dynamic relations between the CCBS and equity markets – even though institutions with diversified portfolios often take simultaneous positions[1] in these markets, an outcome which should constitute a firm ground for understanding how these markets interact dynamically in the financial system beyond static correlations.

In view of the foregoing, this paper explores the dynamic links between equity, cross-currency basis, and credit markets in four major economies: UK, Eurozone, Japan, and Australia. Our main objective is to examine the transmission of shocks across these three markets in the financial systems of each of these four economies, both over the whole period of 2008–2019 for which we have data and for specific event periods. This enables us to uncover the dynamic interdependence between dollar funding liquidity, sovereign credit risk and equities performance. We focus on these economies for several reasons. The first one is the issue of data availability. These are the only developed economies for which we have adequate data for the three asset markets. Second and most importantly, the Eurozone, Japan, and the UK have the largest and most liquid CCBS market globally, both on a notional and DV01 basis. As Barnes (2017) notes, on a DV01 basis, the EUR/USD CCBS market is the largest market, followed by JPY/USD and GBP/USD; on a notional basis, JPY/USD CCBS market is the largest market followed by EUR/USD and GBP/USD.

To capture dollar-funding liquidity conditions, we adopt CCBS spreads of these developed economies' currencies *viz a viz* the US dollar. We also employ CDS spreads and stock market returns as proxies for credit risk and stock market performance, respectively. As noted by Trutwein & Schiereck (2011), CDS spreads are a good barometer of default risk in the financial market. One reason for this is the feature of CDS contracts together with maturation which makes them a good reflection of default risk. Another reason is that CDS contracts are well standardized; hence, they are more liquid than other risk-transfer instruments such as credit-linked notes, total return swaps, and repo transactions. This is because while CDS applies to a wider range of debt issues and loans

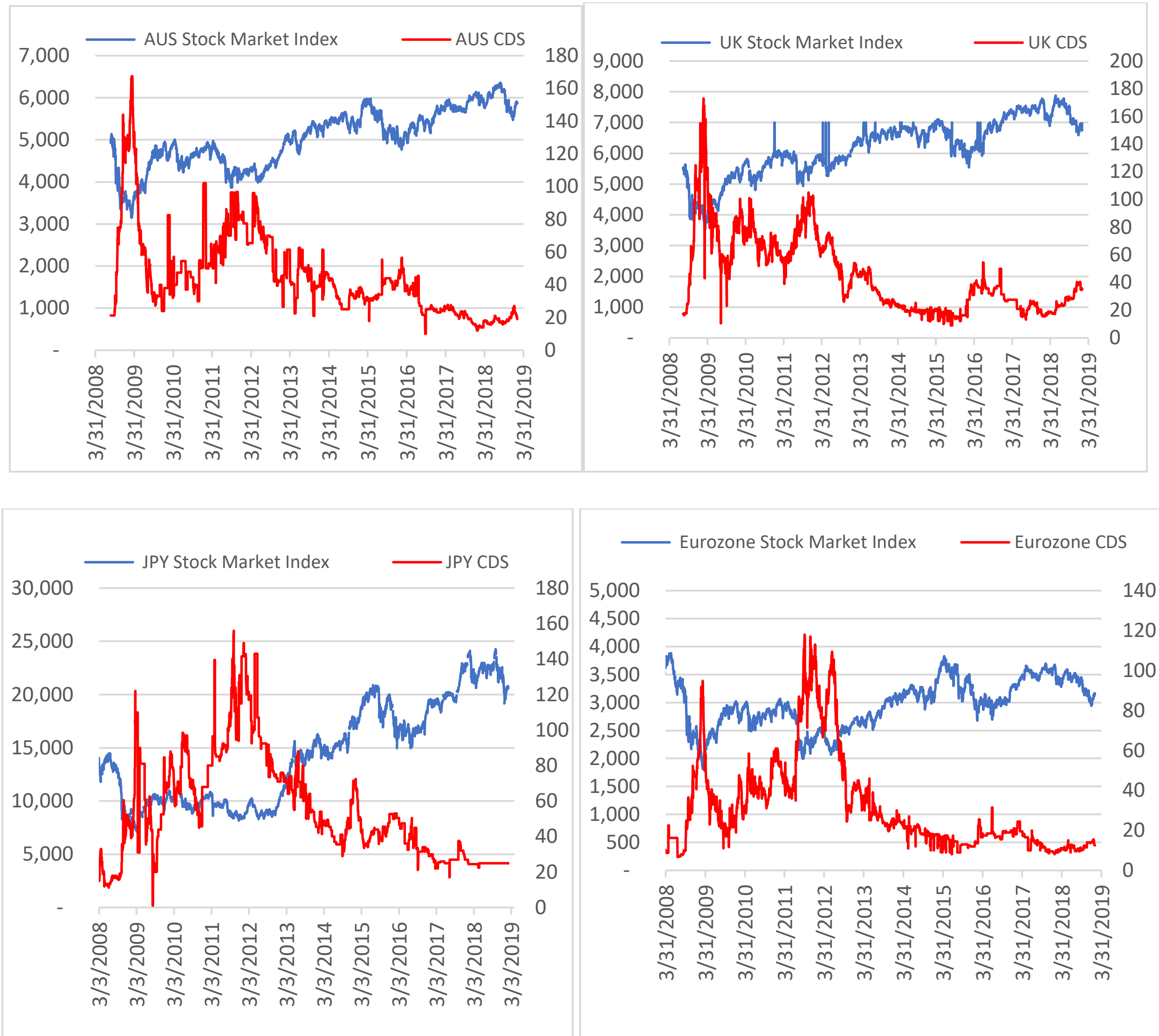
[1] Such positions could be taken, for example, for the purposes of returns maximization, long-term FX hedging, protection against potential default of counterparties or even to generate additional gains via speculations that an unrelated entity will default. In this paper, we attempt to address these issues.

of a reference entity, other risk-transfer instruments are quite limited as they are based on an underlying reference.

This article is motivated by several reasons. First, from a purely financial markets perspective, it is important to comprehend the transmissions and implications of shocks to one asset market on another asset markets within an economy and, more importantly, the possibility of a potential feedback loop. For instance, if positive CDS shocks have damaging effects on CCBS such that they induce wider CCBS spreads and erode stock market returns, then such an outcome may contribute to losses in existing hedges and equity positions which can spill over to other markets in the present world of increasing asset-market integration. In this sense, regulators may intervene to send the right market signals in order to quell concerns that have generated negative sentiments and led to wider CDS spreads. Second, activities in the financial markets can as well be an important indicator of an economy's state. This is eventually a major concern for businesses and policymakers. Accordingly, in the financial system, it is important to possess a firm empirical grasp of how markets link alongside their shock transmission mechanisms, especially within dynamic systems for which credit risk, dollar funding liquidity and equities market performance are of increasing concern.

Figures 1a – 1c show the evolution of the stock markets, CDS and CCBS spreads for the four economies. To provide a preliminary illustration of issues that prompt this empirical study, CDS is indicated in red while stock market is indicated in blue in Fig. 1a. Also, in Fig. 1b, CDS is shown in red while CCBS is in golden color. Lastly, in Fig 1c, the stock market is indicated in blue while CCBS is shown in golden. First, as shown in Fig 1a, when the red line goes up (down), which means CDS spreads expand (contract), stock markets in all four economies tend to deteriorate (rally), suggesting that the stock market indices and CDS spreads are directly opposite each other.

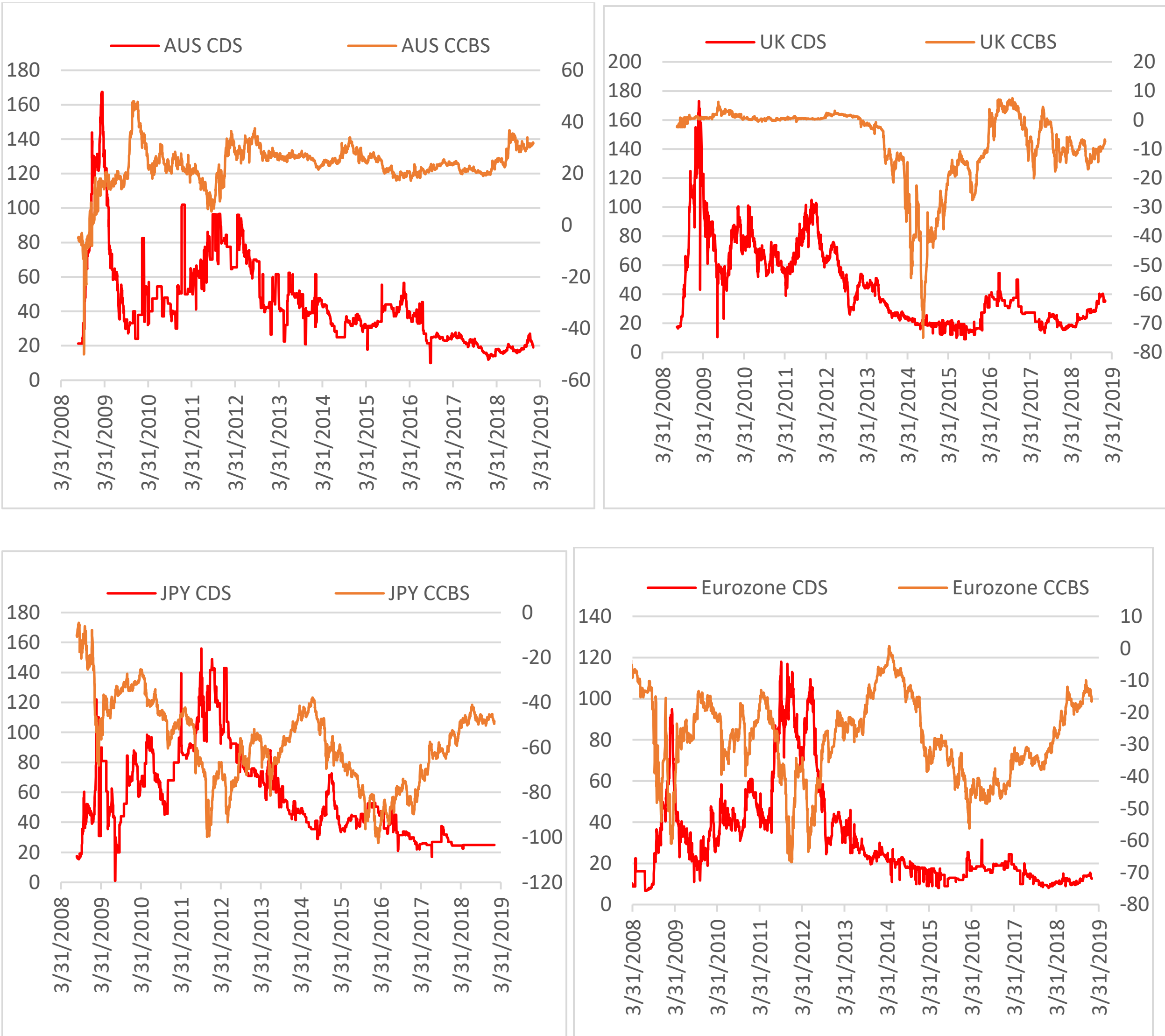
Fig 1a: CDS (right axis) and Stock Market (left axis) – Australia (AUS), UK, Japan (JPY) and Eurozone



Source: Bloomberg CDS is the 5-year sovereign credit default swap spreads. Stock Market is the stock market indices

Second, Fig 1b suggests that in general when CDS spreads expand (contract), the CCBS spreads tend to widen (tighten), implying that foreign entities would pay a relatively higher premium (discount) to obtain US dollars in the CCBS market when CDS spreads expand. Once again, as with the stock markets, we see that CDS and CCBS spreads are opposite of each other. When CDS spreads expand, CCBS spreads widen and *vice versa.*

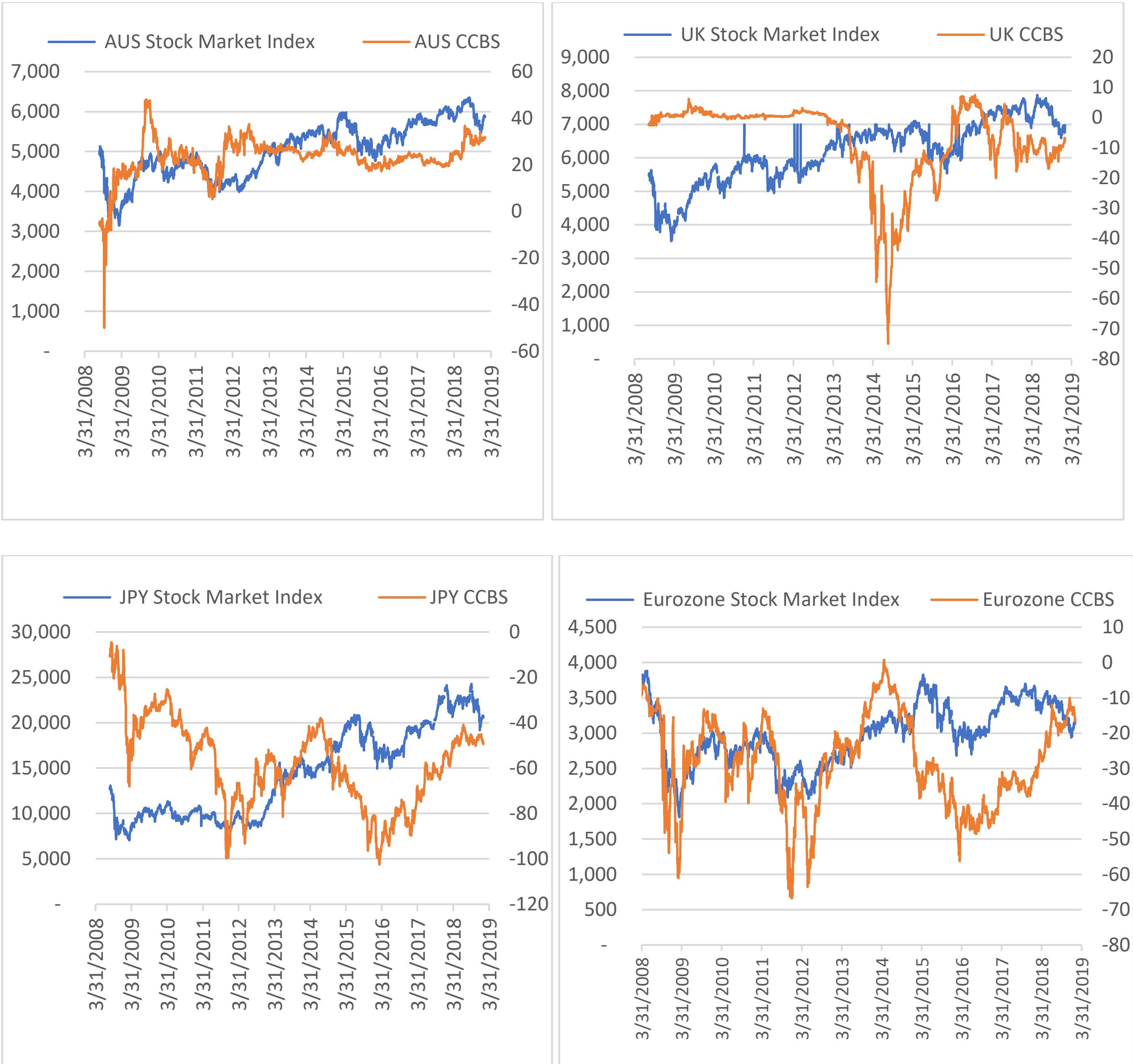
Fig 1b: CDS (left axis) and CCBS (right axis) – Australia (AUS), UK, Japan (JPY) and Eurozone



Source: Bloomberg CDS is the 5-year sovereign credit default swap spreads. CCBS is the 5-year cross-currency basis swap spreads

However, as indicated in Figure 1c, the links for the CCBS and stock market are not as clearly read off and straightforward as the negative relations documented for CDS and stock market as well as CDS and CCBS. In fact, in several periods, the relations appear to provide some preliminary evidence that there is a positive link between the CCBS and the stock market. When CCBS spreads widen (tighten), stock returns fall (rise), and stock market performance deteriorates (improve).

Fig 1c: CDS (left axis) and CCBS (right axis) – Australia (AUS), UK, Japan (JPY) and Eurozone



Source: Bloomberg. CCBS is the 5-year cross-currency basis swap spreads. Stock Market is the stock market indices

Our empirical analysis attempted in the latter parts of this paper appears to support the above preliminary analysis. Results of the empirical analysis reveal that higher CDS spreads link dynamically with wider CCBS spreads and declines in stock market performance. We find that even in various times of heightened market turbulence, there is some support for this finding. We also show that both stock market performance and changes in CCBS spreads respond positively to a shock on the other – though we note that the response of changes in CCBS spreads to positive stock market shocks are stronger, persistent and more significant.

In the same way, there is a lead-lag relationship between stock market performance and changes in CCBS spreads. This result shows that often, the stock market performance leads to changes in CCBS spreads. Relating this to result from impulse response analysis, this suggests that an improvement in stock market performance subsequently leads to tighter CCBS spreads. One possible explanation for this outcome is that sustained improvement in equities performance induces some agents to seek new bargains elsewhere. For USD agents, this incentivizes a focus on the CCBS market where riskless arbitrage profits are possible. Higher level of demand and resources committed to the CCBS market for generating arbitrage profits engenders lower amount of arbitrage profits left to be exploited and consequently tightens CCBS spreads.

Another plausible explanation is that, ceteris paribus, a stronger stock market does not trigger massive selloffs by foreign (dollar) entities with positions in non-dollar stock markets. In this instance, this means the risk of significant declines in dollar liquidity is low. Stronger stock market performance precludes selloffs and significantly reduces foreign outflows, thereby implying that foreigner exits are limited. Thus, this lowers the desire to remove dollar liquidity from the system instead of the well-known dollar liquidity squeeze that accompanies portfolio outflows from foreigners frantically selling non-dollar currencies within a given stock market to obtain dollars and exit the market. This is supportive of a healthy dollar liquidity in the system and a tighter cross-currency basis.

We also observe an interesting relation between changes in CCBS and CDS spreads wherein positive shocks to either of them induces a negative response from the other. This relation is mostly stronger, more persistent and statistically significant when it is the CDS spreads that respond to positive shocks to CCBS spreads than conversely. As with the existing studies detailed above, we confirm a strong negative response of CDS spreads to positive shocks to equities performance. There is more evidence of a significant response of CDS spreads to stock market shocks than there is for the response of stock market to CDS shocks. Besides, we also find that, irrespective of the period, there is more evidence that stock market performance leads to changes in CDS spreads than vice versa. We document both statistically significant differences in the transmission of these shocks, and the importance of these shocks over time.

Overall, by considering the dynamic interdependence of these markets, we provide a fresh contribution to the dynamic links between equities, sovereign CDS and CCBS markets. To the best of our knowledge, this is the first comprehensive study on the dynamic interdependence between these markets in the financial system of selected international economies. The rest of this paper is organized as follows. Following the introduction, section two reviews the literature and formulates hypotheses for the study while section three documents the evolution of CDS and CCBS spreads as well as the stock markets using descriptive statistics. In section 4, issues relating to the methodology are addressed while empirical results are presented in section 5. Section 6 presents robustness checks for our results. Finally, section seven concludes this research.

2. Literature Review

In the literature, studies on the dynamic interaction between the CDS and CCBS markets and between the CCBS and equities markets are scarce. Apart from Liao (2019) - who study the connection of CDS spread differential and covered interest parity deviations for bonds of similar risk but different currency denomination at the corporate level - and Du, Tepper & Verdelhan (2018) - who investigate the contemporaneous linear association between CDS of banks and CCBS spreads for G10 currencies, we are unaware of studies examining the dynamic interconnections between CCBS and CDS markets at the sovereign level. Also, aside from a recent attempt by Ibhagui (2019) at establishing a contemporaneous association between stock market returns and changes in the euro CCBS markets, we are not aware of any other study that examines the lead-lag dynamic interactions between equities and CCBS markets of countries with the most liquid swap markets – eurozone, Japan and the UK. In this article, we attempt to address these gaps. Meanwhile, in general, studies on the dynamic links between the equities and CDS markets are not new and are in fact well covered in the literature. Accordingly, most of the literature reviews presented in this article would naturally be skewed towards such studies.

Over time, understanding these links has given rise to important implications in cross-asset research and portfolio positioning, especially for entities with diversified portfolio positions in these markets. Liu et al. (2015) document substantial correlation dynamics between equities returns and CDS spread changes at the firm level, a result which is critical for cross-market hedging and arbitrage strategies. After decomposing unexpected equities returns into cash flows and discount rate, they find that the dynamics are largely explained by the discount rate news in the short horizon and cash flow news at longer horizons and in periods when the cash flow news is more negatively correlated with CDS spread changes. Using nonlinear techniques, Mateev (2019) performs a firm-level study of the relation between credit risk, captured by CDS, and the stock prices of Markit iTraxx Europe indexed companies. He finds some evidence of cointegration between CDS and stock prices of European investment-grade companies. This result provides evidence for an eventual transmission of shocks between the two segments of the financial market – the credit market (via CDS) and the stock market – even when temporary deviations from long-run equilibrium stifle such transmissions in the short term.

A strand of the literature has also concentrated on the dynamic links in specific regions. Fonseca and Gottschalk (2018) examine the co-movement of credit and equities markets in four Asia-Pacific countries - Australian, Korean, Japanese, and Hong Kong at firm and index levels. After establishing that realized volatility is an important determinant of CDS levels and changes, they find that stock returns, at the firm level, lead changes in CDS spreads whereas the lead-lag relationships are shared among all asset classes at the index level. Gun (2018) investigate the co-movement of CDS and stock markets in 9 emerging economies - Brazil, Chile, Colombia, Czech Republic, Mexico, Peru, Poland, Russia, and Turkey. The main finding is that negative links exist between CDS and stock market indices for most emerging economies and there is a strong unidirectional causality from stock market returns to CDS spread changes, where the stock market plays a leading role in all sample countries. Focusing on 11 countries in the euro area – Portugal, Spain, Italy, France, Greece, Ireland, Germany, Finland, Austria, Netherlands, and Belgium., De Silva (2014) addresses the links between equities and CDS markets to gauge if co-movement between both markets increases with deterioration of sovereign credit quality. Their results support close links between these markets but provide no evidence that the links increase in periods of financial distress.

However, in an earlier study, Fung et al. (2008) examine the market-wide relations between the U.S. stock market and CDS market and reports negative responses of the CDS of investment grade market to positive stock market shocks, where the lead-lag relationship between the U.S. stock market and CDS market appears to depend on the credit quality of the underlying reference entity. The relation is stronger for financial distressed firms, an outcome consistent with Merton (1974) model in that declines in stock prices are associated with increased leverage, and elevated leverage contributes to debt overhang, a rise of default risk and higher CDS spreads. The finding is also consistent with recent studies, for example Marra (2017), that show that co-movements between bid-ask spreads of equities and CDS vary over time and increase over crisis periods. In a related study, Coronado et al. (2011) argue that once evidence exists that a country's credit quality has deteriorated, for example via an appreciable rise in its sovereign CDS, the government begins to face higher interest costs when it raises funds in the market. The high borrowing costs could also extend to corporate borrowers, potentially reducing access to funds as borrowing cost rises – meaning less money to invest and spend and a higher likelihood of a tax increase to cover funding shortfall. Consumption and investment, at the household and firm level, shrink, corporate profits decline, weakening the stock market. This provides a mechanism through which a rise in CDS dampens the performance of equities market.

The direction of the most recent literature on CDS and equities markets dynamic links has evolved into examining how certain events influence the dynamic links between these markets. In this light, Augustine et al. (2020), using a large sample of 241 cross-listing events related to 278 CDS-stock pairs across up to 40 countries, examine how cross-listing, that is listing in multiple markets, affects the dynamic links between CDS and stock returns. They find that cross-listing increases the sensitivity of the CDS market to the stock market, enhances the degree of integration of the CDS market with the stock and bond markets, and raises the statistical synchronicity of CDS and stock prices. Thus, while some studies find evidence that the CDS-stock market dynamics become stronger during periods of stress, Augustine et al. (2020) document that cross-listing is another factor that increases the sensitivity of the CDS market to the stock market, with stronger outcomes for firms having superior media attention, analyst coverage and google search intensity, among others, while Lee et al. (2019) find that CDS returns significantly predict stock returns, particularly their idiosyncratic components. This is besides establishing that CDS contains unique firm credit risk information that is not captured by the prices of other related securities such as stocks and bonds of the same firm.

Bolaman-Avci (2020) examines how a change in investment attitude of domestic and foreign investors in response to increases in sovereign CDS influences the interrelationship between sovereign CDS and the stock market index in Turkey. Their results provide evidence of a unidirectional causality relationship from the stock market to the sovereign CDS market, a result which reveals that sovereign CDS changes are a critical indicator for the financial markets and need be followed by participants in these markets. One reason given for the CDS-stock market dynamic links in Turkey is that the stock market is a leading indicator which often works as the barometer of an economy, and the state of an economy has a significant influence on its sovereign credit risk which the CDS captures. Yang et al. (2020) examine how shocks to net foreign flows to Korean stock market impact the CDS-stock market dynamic links in Korea. They find that

Korean stock market rises when CDS declines and that the dynamic interaction is in response to shocks to net foreign flows to the stock market. Furthermore, by segmenting the purchases into institutional and retail (individual) investors, they show that while positive net stock purchases by institutions lead to positive stock market performance and a decline in CDS in the next period, the reverse is true for individuals. Thus, their analysis shows that the negative CDS-stock market dynamics are stronger when purchases in the Korean stock markets are dominated by institutional investors.

Zhao and Zhu (2020) have recently provided new evidence of the externality effect of customer firms' CDS trading activity on supplier firms' equities market performance, along the supply-chains. They examine how externality influences the impact of customer firms' CDS trading on the stock price informativeness of supplier firms. Using data constructed from CDS trading and merged with supply–chain relationships, they find that stock return synchronicity of supplier firms tends to be lower when a larger proportion of their sales are to CDS referenced customers. That is, supplier firms with a high proportion of sales to CDS referenced customers tend to have more firm-specific embedded information in their stock prices and thus higher stock price informativeness and less stock return synchronicity.

Apergis et al. (2019) examine how financial markets, particularly equities and CDS markets, behave during contagion across European and US financial markets, with an emphasis on the 2008 crisis. They show that contagion occurred across financial markets during the global financial crisis, especially through the channels of the insurance CDS and equities sectors. Their higher order moment contagion tests reveal linkages across markets that have not been previously detected. Their empirical findings allow for identifying contagion across financial markets and regions and could be helpful for the design of specific stabilization policies. Within Europe, their results suggest the presence of contagion between equities and bank and insurance CDS indices. Within the US, they find that shocks propagate between insurance CDS index and all other indices, with the exception of the equities index, which is affected only by the bank CDS index. As for contagion across regions, they find that contagion runs from US insurance CDS market to all European indices, apart from the equities index. By contrast, US insurance CDS index is affected by both European CDS indices and the volatility index. In addition, contagion is transmitted to the

European equities index running from the US bank CDS among others, and contagion also spreads from the European bank CDS index to the US equities index

While the foregoing studies have established connections between the equities and CDS markets, not much attention has been given to understanding the dynamic links of the equities and sovereign CDS markets in individual countries with large sovereign debt issuers and hence deeper sovereign CDS markets. To fill in this gap, we analyze the relation between sovereign CDS and stock markets of some countries that are major sovereign debt issuers. Contrary to studies which focus on equities and firm level CDS spreads, here we assess the empirical relation between sovereign CDS spreads and stock market performance at the aggregate level.

Although scholars have investigated issues relating to financial market interdependence, the simultaneous and joint dynamics of the interdependence between CDS, CCBS and stock markets have not been examined in literature. Existing research has mainly focused on the contemporaneous and intertemporal relationships between corporate or sovereign CDS and the stock market, corporate CDS and CCBS or, more broadly, amongst corporate CDS, corporate bond and stock markets at the firm level. For instance, in an earlier study on the subject, Longstaff et al. (2003), investigates the link across CDS spread changes, corporate bond spreads and stock returns of US firms. They establish a dynamic lead-lag relationship in which both stock and CDS markets lead the corporate bond market. The paper recommends that relevant information about the corporate bond market appears to flow first into stock and credit derivatives markets before they are manifested in the corporate bond markets.

Also, Longstaff, Pan, Pedersen & Singleton (2011) research the nature of sovereign credit risk implementing an extensive set of sovereign CDS data. Their results reveal that most sovereign credit risk can be linked to global factors and that sovereign credit spreads are less related to local or domestic economic factors and instead are more related to the US stock and high-yield markets. In a similar study, Norden & Weber (2009) analyze the interrelationship of CDS, bond and stock markets with major emphasis on the intertemporal dynamic relations. Their results unveil that stock returns lead CDS and bond spread changes and CDS spread changes granger-cause bond spread changes and vice versa, for a higher number of firms. One major issue with the few existing studies is that they neglect the potential dynamic interrelations across the CDS, stock and CCBS markets. This market has gained considerable prominence following the increased interest in dollar funding liquidity and the notable deviations from CIP observed in the market for most foreign exchanges, especially since the global financial crisis. Moreover, existing studies often focus on inter-temporal relations at the firm-specific level and it is unclear how sovereign CDS and stock markets on the aggregate level interact in connection with the CCBS in FX derivatives market, and vice versa.

In some previous studies on financial markets interconnectedness, Josifidis et al. (2014), using a VAR framework, argue that emerging European countries react dissimilarly to parallel international shocks such that common international financial shocks lead to different monetary policies, and potentially divergent asset market responses. On the other hand, Koukouritakis et al. (2014) examine interrelations between eurozone and South-eastern Europe. Using a VAR specification, they find that these countries react in similar ways to eurozone macroeconomic policies and that the euro-dollar nominal exchange rates and member countries within the eurozone are strongly linked. Kębłowski and Welfe (2012) use sovereign credit default swaps (CDS) to examine the zloty-euro currency links and find that the CDS is important as the cumulative shocks to exchange rates and CDS drive the interdependent system in the long run so that exchange rate deviates about 20% from its equilibrium peak level.

In their most recent seminal work on the interdependence of asset markets within the broader financial markets, Reboredoa and Ugolini (2019) employ a VAR framework to generate empirical findings which reveal that the bond market for green bonds is closely linked to the fixed income and currency markets. While this market receives a sizeable shock from the other markets, it transmits a relatively lower shock to these markets. Reboredoa and Ugolini (2019) also demonstrate some interdependence, albeit less strengthened, between the green bond market and other asset markets such as the stock, energy and high-yield corporate bond markets, with implications for portfolio positioning and risk management decisions.

Thus, in general, an important insight that has emerged from these studies, one which seems to have enjoyed some consensus in the literature, is that one can argue for the feasibility of the propagation of shocks in one asset market to other asset markets in the broader financial market system within countries. So far in the literature on market interconnectedness, it is unclear how sovereign CDS and stock markets on the aggregate level interact in connection with the CCBS in the currency derivatives market, and vice versa.

In view of this gap in the literature, we propose the following hypotheses H1 and H2.

- *H1: Positive shocks to sovereign CDS spreads weaken dollar funding liquidity, induce wider CCBS spreads and deterioration of stock market performance*

Du, Tepper & Verdelhan (2018) examine the relation between CDS of banks and CCBS spreads. They argue that if CDS spreads measure credit risk perfectly, then changes in CDS spreads should have a negative effect on changes in CCBS spreads, hence it should cause the basis to widen. Contrarily, in their empirical results, they find slope coefficients that are mostly positive, and with small values for the coefficient of determination.

In this paper, instead, we investigate the CDS-basis relationship at the sovereign level. It is expected that sovereign CDS spreads reflect the extent of credit default risk of sovereigns and possibly corporates. If it rises, for example, due to rating downgrades or other negative events, we would expect potential default risk to be imminent and this perspective to spread across markets and thus for the CCBS spreads to widen, leading us to the hypothesis.

- *H2: CDS and CCBS markets should exhibit lead-lag relations such that positive shocks to CDS should widen the CCBSS inter-temporally.*

According to existing studies on this subject (Kwan, 1996; Norden & Weber, 2009; Forte & Pena, 2009), it is documented that information should be reflected earlier in the stock market before it propagates to other markets. This leads to the following hypothesis:

- *H3: The stock markets should lead the CCBS and CDS markets than conversely, and positive shocks to the stock market should have a more persistent positive effect on the CCBS and negative effect on the CDS markets than vice versa.*

Eventually, the intertemporal links between these markets should be strongly reinforced throughout periods of global or country-specific crisis because of the strong negative risk sentiments and general flight to safety across markets during turbulence. This leads to our last hypothesis:

- *H4: The links between CDS, CCBS, and stock markets are much stronger during periods of crisis that impact each country.*

3. Data and Descriptive Analysis

This section documents the data we adopted for the study. We also explain briefly the credit default swap, cross-currency basis swap, and stock markets and equally present some descriptive analysis.

3.1 Data

All data samples utilized in this article are at the daily frequency. We employ daily stock market indices as well as daily 5-year sovereign CDS and CCBS spreads for the UK, Eurozone, Japan, and Australia. Data are sourced from Bloomberg. Due to data unavailability, all observations do not have the same start date. Hence, in the descriptive analysis, we start from the period of available data for each country and individual asset markets.

The main analysis of dynamic linkages among the asset markets in each country begins from the earliest period of data availability. For ease of comparison across countries, this is chosen between 2008 and 2019. Hence, it includes daily observations of 2,826 for the stock market indices, CDS and CCBS spreads as well as the control variables such as term spreads, dollar exchange rate and the volatility index (VIX). This is with the aim of capturing changes in monetary policy, currency movement and global risk sentiment data for each country. The sample period is chosen to ensure that all asset markets in each country, together with the controls chosen, have data for the period under study.

3.2 CDS and CCBS as Tools for Default Risk Protection and FX Risk Hedging

3.2.1 The Credit Default Swap (CDS) Market

Credit default swaps (CDS) are the most common form of credit derivatives contract designed for transfer of credit exposure of fixed income products between two or more parties. Buying CDS does not eliminate credit risk. Rather, it shifts the risk from the creditor (protection buyer) to the protection (CDS) seller. In general, CDS are traded over-the-counter. The notional value of a CDS refers to the face value of the underlying security. As an illustration, consider an investor A that wishes to limit exposure to downside risk and prevent loss of invested capital. Suppose A purchases a fixed income product or provides a loan to buy a bond issued by entity B, where the notional value is $X\ euro$ and B can be a corporate and sovereign issuer. Suppose further that A believes B has a non-zero default risk and so attempts to protect itself from unfavorable losses. To protect itself from B's default risk, A purchases protection from a third-party C, the protection seller. In this arrangement, A pays an agreed premium to C at regular intervals throughout the period of the contract.

In the event of a default by B, C pays A an amount equal in value to the notional of the bond or loan provided, i.e. $X\ euro$, together with unpaid interests that have accrued up to that point. In return, A transfers of ownership of the bond to C. If the market value of the bond at the time of default is $M\ euro$, where $M < X$, then this is equivalent to saying that, on the notional side, C pays A the sum of $(X - M)\ \ euro$ which, together with the market value of the bond of $M\ euro$ held by A, brings the amount recovered by A to the original notional value of the bond purchased or loan provided, i.e. $(X - M) + M = X\ euro$.

Illustration of Credit Default Swap

Chart 1a: No transfer of bond ownership

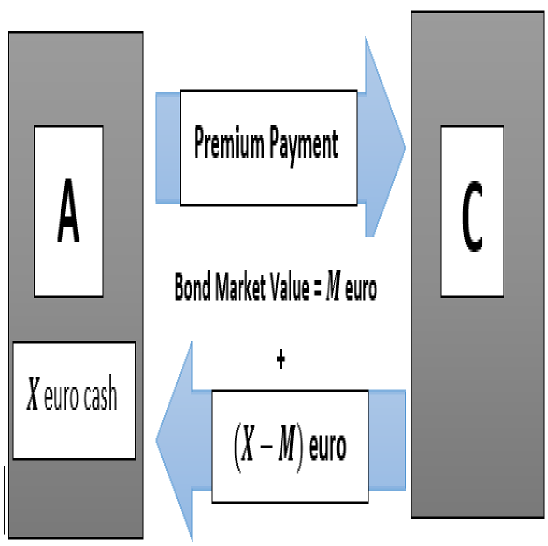
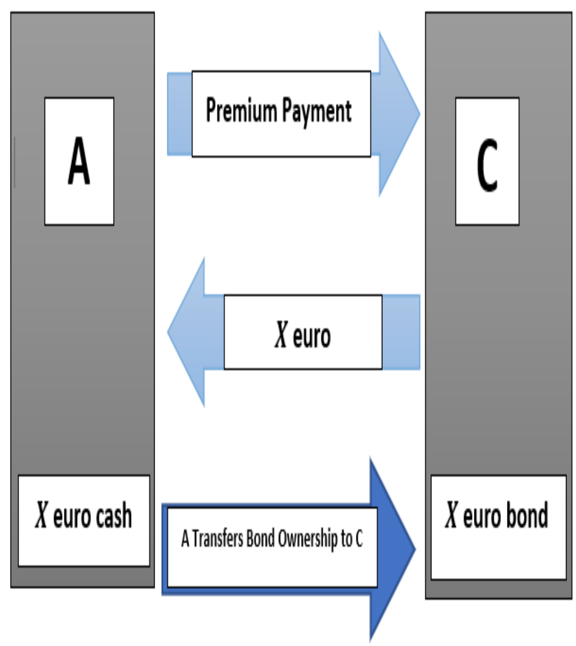
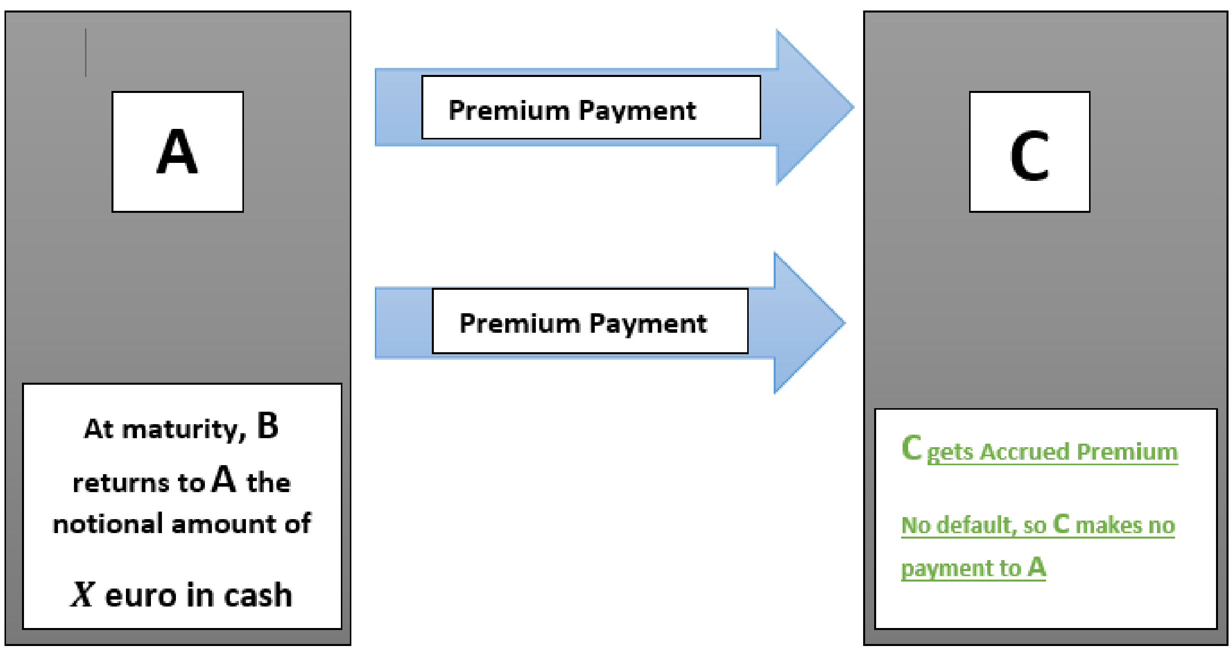


Chart 1b: Transfer of bond ownership



Charts 1a and 1b illustrate how credit default swap works. In both charts, the bondholder A purchases protection from C and thereby makes a series of premium payments to C, where the premium is the value of the credit default swap spreads on the notional amount. In the chart 1a, it is assumed that the bondholder (A) does not transfer ownership of the bond to the protection provider C in the event of a default. Instead, it liquidates the bond at the market value of $M\ euro$ and recoups in cash the decline $(X - M)\ euro$ in the original value ($X\ euro$) of the bond from the protection provider C. At the end of the transaction following default, he gets a cash amount of $X\ euro$ which is equivalent to the exact notional value of the bond. In chart 1b, we assume that there is a transfer of bond ownership, known as a physical settlement. In this case, following a default, C pays the notional amount $X\ euro$ in cash to A. In return, A transfers of ownership of the bond to C and does not care about the market value of the bond. From the perspective of A, the scenarios described in charts 1a and 1b are equivalent as A ends up with its initial notional value or invested capital of $X\ euro$.

Chart 2: No default – C makes no payment to A, generates accrued premium from A



If no default occurs, then C retains all the premiums paid throughout by A, the protection buyer. The protection that A purchases from C is called a credit default swap (CDS). The premium paid on the notional value to C by A is called the credit default swap spread. Higher premium indicates higher perceived likelihood of a credit event which could cause B to default. With the high default likelihood, C charges a higher premium to limit the strain of payout or losses it would incur should a credit event materialize than causes B to default on obligations. This is illustrated in Chart 2.

In the CDS market, there is a risk transfer, where A is a risk seller (or protection buyer) that transfers or sells the risk of default by B to C and in return receives protection from C. On the other hand, C is a risk buyer or protection seller. It absorbs from A, the risk of default by B and receives a periodic premium from A for the protection sold to A. The premium is used to fund the notional value remitted to A in the event of a default by B. Broadly, in the CDS market, the protection buyer need not be an actual investor with direct position in the underlying bond. The protection buyer could, for example, be an arbitrageur who seeks to profit by speculating that some issuer to whom it is unconnected would default.

3.2.1.1 Determination of CDS Spreads

To a protection (CDS) buyer, the value of the CDS spreads (that is, the premium) to be paid periodically on the notional value throughout the life of the contract should equal the present value of the expected payment or coverage that would be provided by the protection seller in the event of default. For the protection seller, the value of the expected payoff to be made to the protection buyer in the event of default should equal the value of the CDS spreads or premium received on the notional value throughout the life of the contract. In either case, the net present value (NPV) is zero, and both parties would be evenly well off.

As a demonstration, consider the standard Hull and White (2000) model following Wen and Kinsella (2013). In this model, the premium or CDS spreads on a € 1 notional value is calculated as follows. Let π represents the risk-neutral probability that there would be no default throughout the life of the CDS contract with maturity T. Let ϑ be the probability of default at some point in the life of the contract. Then, π can be expressed as:

$$\pi = 1 - \vartheta, where\ \vartheta = \int_0^T q(t)dt \qquad (1)$$

where $q(t)$ is the risk-neutral default probability density at time t and T is the maturity of the CDS contract.

First, we consider the protection seller who is most interested in the premium it receives from the protection buyer. From the perspective of the protection seller, if no default occurs throughout the life of the CDS contract, the present value of payments received from the protection buyer is $\varphi\mu(T)$, where φ is the total payment or premium made per year by the protection buyer and $\mu(t)$ is the present value of payments at the rate of € 1 per year on payment dates between time zero and time *t*. The expected present value of payments from the protection buyer if no default occurs throughout the life of the CDS thus equals:

$$\pi\,\varphi\mu(T) = (1-\vartheta)\varphi\mu(T) \tag{2}$$

If a default occurs at a time $t < T$, the present value of the payments made by the protection buyer to the seller before a credit event equals $\varphi(\mu(t)+\gamma(t))$, where $\gamma(t)$ represents the present value of an accrual payment at a time *t* which equals to *t-t**, where *t** is the payment date immediately prior to time t. Thus, the expected present value of the payments received by the protection seller if a default occurs at some point in the life of the CDS is:

$$\int_0^T \varphi(\mu(t)+\gamma(t))q(t)dt \tag{3}$$

Consequently, the expected present value of the payments received by the protection seller given the possibility of either scenario is given by:

$$\pi\,\varphi\mu(T) + \int_0^T \varphi(\mu(t)+\gamma(t))q(t)dt \tag{4}$$

Turning now to the protection buyer, the protection buyer is most interested in the expected payoff that would be received from the protection seller in a CDS contract in the event of a default. On default, let the expected recovery rate on a €1 notional value of the underlying asset be R and let the interest accrued on the underlying asset prior to default be $A(t)$. Afterwards, by the time of default, the investor gets the recovered value of the face value of the asset together with the recovered value of all interests earned until default. So, he gets $R(1+A(t))$ from the market (i.e. recovers this sum from the reference issuer or borrower) and receives a payoff of $1-R(1+A(t))$ from the CDS protection seller (i.e. a payoff which equals the one it could not recover). The present value of expected payoff received by the protection buyer given default is thus:

$$\int_0^T \left[1-R\left(1+A(t)\right)\right]q(t)v(t)dt \tag{5}$$

where $v(t)$ is the present value of € 1 received at time *t*.

For neither the CDS protection seller (who receives premium) nor the buyer (who receive a payoff in the event of a default) to be worse off in the CDS contract, it must be that the seller believes that the expected present value of the premium payments received fairly reflects the present value of the expected payoff to be made to the protection buyer in the event of default. Conversely, the protection buyer must also believe that the expected payoff received from the protection seller in the event of a default reflects (at least) the premium payments made to a protection seller. Both scenarios are equivalent to equating (4) and (5). That is:

$$\pi\, \varphi\mu(T) + \int_0^T \varphi(\mu(t) + \gamma(t))q(t)dt = \int_0^T \left[1 - R\,\big(1 + A(t)\big)\right]q(t)v(t)dt \quad (6)$$

The premium φ for which the equality in (6) holds is the CDS spread. Thus, the CDS spread, φ, is given by

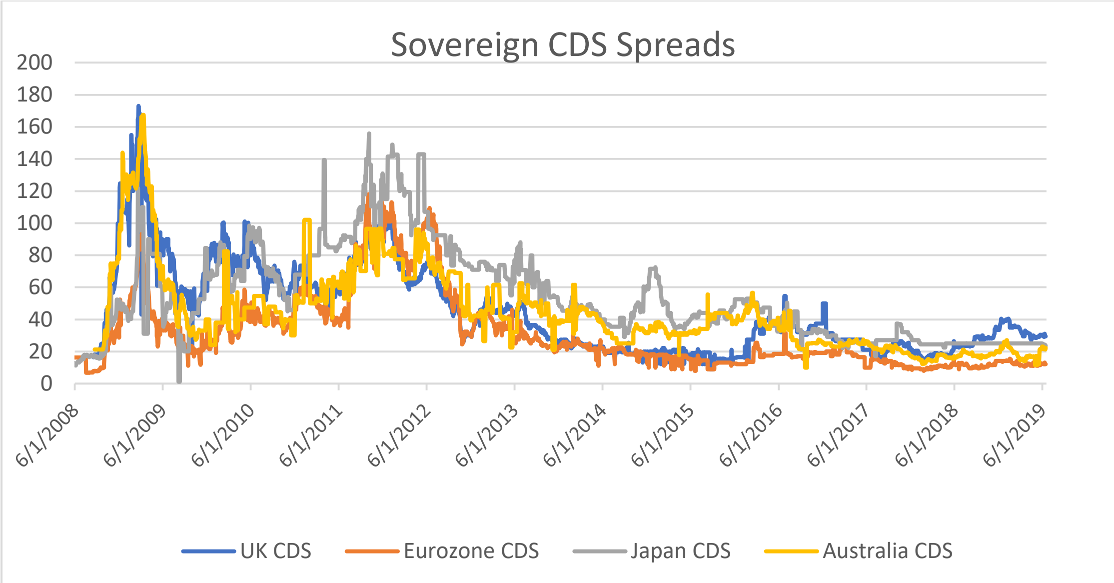
$$\varphi = \frac{\int_0^T \left[1 - R\,\big(1 + A(t)\big)\right]q(t)v(t)dt}{\pi\, \mu(T) + \int_0^T (\mu(t) + \gamma(t))q(t)dt} = f(R^-, q(t)^+, \pi^-, \dots) \quad (7)$$

Thus, the CDS spread is a function of the expected recovery rate, R, the risk-neutral default probability density, $q(t)$, and the risk-neutral probability of no default, π. When the expected recovery rate is low, the protection seller charges a higher premium as compensation for protecting an asset with a low expected recovery rate upon default. When the risk-neutral default probability increases, the CDS spread also rises since the protection seller charges a premium as compensation for providing a cover for an asset with a high default probability. The same argument holds for an asset with a low probability of no default.

With explanations of the CDS market briefly presented, we turn now to a preliminary look at the sovereign CDS data of the four economies being studied.

Our daily sovereign CDS spreads data are obtained from Bloomberg. We proxy Eurozone CDS spreads using the CDS spreads for Germany. The paper concentrates on the 5-year CDS spreads because they are the most liquid and commonly used in the market. Figure 2 below shows the CDS spreads for the UK, Eurozone, Japan, and Australia between 2008 and 2019.

Fig 2: Evolution of Sovereign CDS Spreads



Source: Bloomberg. Author, 2019.

As it is well-documented, the sovereign CDS spreads were low for all 4 economies prior to the deepening of the global financial crisis. During the periods of 2008 to 2009 when the global financial crisis worsened, there were large expansions in sovereign CDS spreads across the economies - especially around September 2008 which coincides with the period when Lehman Brothers filed for Chapter 11 bankruptcy protection - with some CDS spreads spiking to as much as 180 bps. The CDS spreads subsequently decelerated for a short while at the latter stages of 2009 and early 2010 but picked up significantly at the height of the Eurozone sovereign crisis which occurred between 2010 and 2012. Besides the Eurozone CDS spreads which spiked in this period, Japan is one of the developed non-Eurozone economies with a relatively significant spike in CDS spreads at the height of the Eurozone crisis. This can be shown by the fact that China has a significant export exposure to the Eurozone, and it is equally Japan's top export destination, so a crisis in the Eurozone which weakens China would lower sentiments towards Japan. Expansion in CDS spreads decelerated remarkably after the Eurozone crisis and has been significantly below the crisis levels consistently in the last few years.

Table 1: Descriptive Statistics for CDS Spreads across Markets

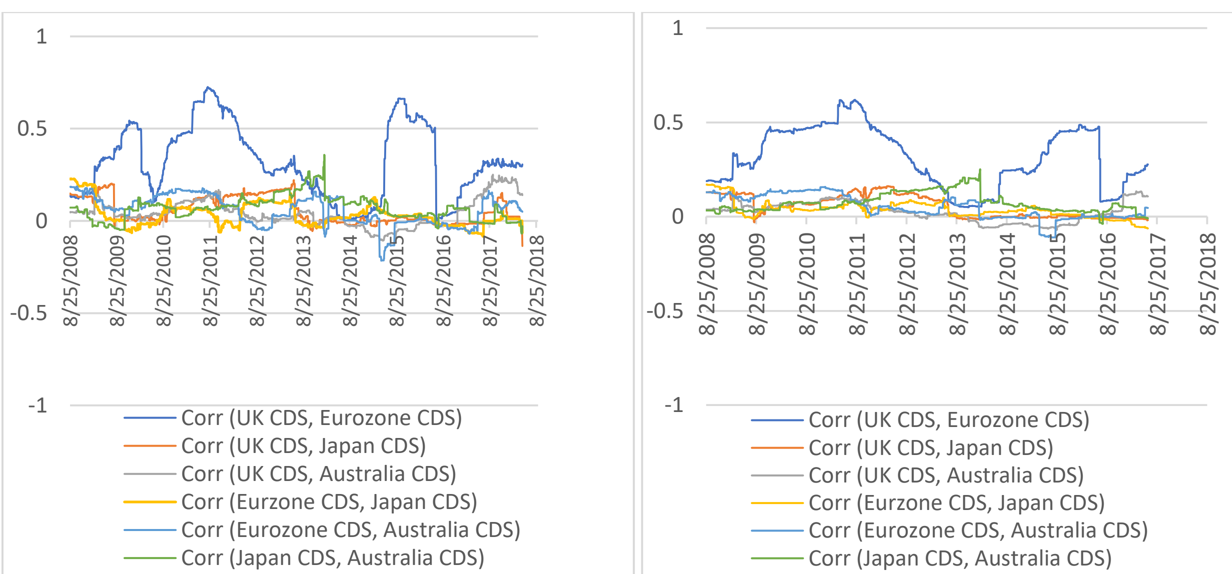
CDS Spread	2008-2019	2008-2009	2010-2012	2013-2019
UK CDS	44.96	78.41	68.11	31.42

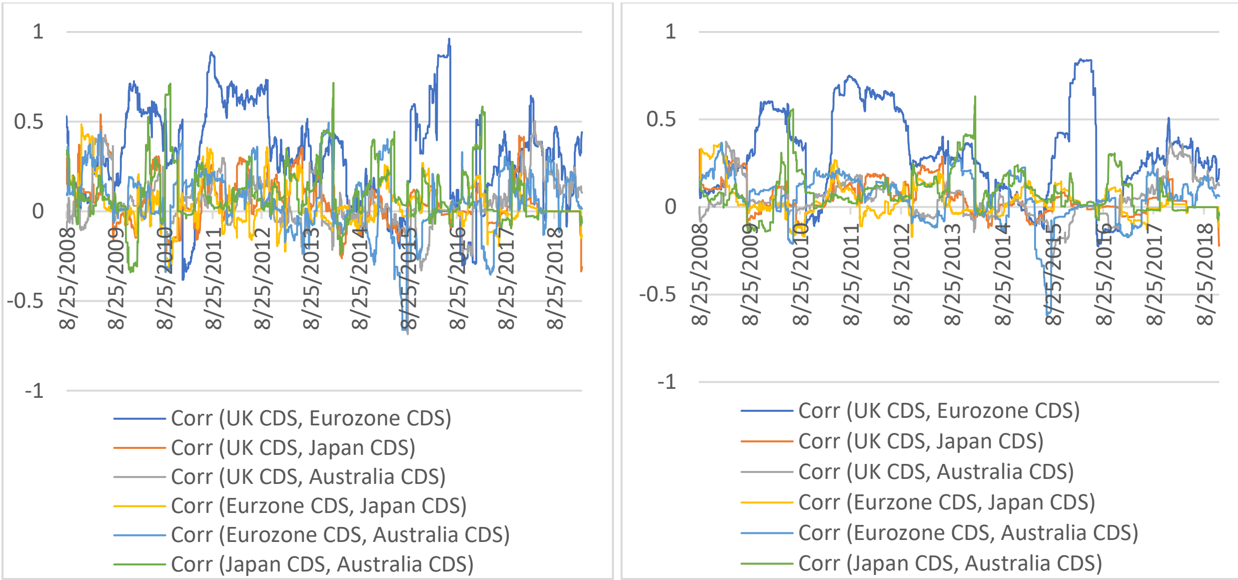
	(27.63)	(35.55)	(24.44)	(27.63)
Eurozone CDS	31.41	(35.03)	(58.95)	(24.89)
	(23.75)	(18.74)	(25.35)	(23.74)
Japan CDS	55.14	49.66	90.01	48.17
	(28.97)	(22.99)	(30.12)	(28.97)
Australia CDS	44.38	70.80	62.07	35.64
	(26.12)	(42.20)	(28.21)	(26.11)

Data Source is Bloomberg. Table 1 reports the mean and standard deviation of sovereign CDS spreads for UK, Eurozone, Japan and Australia. Standard deviations are shown in parentheses. Germany CDS spreads represent Eurozone CDS spreads.

Table 1 displays the summary of the mean and standard deviation of the 5-year CDS spreads across three periods: 2008 to 2009, 2010 to 2012, and 2013 to 2019. The starting point is 2008 as this is the period that all the economies have available data. On average, the UK and Australia CDS spreads were highest and most volatile during the global financial crisis, whereas the Japanese and Eurozone CDS spreads were highest during the Eurozone crisis, suggesting that on average sentiments towards Japan were more sensitive to the Eurozone crisis than the global financial crisis. Summary statistics also show that the CDS spreads for each economy have since decelerated after the crisis. Among the major economies represented in Table 1, Japan has the highest volatility of CDS spreads post-crisis, which is in line with its volatility in the Eurozone crisis period but contrasts with the relatively low volatility in the global financial crisis period.

Fig. 3: Rolling correlation of CDS Spread Changes (1- and 2-year, top row; 3- and 6-month bottom row)





Data Source is Bloomberg. Corr is the rolling correlation. CDS is the 5-year sovereign credit default swap (CDS) of the countries.

Figure 3 displays the rolling correlation of changes in CDS spreads for the four countries over time. We calculate daily rolling correlation with a rolling window of 3 months, 6 months, 1 year and 2 years over our sample span, based on the number of trading days per year. Overall, the rolling correlation between UK and Eurozone show the highest and most consistent positive coefficients across all the rolling windows followed by the rolling correlation between Japan and Australia which appears to be higher and more noticeable in the high frequency rolling windows (i.e. 3 months and 6 months window) than at the lower frequency rolling window (i.e. 1 year and 2 years). Interestingly, the rolling correlations also reveal that the positive correlation between EU and UK CDS spread changes exhibits some tri-modal characteristics, as it peaked during the 2008 global financial crisis, during the 2011 Eurozone debt crisis and finally in 2016 which interestingly coincides with the period of Brexit turbulence. The positive high correlation between EU and UK CDS spread changes provides a hint that changes in CDS spread of both economies are associated and may respond correspondingly to similar macroeconomic or financial shocks. This motivates the additional event study which we perform for both economies in the empirical part of this paper.

3.2.2 The Cross-Currency Basis Swap (CCBS)

With a cross-currency basis, a foreign entity seeks to obtain long-term funding in a currency of choice, usually the US dollars (i.e. dollar funding liquidity), by swapping a foreign currency, say euro, for the US dollars, receiving the basis and paying interest on the US dollars to the dollar provider. In this contract - which extends beyond the 18-month period that traditional FX swaps cover - the exchange rate risk is fully hedged. At maturity, the two parties in the contract re-exchange the notional values after earning interest on their respective notional values throughout the life of the contract.

Let $D^{\$}$ denote the cost of \$1 in the direct cash market. This can be interpreted as the cost of obtaining \$1 in the direct cash market. Let D^S represent the cost of synthetic US dollars in the swap market, where "synthetic" represents the US dollars obtained by swapping a foreign currency into US dollars in the swap market. To be clear, D^S is the interest earned by the dollar entity for providing dollars in the swap market. The cross-currency basis swap spread (CCBSS) can be defined as

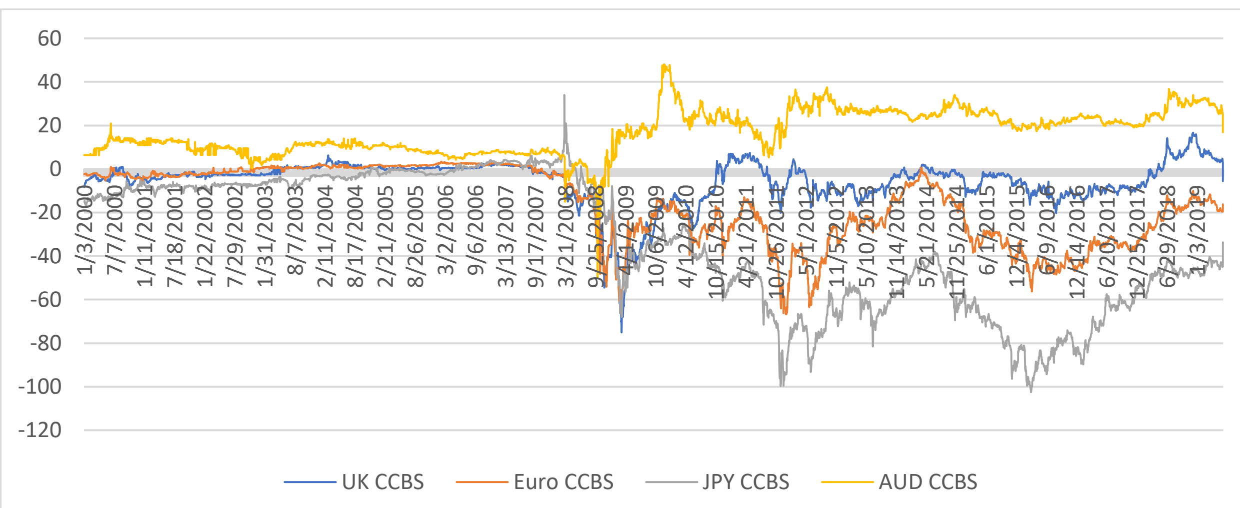
$$CCBSS = D^{\$} - D^S$$

Let y^f stand for the interest rate on the asset in the foreign currency, e the per US dollar spot exchange rate (in log) and f the per US dollar forward exchange rate (in log). Then, D^S- when viewed as the dollar amount earned by the US dollar entity on \$1 invested in the foreign asset by hedging exchange rate risk via cross-currency swap market - can be written as $D^S = \$1(y^f + s - f)$. D^S can also be viewed as the implied interest or cost to the foreign entity for obtaining synthetic USD.

Depending on whether $CCBSS < 0$ or > 0, the following potential arbitrage opportunities, with exchange rate risk fully hedged, are possible. If $CCBSS < 0$, so that $D^{\$} < D^S$, a (dollar) agent can borrow dollars directly from the cash market at a lower rate $D^{\$}$ and lend to a foreign entity seeking dollars via the swap market, earning higher implied dollar interest D^S with FX risk fully hedged. In this instance, the more negative is the $CCBSS < 0$, the larger the potential arbitrage profit. These trades are possible with JPY and Euro bases which are quite negative. Conversely, if $CCBSS > 0$, a foreign non-dollar entity can earn arbitrage profit by going in the opposite direction. Here, $CCBSS > 0$, so that $D^S < D^{\$}$. In this case, the non-dollar entity can invest in a dollar asset, with currency risk fully hedged, via cross-currency swaps. To do this, they can enter a cross-currency basis swap contract which enables them to obtain synthetic dollars at lower implied cost D^S and then invest the dollar amount in the US direct cash market, earning a higher interest $D^{\$}$ with FX risk fully hedged. Here, more positive CCBSS indicates that greater arbitrage profit can be made. Potential candidates for these trades include AUD, NZD and GBP bases which are positive. In general, the cross-currency basis measures the extent of dollar funding liquidity shortages in the market. As the basis becomes more negative or less positive, this means shortages of dollar funding liquidity are becoming severe. On the other hand, as the basis becomes less negative or more positive, this suggests that dollar funding liquidity is improving, or dollar shortages are becoming less severe.

In Figure. 4, we present the evolution of 5-year cross-currency basis swap spreads associated with the currencies of the four economies which are the focus of study in this paper. The graph shows the cross-currency basis swap spreads for the periods in which data are available, between 2000 and 2019.

Fig 4: Cross-Currency Basis Swap Spread across Countries



Source: Bloomberg. Researchers, 2019. Cross-currency basis swap (CCBSS) spreads

The four CCBS spreads represented were closer to zero in the displayed dates prior to the global financial crisis. The widening started during the global financial crisis, extended some more during the Eurozone crisis and have not receded to the pre-crisis levels as they have been persistently different from zero. The case of Australia presents an interesting account. While the other bases widened significantly to negative values during the global financial crisis and Eurozone crisis, Australia's basis moved in the opposite direction – it came to be relatively more positive. This supports the finding of Fukuda & Tanaka (2017) which document that a combination of financial instability and price instability stoked inflationary pressure in Australia. On the other hand, other advanced economies experienced a combination of financial instability and price instability of a deflationary type. In this way, while these other advanced economies embraced a much more accommodative monetary policy and lowered policy rates to improve financial stability via facilitating growth and price stability by overcoming deflationary pressure, Australia implemented a largely opposite policy[2].

Table 2: Descriptive Statistics for CCBS Spreads

CCBS Spreads	2000 - 2019	2000-2007	2008-2009	2010-2012	2013-2019
UK CCBS	-5.66	-0.88	-25.81	-6.85	-4.78
	(10.35)	(2.37)	(16.06)	(8.32)	(6.93)
Euro CCBS	-16.14	-0.02	-22.57	-32.35	-26.58
	(16.91)	(2.10)	(14.50)	(12.49)	(12.37)
JPY CCBS	-33.60	-4.23	-21.77	-57.10	-62.73
	(30.22)	(4.84)	(19.98)	(17.86)	(15.31)
AUD CCBS	16.90	9.24	10.10	24.58	24.93
	(9.85)	(2.74)	(14.40)	(7.30)	(3.86)

Table 2 displays a summary of the mean and standard deviation of the 5-year CCBS spreads for the periods 2000 – 2019, 2000 – 2007, 2008 – 2009, 2010 - 2012, and 2013 - 2019. Standard deviations are shown in parentheses. Source: Bloomberg, 2019. Author computation

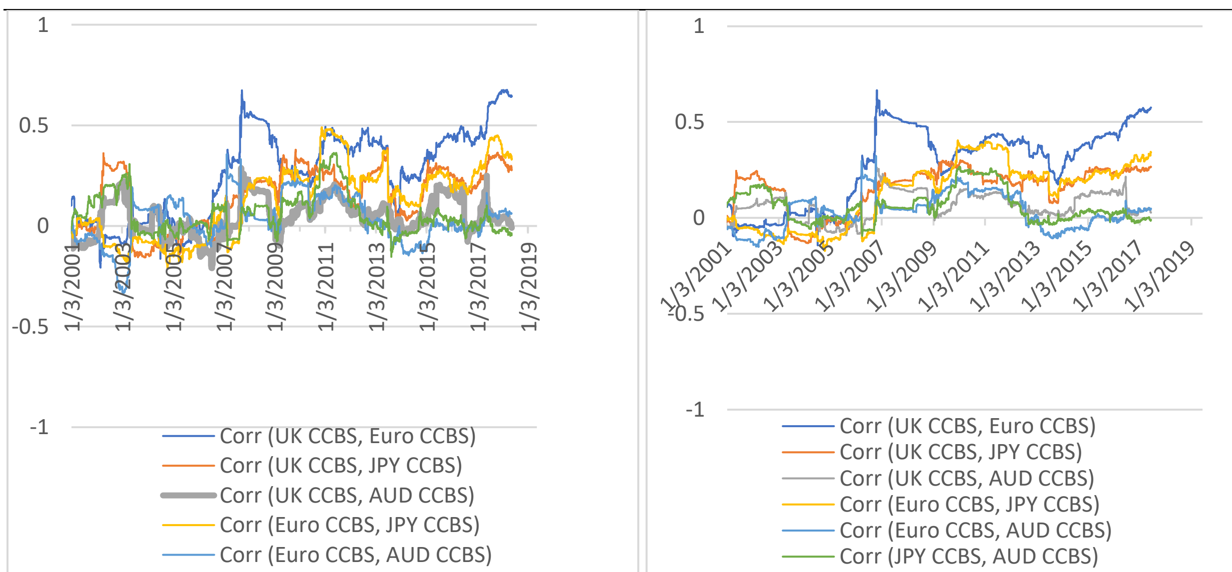
For descriptive purposes, we initiate from the starting point of 2000 since this is the earliest time when all economies first have available data. In the main modeling exercise, we will begin from 2008 to be on par with other variables whose data begin in 2008. Looking at Table 2, we notice

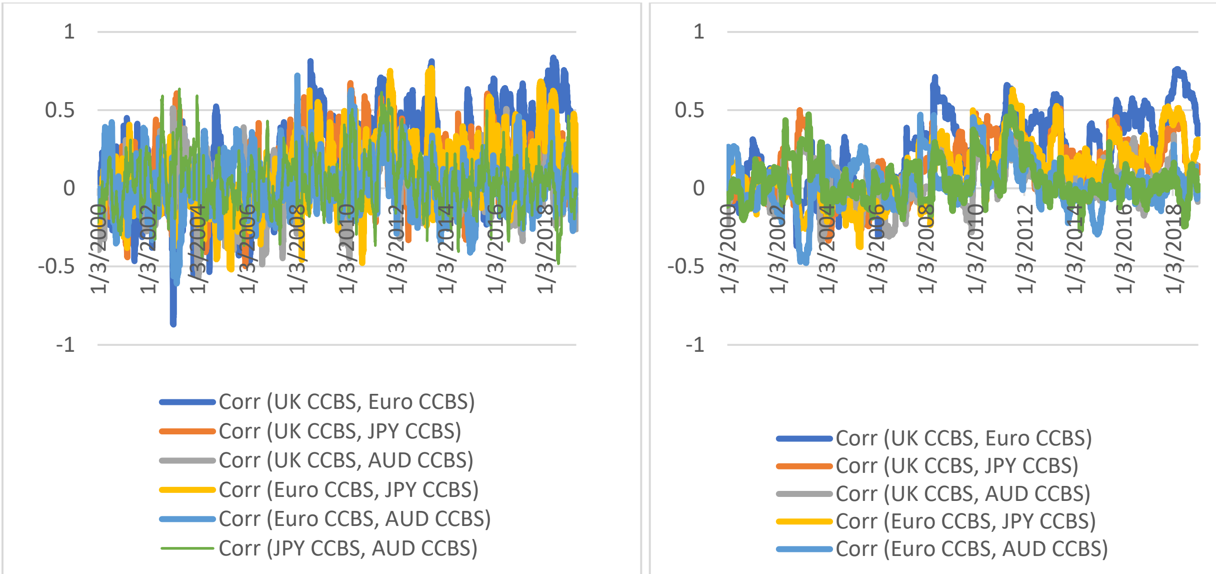
[2] In Australia, as in New Zealand, it was not so feasible to embrace expansionary monetary policy to accelerate financial stability and price stability as the inflation rate was already much closer to the target. A slacker monetary policy aimed at accelerating financial stability would heighten the already high inflation rate, beyond the target levels, and further, worsen inflationary price instability. As a result, even though peers favored massive rates cut, Australia policy rates were less accommodative. The less accommodative monetary policy in Australia relative to peers lowered the hunt for external yields by Australian dollar entities and lowered demand for dollar hedging activities, which lowered the realizable interest on synthetic dollars in the swap market and hence prevented the Australia basis from falling to the negative terrain.

that on average, even prior to the crisis, Australia's CCB spread was the highest in magnitude and most positive, whereas Japan's CCBS spread was the most negative and volatile during this period.

By the global financial crisis period, UK, Eurozone and Japan's CCBS spread had widened significantly to become much more negative and volatile, with the UK basis being the most negative on average and Japan's CCBS spread the most volatile. Yet again, Australia's CCBS spread remained positive. A similar pattern is repeated in the Eurozone crisis, but this time the positive average CCBS spread for Australia had increased by more than two folds while the negative basis for Japan had widened by nearly three folds compared to the era of the global financial crisis, making Japan's CCBS spread the widest, most negative and also most volatile relative to the other three CCBS spreads, including the euro, during Eurozone crisis. As with the CDS spreads, this suggests that on average Japan's CCBS spread were more sensitive to the Eurozone crisis than the global financial crisis. The summary statistics also exhibit that, although the average basis widening slowed down post-crisis, the widening of Japan's CCBS spreads have quickened to average levels that are higher than those recorded priors to and during the crisis Japan's CCBS spread volatility is also the greatest post-crisis. Meanwhile, the UK's CCBS spreads have the least negative value post-crisis, while Australia's CCBS spread retain their most positive position.

Fig 5: Rolling correlations of CCBS changes (1- and 2-year at top row; 3- and 6-month at bottom row)





Source: Author, 2019. Bloomberg. Corr is rolling correlation. CCBS is the 5-year cross-currency basis swap spread

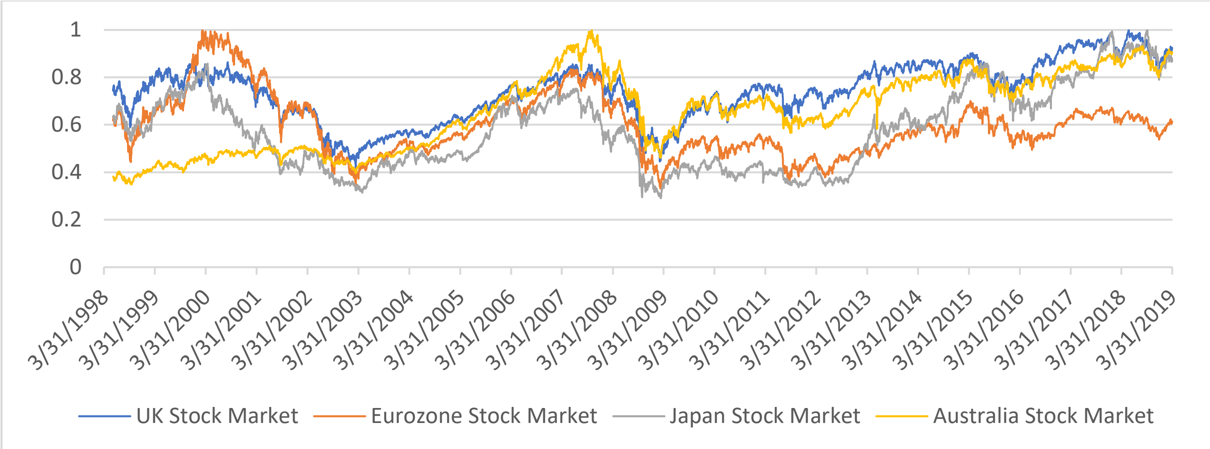
Figure 5 display the rolling correlations of the changes in CCBS spreads of the four countries for the periods under study. As before, we calculate rolling correlations using a rolling window of 3 months, 6 months, 1 year and 2 years, based on daily trading data. In general, some interesting new patterns emerge from these rolling correlations. First, as in the case of CDS spreads, the rolling correlations between the UK and Eurozone's CCBS spread changes are positive and the highest overtime. However, unlike the CDS spreads, most of the rolling correlations between the CCBS spread changes of the other countries are frequently more positive and generally non-trivial over time.

Second, the correlation between CCBS spread changes between country pairs tend to be much stronger overall than those of CDS spread changes. Indeed, besides the strong positive correlation between the UK and Eurozone CCBS spread changes, we also note the strong and positive correlation between changes in the CCBS spread of the UK and Japan, and Eurozone and Japan, where the correlation appears to move in lockstep over time. This pattern is especially visible in the low-frequency rolling window (i.e. 1- and 2-year rolling window), but it is also quite visible in the more volatile high frequency rolling window (i.e. 3-month and 6-month rolling window). For these same pairs, the correlation of CDS changes are generally weak, which suggests that their CCBS markets are more highly connected than their CDS markets, meaning that the scope of diversification across these CCBS markets is limited over time. For most of the country pairs, these correlations appear to have trended upwards, proposing that the short-term associations appear to have strengthened after the global financial crisis. This is in line with the finding of Ibhagui (2019) on the association between CCBS markets in the post-crisis era. Third, Australia and Japan show less correlation in the CCBS market than the CDS market. This suggests that their CCBS markets are less connected relative to their CDS market, at least in the short term. Hence, it should offer short-run diversification advantage for investors looking to diversify away some idiosyncratic risk in a portfolio of CCBS. Lastly, immediately preceding the crisis, and especially starting from the crisis, there was a notable correlation surprise, depicting the commencement of unusualness in the market. A correlation surprise implies that most of the previously held negative correlations between the CCBS spread changes turned positive. In general, a change in previously held correlations, known as a correlation surprise, often precedes the commencement of an unusual market event.

3.3 The Stock Market

As the third asset market, we provide a brief descriptive analysis of stock markets of the UK, Eurozone, Japan, and Australia using their respective stock market indices. The major stock market indices are FTSE 100 (UK equities), Euro Stoxx 50 (Eurozone equities), Nikkei 225 (Japan equities) and S&P/ASX 200 (Australia equities). For the descriptive analysis, we have acquired the complete transaction history of the stock market indices from 1998, being the earliest year for which data are available for all the stock market index, through 2019. Index data are in the respective national currency and are obtained from Bloomberg. Figure 6 depicts the stock market indices for the UK, Eurozone, Japan, and Australia between 1998 and 2019. The figures on the axis are rescaled so that they have a maximum and minimum value of 1 and 0 respectively. This ensures we can plot these indices on the same graph for easy comparison.

Fig. 6: Stock Market Indices



Note: Each market is scaled by its maximum index so that all plotted all index range from zero to one. FTSE 100 (UK equities), Euro Stoxx 50 (Eurozone equities), Nikkei 225 (Japan equities) and S&P/ASX 200 (Australia equities). Data from Bloomberg

As shown in Figure 6, the stock market indices peaked prior to the global financial crisis and then slumped at the height of the global financial crisis in 2008, with both Japan and Eurozone stock market indices reaching their minimum levels in this period. Following the crisis, there was some improved upward move in these indices. However, Eurozone and Japan stock markets both deteriorated once more during the Eurozone crisis in 2012 while the UK and Australia stock markets were more resilient. Overall, there were strong close ties binding the markets together during the global financial crisis. These ties were however weak during the Eurozone crisis and appeared to be segmented between markets so that the four stock markets indices are no more close-knit in the Eurozone crisis period as they were in the global financial crisis period. This seems to be suggesting that the global financial crisis brought out a similar reaction from the stock markets, whereas the effect of the Eurozone crisis appears to be relatively more heterogeneous affecting some stock markets (Japan and Eurozone) much more than others (the UK and Australia). All the four stock markets have mostly recorded an upward movement following the crisis, much earlier for the UK and Australia stock markets but true for the four stock indices.

Table 3: Descriptive Statistics of Stock Markets and Volatility (Annual Average Returns)

Annualized Stock Market Returns and Volatility	1998 - 2019	1998-2007	2008-2009	2010-2012	2013-2019
UK Equities	1.04	1.00	-8.98	3.23	3.44
	(19.07)	(18.67)	(32.66)	(18.00)	(13.55)
Eurozone Equities	-0.07	2.81	-18.47	-4.06	4.11
	(23.53)	(23.33)	(35.39)	(24.92)	(17.65)

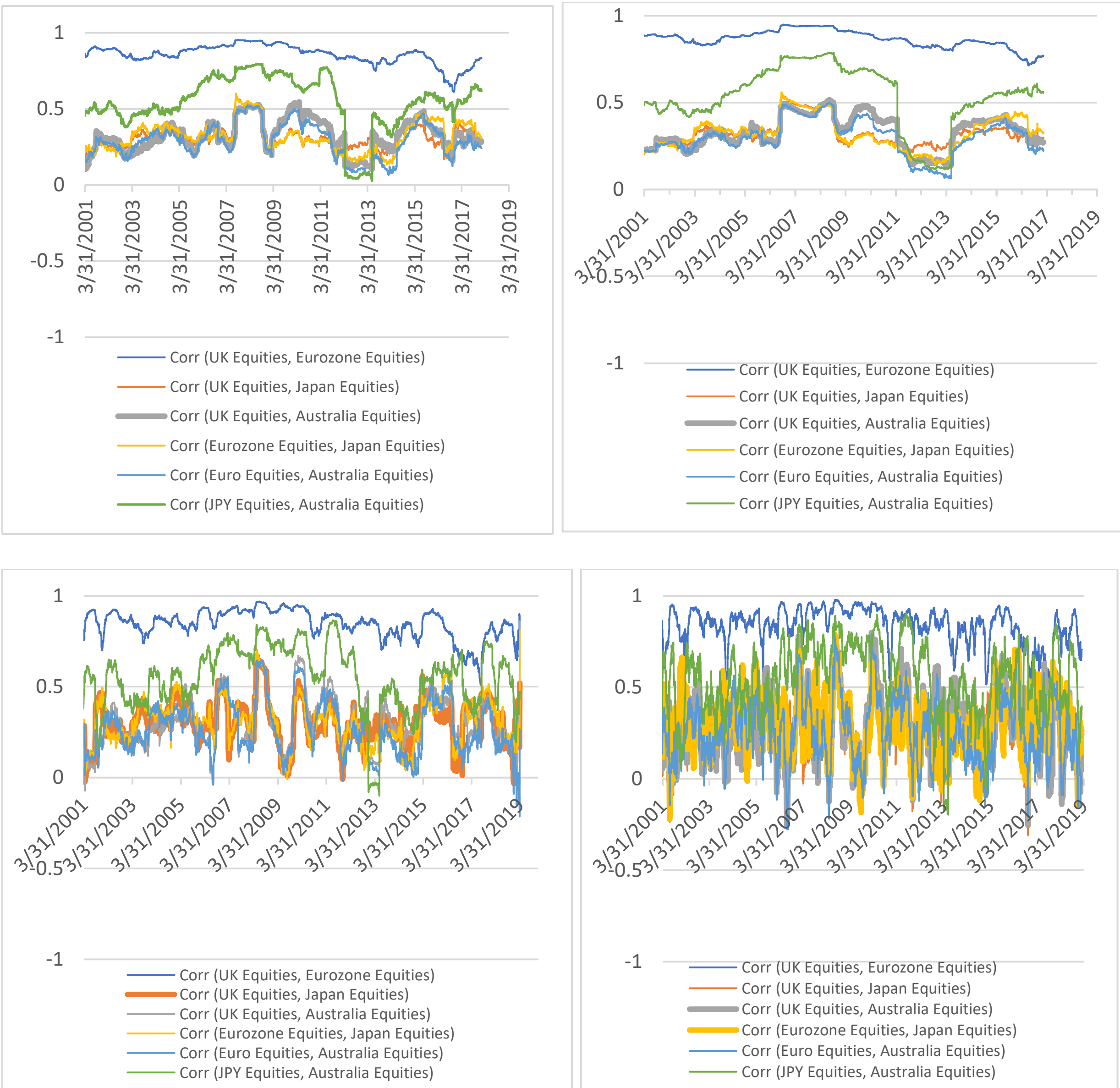
Japan Equities	1.61	-0.03	-17.51	-0.49	12.47
	(23.88)	(22.27)	(38.37)	(20.54)	(21.63)
Australia Equities	4.35	9.97	-13.08	-1.16	4.73
	(16.63)	(12.92)	(29.03)	(16.47)	(16.35)

Note: Annualized average daily stock market returns are reported at the top while the annualized volatility is reported in parenthesis. The major stock market indices used are FTSE 100 (UK equities), Euro Stoxx 50 (Eurozone equities), Nikkei 225 (Japan equities) and S&P/ASX 200 (Australia equities). Source: Author, 2019. Data – Bloomberg

Table 3 recaps the annualized stock market returns and standard deviations for different periods. For the whole sample period, which is over the last twenty years at least, the Australia stock market index has been the clear leader, with the largest annualized returns and the least volatility compared to the Eurozone stock market index that generated the least annualized returns and has the largest volatility. In the pre-crisis sample (1998 to 2007), the Australia stock market again led the pack with the highest annualized returns and least volatility while Japan reported the lowest annualized returns and one the highest volatility.

Looking at the period of the heightened global financial crisis, Australia and the UK recorded the least loss and lowest volatility while Japan and the Eurozone experienced the greatest losses with the highest volatility. During the Eurozone crisis, only the UK stock market recorded annualized gains. The Eurozone stock market experienced the largest losses and highest volatility. Japan and Australia also saw some pullback in their stock market performances. Interestingly, it is substantial to note that the global financial crisis had a much worse impact on all the performances of all four stock markets than the Eurozone crisis. To put this in perspective, its negative effect on Eurozone stock market performance is more than four times worse than the negative effect of the Eurozone crisis on Eurozone stock market performance. Ultimately, the annualized returns for all the stock markets have been positive in the post-crisis environment. Interestingly, on annualized terms, the Japan stock market has generated the highest returns in the post-crisis environment. However, its volatility has equally been the highest relative to other stock markets.

Fig 7a and b: Rolling Correlations of CCBS Spread Changes (1- and 2-year, top row; 3- and 6-month bottom row)



Note: FTSE 100 (UK equities), Euro Stoxx 50 (Eurozone equities), Nikkei 225 (Japan equities) and S&P/ASX 200 (Australia equities). Corr means rolling correlations. Source: Bloomberg Data. Author calculation, 2019.

Figure 7a and 7b display the rolling correlations of the stock market returns of the four countries. Overall, the rolling correlations suggest that the correlations between the stock markets are mostly positive and visibly much stronger over time than those recorded in the CDS and CCBS markets. All pairs of the stock market returns appear to be strongly positively correlated over time, even for the more volatile 6-month and 3-month rolling correlations. As in the CDS and CCBS markets, the rolling correlation between UK and Eurozone stock markets is the most positive and consistent across all the rolling windows. Meanwhile, most of the countries with weak or no positive correlation in the CDS and CCBS markets have positively correlated stock market returns. The rolling correlations neither trend upward nor downward but are relatively flattish, suggesting that not only is the rolling correlations positive, on average their coefficients are not significantly different from one period to the other. This also means that the distinctive spikes recorded in correlation during periods of crisis, as evidenced in the correlations observed in the CDS and CCBS markets respectively, are by and large not evidenced in the stock market. If anything, they are only evident to a very small extent in the stock market. In summary, this descriptive analysis reveals one major finding – in general, the countries are more positively connected through the stock markets than through CCBS and CDS markets.

4. Methodology

The last section has focused briefly on explaining the asset markets and providing preliminary descriptive statistics. In this section, we analyze the inter-temporal dynamic linkages between CDS, CCBS and stock markets using the standard VAR model. More specifically, we adopt impulse response functions to examine the cumulative response of each of CDS spread changes, CCBS spread changes and stock market returns to their own shocks as well as to the other asset markets shocks in a dynamic system of the three-dimensional VAR model. We also examine the potential of lead-lag relationships by establishing the existence of some causality between the variables using the Granger causality test. We employ the VAR approach in our empirical analysis to determine the dynamic linkages across the three asset markets in each country for the following reasons. First, it adequately captures the lead-lag relationships between stationary endogenous variables in a multivariate framework. This helps to capture the linear inter-dependencies among multiple time series. Second, it reflects the inter-temporal links between variables that make it useful for describing the dynamic behavior of economic and financial time series.

Our three-variable VAR model together with the exogenous controls can be written as follows:

$$\begin{cases} \Delta SMP_t = \beta_0^{SMP} + \sum_{i=1}^{p} \beta_i^{SMP} \Delta SMP_{t-i} + \sum_{i=1}^{p} \delta_i^{SMP} \Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_i^{SMP} \Delta CCBS_{t-i} + A^{SMP} \Delta \boldsymbol{X}_t + \varepsilon_t^{SMP} \\ \Delta CDS_t = \beta_0^{CDS} + \sum_{i=1}^{p} \beta_i^{CDS} \Delta CDS_{t-i} + \sum_{i=1}^{p} \delta_i^{CDS} \Delta SMP_{t-i} + \sum_{i=1}^{p} \gamma_i^{CDS} \Delta CCBS_{t-i} + A^{CDS} \Delta \boldsymbol{X}_t + \varepsilon_t^{CDS} \\ \Delta CCBS_t = \beta_0^{CCBS} + \sum_{i=1}^{p} \beta_i^{CCBS} \Delta CCBS_{t-i} + \sum_{i=1}^{p} \delta_i^{CCBS} \Delta SMP_{t-i} + \sum_{i=1}^{p} \gamma_i^{CCBS} \Delta CDS_{t-i} + A^{CCBS} \Delta \boldsymbol{X}_t + \varepsilon_t^{CCBS} \end{cases} \tag{8}$$

where ΔSMP_t, ΔCDS_t, and $\Delta CCBS_t$ are the stationarized values representing stock market returns, changes in credit default swap spread and changes in cross-currency basis swap spreads, respectively. They are obtained by computing the logarithmic returns of the stock market index (SMP_t) and taking the first difference of the credit default swap spread (CDS_t) and cross-currency basis swap spread ($CCBS_t$). Also, $\boldsymbol{\varepsilon}_t = (\varepsilon_t^{SMP}, \varepsilon_t^{CDS}, \varepsilon_t^{CCBS}) \sim N(\mathbf{0}, \boldsymbol{\Omega})$ and $(\boldsymbol{\beta}_i, \boldsymbol{\delta}_i, \boldsymbol{\gamma}_i)$ are the *p-lag* coefficients of the model. We also include $\Delta \boldsymbol{X}_t$ which is the vector of exogenous control variables that include changes in term spread, exchange rate and the volatility index (VIX) to capture changes in monetary policy, currency movement, and global risk sentiments. They control for factors that could potentially affect the dynamics of the three endogenous variables. In this study, we consider the variables in $\Delta \boldsymbol{X}_t$ as exogenous since we are not interested in studying the effects of the chosen endogenous variables on their dynamics. The specification in (8) allows for a feedback loop wherein the endogenous variables can affect one another without restrictions. The specification is a reduced form model where we give every variable a chance. We do not impose any restrictive economic specification on how these equations should evolve as we are more interested in allowing the data to provide guidance. With our 3-variable VAR, we adopt a fairly general model that gives autonomy to the data to uncover the true links among endogenous variables[3].

In our specification, rather than impose a lag order, we determine the appropriate lag order *p* for each country using standard information criterion. Following Liew (2004), and given our relatively large number of observations, the appropriate lag length used for the VAR is chosen based on the Hannan-Quinn criterion. This implies that an optimal lag order of 6, 2, 1 and 3 are selected for the UK, Eurozone, Japan, and Australia, respectively. In an unreported analysis, we find that our results, in general, are not very sensitive to the number of lags length chosen. In the next section, we formally examine the empirical detail of the dynamic linkages among the markets in each country for the whole sample period. Following this, we reexamine the problem in different crisis sub-periods to check for stability of results, and we perform a Brexit event study.

[3] Allowing the data to reveal the hidden links among these markets, we employ the standard generalized impulse response functions, and Granger causality based on a vector autoregressive (VAR) model to analyze the dynamics of these markets using daily data for the period of 2008 to 2019 and for different sub-periods characterized by notable events in the global economy. Particularly, the sub-period analysis for each country covers the global financial crisis and the eurozone crisis. For the UK and Eurozone, it also includes before and after Brexit.

5.0 Empirical Results and Discussions of the Dynamic Interdependence between CDS, CCBS and Stock Markets

For each country, we present results of the response of one asset-market to shocks in the other asset markets. We also present the results of granger causality tests to uncover potential lead-lag relations.

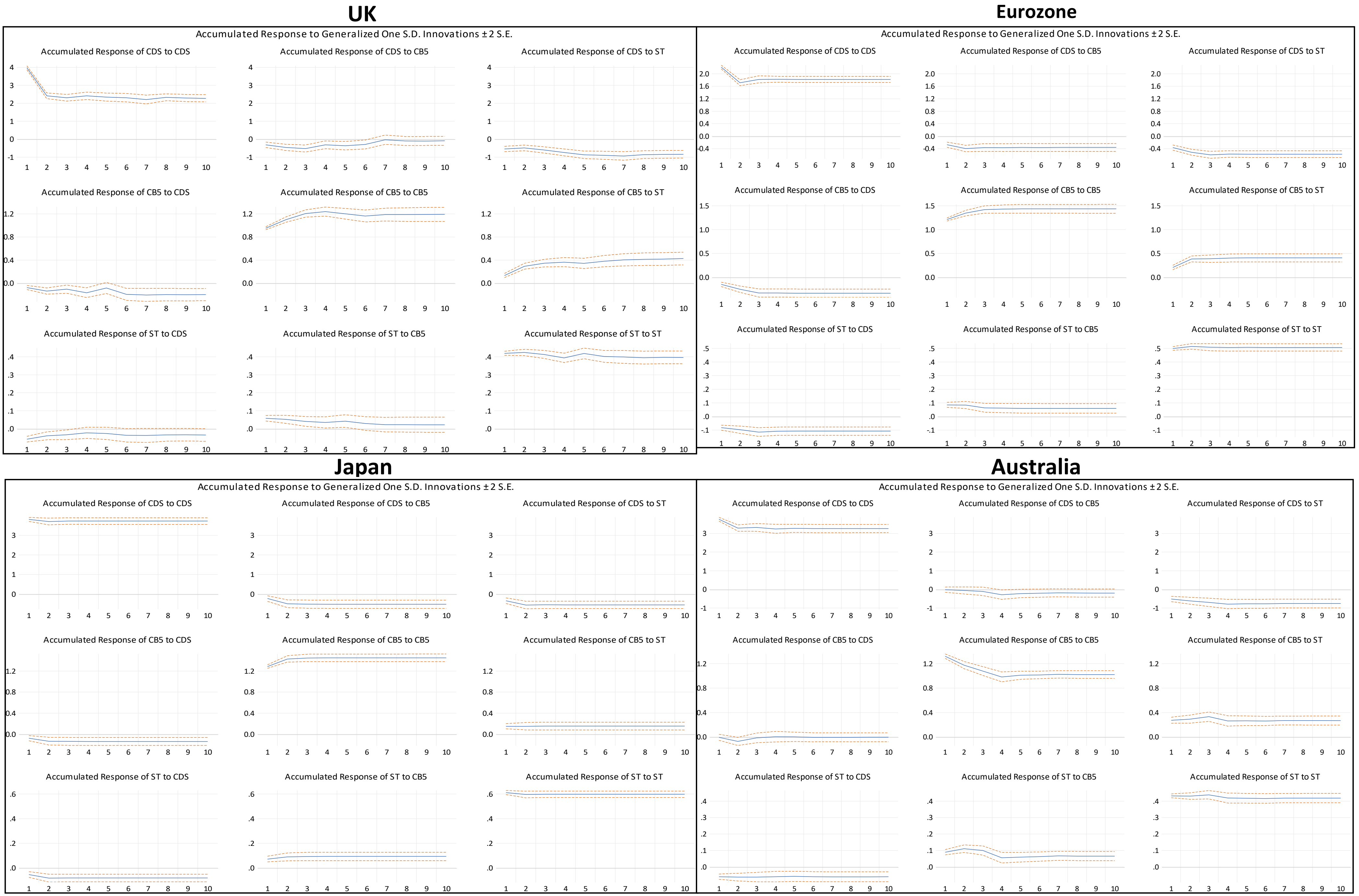
5.1 Analysis of the Three-dimensional Models and Impulse Response

We estimate VAR system for the UK, Eurozone, Japan, and Australia. Figure 8 reports the accumulated impulse responses within the 95% confidence bands associated with a positive shock to each asset market based on generalized impulse response functions. It is well known that the analysis of impulse responses performed via Cholesky decomposition requires specifying some causal orderings of variables in the VAR system. Such causal orderings often rely heavily on restrictions that are determined by established theories. However, in this paper, a theory that is fully supportive of a particular causal ordering is hard to justify, more so in the context of high frequency daily data as used in this analysis. Thus, to obtain a global view on the interdependence of the three markets under study, we have instead employed the generalized impulse responses (GIR) in the spirit of Pesaran & Shin (1998) and Alter & Schuler (2012). Unlike others, one major advantage of GIR is that it does not require any causal ordering specifications of variables in the system.

For every country being studied, each row shows the accumulated response of one asset market to its shocks and to shocks to other asset markets. For instance, the first row displays the accumulated response of the credit default swap market (CDS) to its shocks as well as to shocks in the cross-currency basis swap market (CB5) and stock market (ST). The second row shows the accumulated response of CB5 to its shocks and to shocks in CB5 and ST. The last row shows the accumulated response of ST to CDS and CB5 as well as to its own shocks. Note that CB5 is CCBS and represents changes in cross-currency basis swap spreads, ST stands for stock market returns performance (SMP) and CDS represents changes in sovereign credit default swap spreads.

First, in the UK, the cumulative effect of a positive shock to CCBS decreases CDS across time. Identically, the effect of a positive shock to CDS widens CCBS. Therefore, the CCBS and CDS markets have a negative inter-temporal relation. Importantly, the negative accumulated response of the CCBS following a positive shock to the CDS is more persistent. Truly, while the negative accumulated response of CDS loses its significance after around 7 days, the negative accumulated response of CCBS remains persistent and does not lose its significance even after seven days. Thus, in the UK, accumulated response of CCBS spread to a positive shock that expands the CDS spread is negative and much more persistent than conversely. Second, the response of CDS spreads to stock market shocks is negative while the response of the stock market to a positive CDS shock is also negative. The accumulated response of CDS to stock market shocks appears to be slightly more persistent and statistically significant than the response of stock market to positive CDS shocks, suggesting that information about the CDS market may first be reflected in the stock markets slightly more so than information about the stock markets that can be obtained from the CDS markets.

Fig. 8: Accumulated impulse responses of each asset market to its own shocks and to shocks to the other asset markets



Note: Accumulated impulse responses to 1 standard deviation shock for the whole sample period (2008 – 2019)

In the end, the CCBS and stock market in UK appear to exhibit a positive intertemporal linkage as shocks to the stock market seem to induce a positive response from the CCBS market, leading to tighter CCBS spreads which remains persistently significant. In the same vein, a positive shock to the CCBS spread also increases stock market returns, but the cumulative effect becomes statistically insignificant after about five days. Thus, like the CDS market, our result suggests that the inter-temporal linkages between the stock market and CCBS market are such that the UK stock market seems to provide more information about the CCBS market than the information provided to the stock market via the CCBS market. To sum up, in the UK, the accumulated impulse response analysis suggests that the CCBS and CDS market, and the CDS and stock market have a negative dynamic inter-temporal relation, but the CCBS and stock market exhibit a positive inter-temporal relation.

Afterwards, we focus on the Eurozone and analyze the accumulated responses of asset markets to their own shocks as well as to shocks in the other asset markets. Results for the Eurozone show that the accumulated impulse response functions associated with these shocks are alike to results for the UK in most respect. However, unlike the UK, results for the Eurozone have a feedback mechanism that is persistently more significant. Indeed, in the case of the UK where the significance of accumulated responses of the CDS market and stock market to CCBS shocks die out after seven days and five days respectively, the statistical significance for the same dynamic relations in the Eurozone seems to be more persistent and carry on much further. This suggests that the significance of inter-temporal dynamic relations tends to be stronger for these markets in the Eurozone than in the UK. Turning to Japan, in general, the behavior of accumulated impulse responses is in line with the results obtained for Eurozone. Not only are the inter-temporal dynamic links between asset markets consistent with results for the UK and Eurozone, but the statistical significance also persists, in line with the results for Eurozone.

Lastly, for Australia, the inter-temporal dynamics appear to be similar to those obtained for the other countries except that intertemporal links between the CDS and CCBS markets are either very small, much smaller than for the other countries, or statistically insignificant. For instance, the accumulated response of the CDS market only becomes statistically significant after 4 days. And even then, the magnitude of this response is small. On the other hand, the accumulated response of the CCBS market to CDS market shocks becomes both statistically and economically insignificant after 2 days as the accumulated impulse response shrinks to zero.

In summary, although at varying levels of significance, magnitude, and persistence, in each of the four economies analyzed, there seems to be some consensus in the dynamics of linkages between the CDS, CCBS and stock markets over the period of analysis. A positive shock to the stock market, which raises stock market returns performance, lowers CDS spreads and induces tighter (less negative or more positive) CCBS spreads. A positive shock to the CCBS market, which tightens the CCBS spread, lowers the CDS spreads and improves stock market returns. A positive shock that elevates sovereign CDS spreads widens the CCBS spread and decreases the performance of the stock market. The magnitude and persistence differ from case to case. The dynamic relations are strongest, most persistent and statistically significant for the Eurozone and Japan. These results illustrate the importance of knowing the inter-connectedness of asset markets over time, particularly in working out the market from which evidence exists that financial shocks propagate to other markets.

5.2 Analysis of the lead-lag causal relationship among CDS, CCBS(CB5) and ST

Table 4 reports p-values of the Granger causality results to examine the lead-lag dynamic links between the three asset markets for each country group. It shows results for that stock market returns (ST), changes in credit default swap spreads (CDS) spreads, and changes in cross-currency basis swap (CB5) spreads for the entire period from 2008 to 2019. At the 5% level, ST leads CDS and CB5 in all four countries while CDS and CB5 lead ST in two out of the four countries.

Table 4. Granger Causality Results

	From CB5 to CDS	From ST to CDS	From CDS to CB5	From ST to CB5	From CDS to ST	From CB5 to ST
	p-value	p-value	p-value	p-value	p-value	p-value
UK	0.000	0.000	0.000	0.000	0.092	0.479
Eurozone	0.000	0.000	0.000	0.000	0.037	0.013
Japan	0.000	0.001	0.007	0.041	0.016	0.127
Australia	0.137	0.048	0.009	0.004	0.967	0.000

Notes: p-value <0.01, <0.05 and <0.10 indicate statistical significance at the 1%, 5% and 10% level respectively. CDS, CB5 and ST represent changes in CDS spreads, changes in cross-currency basis swap spreads and the stock market returns. Source: Author calculation, 2019.

CDS lead CB5 in all the four groups while CB5 lead CDS in three out of the four groups. As documented in the impulse response analysis, irrespective of the direction, these lead-lag relations imply that the dynamic link between ST and CB5 is positive, ST and CDS are negative and CB5 and CDS are also negative.

By and large, the Granger causality test result reported in Table 4 echoes the fact that the dynamic interrelations between the asset markets for the entire period of analysis are indeed strongest in the Eurozone and Japan. Moreover, there is a strong lead-lag relationship from the stock market to both the CDS market and CCBS market, reiterating that each stock market contains relevant information that drives the behavior of other asset markets. This advances the view that information first manifests in the stock market before trickling into other asset markets. This finding is consistent with Norden & Weber (2009) who find that the stock market leads the CDS market for individual corporates. Nevertheless, the present study extends this to the sovereign CDS market and the broader stock market, rather than corporate CDS and individual stock returns.

In most examples, the results show that the inter-temporal relations are very similar for the four groups of countries in that there is a strong feedback relation that is highly statistically significant (mostly at 1% level or better) between the asset markets in each country or group. Nonetheless, for Australia, the results suggest that the direction of causality is from the CDS market to the CCBS market and from the stock market to the CDS market, rather than the other way around. For Japan and the UK, the lead-lag relation between the stock market and CCBS market flows from the stock market to the CCBS market, not otherwise. Overall, with the Granger causality test results, we see that there is no instance in which there is an absence of at least one lead-lag relationship between the asset markets. Accordingly, there is evidence of strong dynamic relationships between the asset markets in each of the four groups for the entire period analyzed.

We now relate these results to the hypotheses formulated earlier. Together with the accumulated impulse response functions, these results reveal that there are several inter-temporal linkages across the three-asset market. As stated in the first hypothesis H1, there is evidence to support the view that positive shocks to sovereign CDS spread have a significantly negative impact on the CCBS spread, i.e. lower or weaker dollar funding liquidity, and deterioration of the broader stock market performance in each country group. Moreover, we observe two-way linkages across these markets in most groups. The results for the entire period suggest that the CDS and CCBS markets exhibit negative lead-lag dynamic relationships such that positive shocks to CDS spread result inter-temporally to wider CCBS spreads, giving support to the second hypothesis – H2. Although not evident in all countries, there also exists evidence of a reverse lead-lag relationship that runs from CCBS to CDS markets, indicating two-way linkages across these asset markets. On the whole, our detailed empirical analysis investigates the lead-lag relationships between the three-asset market in a differentiated and country-specific dynamic analysis that gives us the avenue to explore country-specific properties that might be missed or not be apparent in a more generic combined panel-based study.

Interestingly, as supported by Granger causality results, stock market returns are the least forecastable while CCBS is the most forecastable. In fact, for the entire period, the stock market leads both the CCBS and CDS markets than vice versa and has a more persistent effect on these asset markets in each country, providing evidence in favor of hypothesis 3 (H3). Indeed, while there is reverse Granger causality in some cases, we find that the leading role of the stock market for other asset markets is more predominant than conversely, which provides support for H3. Thus, the relevant information is manifested in the stock market before they propagate to these other asset markets.

In summary, the accumulated impulse response functions and Granger causality tests provide evidence of the significant dynamic inter-dependence of the three asset markets in the majority of the countries analyzed for the entire period. The results show that in all countries, the stock market predominantly leads the CCBS and sovereign CDS markets, which provide some evidence that information which is relevant to the financial markets is first reflected in the stock markets before propagating to sovereign credit default swaps (CDS) and cross-currency basis swaps (CCBS) markets. This seems to be suggesting that the stock market is more sensitive to news than other asset markets. Studies such as Norden & Weber (2009) and Trutwein & Schiereck (2011) document that this difference in sensitivity can be explained by liquidity. They argue that the stock market is highly liquid, and it is this liquidity that heightens the stock market's sensitivity to new information relative to other asset markets. In the following sub-section, we examine the robustness of the dynamic interrelations across the asset markets for each group.

5.3 Robustness Checks

In this section, we carry out a battery of robustness checks to explore whether prevailing dynamic interrelations between the asset markets in each group is regime dependent; that is, whether they are more sensitive to the periods chosen and perhaps intensify during periods of turbulence. The two major turbulent periods chosen are the global financial crisis and Eurozone crisis. We also perform a "Brexit event study" with a focus on the UK and Eurozone. Under this analysis, we examine the dynamic links among the three asset markets in the UK and Eurozone before and after Brexit.

Thus, in this section, we examine whether our results might be potentially altered under different scenarios and determine whether the main results obtained for dynamic interrelations of the three asset markets are stable over time. Moreover, we re-estimate the VAR for different time periods to study the links among the variables, specifically during the global financial crisis, Eurozone crisis and after both crises. We also perform an event study for the UK and Eurozone. In this event study, we re-examine the dynamic links before and after the Brexit vote of June 23, 2016, to examine how the Brexit event might have altered the dynamic relationship. We begin first with the crises and post crises sub-samples before moving to the Brexit event study.

Table 5: Granger causality test results for the global financial crisis GFC subsample (2008-2009)

	From CB5 to CDS	**From ST to CDS**	**From CDS to CB5**	**From ST to CB5**	**From CDS to ST**	**From CB5 to ST**
	p-value	p-value	p-value	p-value	p-value	p-value
UK	0.1041	0.0262	0.0001	0.0002	0.5336	0.9172
Eurozone	0.1878	0.0029	0.0164	0	0.9629	0.1027
Japan	0.0254	0.166	0.0125	0.4225	0.4891	0.7914
Australia	0.2143	0.1328	0.0002	0.0514	0.7142	0.0007

Source: Author calculation, 2019. CDS, CB5 and ST represent changes in CDS spreads, changes in cross-currency basis swap spreads and stock market returns.

Table 5 shows the results for the turbulent periods of the global financial crisis from 2008 to 2009. The dynamic relations between the asset markets are moderately strong, but some lead-lag relations, which were highly significant for the entire period, are no more significant. For all the countries, the CDS market seems to play the most dominant leading role in the CCBS market. This is followed by the stock market which also plays a leading role for the CCBS except in Japan where the stock market does not lead the CCBS market during this period. It turns out that the CCBS market is the most predictable from both the CDS and stock markets, most especially the sovereign CDS market, thereby highlighting the sheer importance of this market for the CCBS market in all these countries during the global financial crisis. This is further supported by the results which also manifest that there is mostly no lead-lag relationship from the CCBS market to either the stock or CDS markets.

Table 6: Granger causality test results for eurozone sovereign crisis subsample (2010 – 2012)

	From CB5 to CDS	From ST to CDS	From CDS to CB5	From ST to CB5	From CDS to ST	From CB5 to ST
	p-value	p-value	p-value	p-value	p-value	p-value
UK	0.1222	0.0011	0.0460	0.0017	0.5613	0.6511
Eurozone	0.765	0	0.2898	0.0007	0.0727	0.0385
Japan	0.6421	0.0967	0.821	0.9136	0.0619	0.0491
Australia	0.6903	0.4148	0.6233	0.0011	0.3525	0.6038

Source: Author calculations, 2019. CDS, CB5 and ST represent changes in CDS spreads, changes in cross-currency basis swap spreads and stock market returns.

Turning now to the next period of turbulence, the Eurozone crisis period, Table 6 shows the results for this period. The stock market turns out to be the most dominant leading asset market for the other asset markets in almost all the groups, much more than the CDS market which mostly led other asset markets during the global financial crisis. Where significant, the degree of significance and influence of the stock market as a leader of other asset markets is stronger on the CCBS market than on the CDS market. Meanwhile, as in the turbulent period of the global financial crisis, the CCBS market has no significant leading influence on the CDS market in all groups, although it shows some influence on the stock market in the Eurozone and Japan. Further, the lead-lag links between the CCBS and stock market exhibit a feedback mechanism in the Eurozone. Unlike during the global financial crisis, the CDS market fails to exert a significant leading influence on the CCBS market during the Eurozone crisis across most countries (except for the UK).

Altogether, there is some evidence of dynamic interrelations among the asset markets in each country during the Eurozone crisis period. The manner of dynamic linkages during the Eurozone crisis is in general slightly different from the global financial crisis. While the CDS market, followed by the stock market, played the most dominant leading role for the CCBS market at the height of the global financial crisis, it is principally the stock market that played the dominant leading role for the CCBS and CDS markets during the Eurozone crisis. This signifies that for most groups, the CCBS and CDS markets are most predictable from the stock market than vice versa during the period of Eurozone turbulence, hence further highlighting that the stock market has been an important leading influencer of the CCBS and CDS markets during the Eurozone crisis. In summary, the results present some support for the fourth hypothesis, H4 (i.e. the links among CDS, CCBS, and stock markets are generally much stronger during periods of crisis).

We now turn to the post-crisis period. Table 7 reports the results. Interestingly, even though some dynamic links are lost, we see that, overall, the stock market continues to exhibit some important leading influence on other asset markets, especially the CDS market but also for the CCBS market, albeit to a lower extent. This result reinforces the importance of the stock market for the CDS and CCBS markets even in the post turbulence era. Overall, it is worth noting that while there is nearly a feedback mechanism across all these three asset markets in the UK and Japan, we note that in no other period is the Eurozone without at least a lead-lag relationship between the asset markets as is the case in the after-crisis period. This suggests that taken together, the significance of lead-lag dynamic relations across these asset markets have weakened after the crisis. Thus, in line with the fourth hypothesis, the links between the CDS, CCBS, and stock markets are in general much stronger during the periods of the crisis. As no significant inter-temporal dynamics exist among asset markets in the Eurozone, and only one exists in Australia, it is fair to say that previous results obtained for the entire period may not carry over into different periods for all the countries. Together with the results for both crisis periods, this shows that the inter-temporal dynamics generally intensified during turbulent periods. By and large, the results for both turbulent periods are largely consistent with those for the entire period, suggesting that these crisis periods drive the outcome for the entire period. In a nutshell, there are dynamic inter-connections across the three asset markets, and stock market can be an important lead for the CDS and CCBS markets in each country.

Table 7: Granger causality test results for the post-crisis subsample (2013 to 2019)

	From CB5 to CDS	**From ST to CDS**	**From CDS to CB5**	**From ST to CB5**	**From CDS to ST**	**From CB5 to ST**
	p-value	p-value	p-value	p-value	p-value	p-value
UK	0.0026	0.0099	0.1110	0.0838	0.0907	0.0007
Eurozone	0.2788	0.1228	0.9334	0.7419	0.2113	0.5131
Japan	0.0253	0.0304	0.0749	0.0002	0.0274	0.7659
Australia	0.2743	0.0097	0.1789	0.6585	0.6662	0.5082

Source: Author calculations, 2019. CDS, CB5 and ST represent changes in CDS spreads, changes in cross-currency basis swap spreads and stock market returns.

5.4 Event Study – The Lead-Lag Dynamics of the Asset Markets in the UK Before and After Brexit

The Brexit vote took place in the UK on June 23, 2016, the outcome of which sent shock waves simultaneously to the UK and Eurozone asset markets. In this section, we examine the foregoing lead-lag dynamic inter-connections between asset markets in the UK and Eurozone both in the pre- and post-Brexit periods in order to determine to what extent Brexit might have brought a regime change in the lead-lag dynamics of the asset markets in each country. We also investigate the pattern of regime changes to ascertain the extent to which they are similar or dissimilar in both countries. Daily frequency data is the most suitable for answering these questions. In view of this, to perform the event study, we split the data into two non-overlapping sub-samples: before Brexit (January 1, 2010 – June 22, 2016) and since Brexit (June 23, 2016 – June 18, 2019) and estimate the lead-lag dynamics with data from each sub-sample respectively. The results obtained are reported in Table 8 and 9 which offer some interesting insights.

Table 8: Granger Causality Results for Event Study Before Brexit

	From CB5 to CDS	From ST to CDS	From CDS to CB5	From ST to CB5	From CDS to ST	From CB5 to ST
	p-value	p-value	p-value	p-value	p-value	p-value
UK	0.6385	0.0034	0.0556	0.0000	0.1311	0.4710
Eurozone	0.0592	0	0.0166	0.0014	0.0047	0.0709

Source: Author calculations, 2019. CDS, CB5 and ST represent changes in CDS spreads, changes in cross-currency basis swap spreads and stock market returns.

Table 9: Granger Causality Results for Event Study After Brexit

	From CB5 to CDS	From ST to CDS	From CDS to CB5	From ST to CB5	From CDS to ST	From CB5 to ST
UK	0.0045	0.0150	0.2658	0.2671	0.0000	0.0206
Eurozone	0.9178	0.5558	0.0345	0.7776	0.4667	0.4626

Source: Researchers, 2019. Source: Author calculations, 2019. CDS, CB5 and ST represent changes in CDS spreads, changes in cross-currency basis swap spreads and stock market returns.

First, the asset market pairs with a significant lead-lag relationship prior to Brexit lose their significance post Brexit while those for which the lead-lag relations are not significant prior to the crisis becomes significant post-crisis. Interestingly, this pattern is observed in both the UK and Eurozone, providing some empirical evidence that what qualifies as an important leading asset market prior to Brexit may no more be appropriate post-Brexit. Conversely, the asset markets which fail to lead other markets prior to Brexit may have well become significant leading asset markets for other asset markets in the post Brexit era. For instance, prior to Brexit, the stock market and CDS market notably led the other asset markets whereas except for the lead-lag relation from the stock market to the CDS market, they generally do not lead other asset markets after Brexit. Conversely, the CCBS market does not lead the CDS and stock markets pre-Brexit. Also, the CDS market does not lead the stock market before Brexit. Still, both become important leading asset markets after Brexit.

In a similar pattern, there was a strong feedback mechanism in the Eurozone during the pre-Brexit period as all the asset markets more or less led each other. However, in the post-Brexit, it is noteworthy that the leading role of most asset markets in comparison to the other markets has deteriorated. Most of the asset markets fail to exhibit a lead-lag relationship in any direction with other asset markets. These outcomes for the Eurozone are consistent with the view that the dynamic lead-lag links between the asset markets deteriorate after turbulence. One exception is the CDS market which clearly leads the CCBS market in the pre- and post-Brexit subsamples, reflecting the importance of the sovereign CDS market. The lead-lag granger causality results for the crises and post crises subsamples as well as the event study analyses are generally consistent with the accumulated impulse responses of these asset markets for the different subsamples (see Appendix).

In summary, analysis of the subsamples suggests that the lead-lag inter-temporal dynamics between the asset markets generally intensify during turbulent periods. Insights from results in the turbulent periods are consistent with those for the entire period, suggesting that the outcome for turbulent periods drive the entire period outcome. Accordingly, results for the entire period may not carry over into all different sub-periods. Meanwhile, there are dynamic interconnections amidst the three asset markets, and the stock market can be an important leading asset market for the CDS and CCBS markets in the countries analyzed. In most sub-periods, there is a robust lead-lag link from the stock market to other asset markets. There is evidence that the stock market is influential and significantly leads the CDS and CCBS market during crisis and in the post turbulence era to some extent. The leading role of stock market in comparison to both other markets is most visible in the turbulent periods. The event study, which examines how Brexit has influenced the dynamic relations of the asset markets in the UK and Eurozone, shows that in each of the two groups, most of the asset markets which led other asset markets prior to Brexit have become insignificant post-Brexit while those which had no leading influence on other asset markets prior to Brexit have turned out more significant and influential post-Brexit. Overall, our robustness analysis and event study provide insights into the intertemporal stability of dynamic linkages among these three asset markets.

5.5 Big picture summary of results, statement of contribution, and implications for the markets

In general, the securities and asset markets in a given economy or financial system should broadly reflect the state of uncertainty inherent in that economy. In this case, it is not unusual that, in making decisions to invest or to not invest, market participants often incorporate differing degrees of country exposures to sovereign risk into assets or entities emanating from these countries. This has implications not only for risk management but also for liquidity across markets. In this regard, understanding the dynamic interactions of diverse asset markets within a given economy becomes imperative. In this article, we perform a new empirical examination that simultaneously links sovereign credit default swaps (CDS - that is, a gauge of sovereign default risk), cross-currency basis swaps (CCBS/CB5 - a measure of relative availability of dollar funding liquidity or the cost of hedging against US dollar depreciation for non-US dollar entity), and stock market performance (ST/SMP) of four major economies – UK, Eurozone, Japan Australia.

Our paper contributes to empirical finance literature in several ways. Not only have we studied the links between CCBS and stock markets for major economies with the largest CCBS market, but we have also investigated the lead-lag dynamics between CDS, CCBS, and stock markets. Our findings are especially relevant for market participants, especially those with interests in cross-asset relations on the aggregate level, who depend on signals from one asset market in taking decisions or positions in other asset markets. Once the dynamics of asset markets are established, signals from some asset markets should provide an avenue for market participants to formulate a near-term outlook for other asset markets. This would provide the necessary exposure for informed market participants to preempt unfavorable events across asset markets. For instance, our results may prove useful for investors and financial institutions who seek to understand how shocks propagate from one asset market to other asset markets and assemble profitable portfolios on the back of asset allocation strategies that rely on information from cross-asset markets. Such information could aid in trading equities, hedging against sovereign credit risk and FX risk using CDS and CCBS respectively or even trading CCBS to latch on potential arbitrage profits.

5.6 Theorizing the positive link between cross-currency basis and stock markets

In the preceding narrative, we have given some evidence, among others, that there exist positive links between cross-currency basis and stock markets. A positive stock market performance, represented as improvements in stock market returns, induces tighter cross-currency basis swap spreads. In what qualifies as a preliminary illustration to theoretically explain this positive link, we sketch below a simple model combining the standard deviation of cross-currency basis swap spreads and global capital asset pricing model (GCAPM) as in Stulz (1995a) and Stulz (1995b). GCAPM has the same structure as the traditional CAPM of Sharpe (1964) and Lintner (1965), but with the global stock market universe index replacing the domestic stock market index as the market portfolio.

1. **Stock market returns**

The representative stock market index is a subset of a much broader global stock market universe. We assume that the stock market indices are investable securities which are riskier than the global stock market index.

Based on GCAPM, the required return on representative stock market index is given by

$$\hat{R}_{n,t} = y_{n,t} + \beta\left(R_{n,t} - y_{n,t}\right) \qquad (a)$$

The corresponding required return on the US stock market index can be written as

$$\hat{R}^{US}{}_{n,t} = y^{US}_{n,t} + \beta^{US}\left(R_{n,t} - y^{US}_{n,t}\right) \qquad (b)$$

where $\hat{R}_{n,t}$ is the n-year return on the representative stock market index, $\hat{R}^{US}{}_{n,t}$ is the n-year return on the US stock index, $y_{n,t}$ is the n-year yield in the representative country, $y^{US}_{n,t}$ is the corresponding n-year yield in the US, $R_{n,t}$ is the return on the world stock market index, while β and β^{US} are the betas of returns on the representative stock market index and US stock market index viz a viz the world stock market index.

Betas β and β^{US} represent the sensitivity of returns on each stock market index to returns on the global stock market index, where

$$\beta = \frac{\mathrm{Cov}(\hat{R}_{n,t}, R_{n,t})}{Var(R_{n,t})}, and \quad \beta^{US} = \frac{\mathrm{Cov}(\hat{R}^{US}{}_{n,t}, R_{n,t})}{Var(R_{n,t})}$$

Under the assumption that the representative stock market index and the US stock market index are riskier than the world stock market index, we have $\beta > 1$ and $\beta^{US} > 1$, where the beta of global stock market index is 1.

2. Cross-currency basis swap spreads

Following Avdjiev et al. (2018), let $xccy_{n,t}$ denote the n year cross-currency basis swap spread of each country's currency vis-à-vis the US dollar at time t where, as is standard, $xccy_{n,t}$ denotes the extent of deviations from covered interest parity (CIP) between each currency and the US dollar. Following standard definitions to augment deviations from CIP, we have:

$$\left(1 + y_{n,t}^{US}\right)^n = \left(1 + y_{n,t} + xccy_{n,t}\right)^n \frac{S_t}{F_{n,t}} \qquad (c)$$

where S_t is the spot exchange rate of each currency per unit of US dollar and $F_{n,t}$ is the forward exchange rate to be implemented n period from now. Taking the logarithm of both sides of (c), we get

$$xccy_{n,t} = (y_{n,t}^{US} - y_{n,t}) + \delta_{n,t} \qquad (d)$$

where $\delta_{n,t} = \frac{1}{n}\left[\log\left(F_{n,t}\right) - \log(S_t)\right]$ is the forward premium to hedge against US dollar appreciation. Indeed, if $\delta_{n,t} > 0$, so that $\log\left(F_{n,t}\right) > \log(S_t)$ or equivalently, $F_{n,t} > S_t$, then the US dollar is at a depreciated level and the basis is less negative (or more positive or tighter), so the US dollar entity/holder pays relatively more (a premium) to hedge against US dollar appreciation when taking a foreign position. On the other hand, if $\delta_{n,t} < 0$ so that $F_{n,t} < S_t$, then the reverse is the case. The US dollar is at an appreciated level and the basis is more negative (or wider or less positive). In this case, the US dollar holder pays relatively less (a discount) to hedge against dollar appreciation when taking foreign positions. Equation *(d)* is the well-known definition of the basis as a measure of the difference between the direct dollar interest rate in the cash market and the synthetic dollar implied interest rate in the swap market.

3. Combining stock market returns and cross-currency basis swaps

We combine both stock market returns and the cross-currency basis swap spreads. Subtracting (a) from (b) yields

$$\hat{R}^{US}{}_{n,t} - \hat{R}_{n,t} = \left(y_{n,t}^{US} - y_{n,t}\right) + \beta^{US}\left(R_{n,t} - y_{n,t}^{US}\right) - \beta\left(R_{n,t} - y_{n,t}\right) \qquad (e)$$

For simplicity, and without loss of generality, we assume the representative stock market index and the US stock market index have similar beta relative to the broader global stock market universe. This assumption yields, $\beta^{US} = \beta$. So, we can write $y_{n,t}^{US} - y_{n,t}$ from (e) as

$$y_{n,t}^{US} - y_{n,t} = \frac{1}{1-\beta}\left(\hat{R}^{US}{}_{n,t} - \hat{R}_{n,t}\right) \qquad (f)$$

From (f), the expression for the cross-currency basis swap spreads in (d) can be written as[4]

$$xccy_{n,t} = \frac{1}{1-\beta}\left(\hat{R}^{US}{}_{n,t} - \hat{R}_{n,t}\right) + \delta_{n,t} \qquad (g)$$

As our interest is in how the representative country' stock market index returns $\hat{R}_{n,t}$ and cross-currency basis swap spreads $xccy_{n,t}$ interrelate, we have

$$\frac{\partial xccy_{n,t}}{\partial \hat{R}_{\ n,t}} = \left(\frac{\partial \hat{R}_{\ n,t}}{\partial xccy_{n,t}}\right)^{-1} = -\frac{1}{1-\beta} > 0 \ \text{ for } \ \beta > 1 \qquad h)$$

showing that the link between the stock market performance and the cross-currency basis swap spreads is positive.

Also,

$$\frac{\partial xccy_{n,t}}{\partial\left(\hat{R}^{US}{}_{n,t} - \hat{R}_{n,t}\right)} = \left(\frac{\partial\left(\hat{R}^{US}{}_{n,t} - \hat{R}_{n,t}\right)}{\partial xccy_{n,t}}\right)^{-1} = \frac{1}{1-\beta} < 0 \ \text{ for } \ \beta > 1$$

Thus, when the US stock market rallies and returns outperform other stock markets, the cross-currency basis swap spreads of the corresponding non-USD currency tend to widen.

[4] Note that we are able to introduce (d) into (f) because even with the risk-free rate that is not as unsecured and risky as the Libor rate and is devoid of any default or credit risk, the cross-currency basis is still persistently different from zero (see Du et al. 2018). Note that Du et al. (2018) have shown that the cross-currency basis exists even in the absence of credit risk difference across countries and for actual interest rate quotes. To show this, they use repo rates which are fully collateralized and thus do not exhibit any credit risk (Kreditanstalt für Wiederaufbau) as well as KfW bond yields which are fully backed by the German government and thus exhibit very minimal credit risk. Even with these largely risk-free rates, they still find that the cross-currency basis is persistently and significantly different from zero for the G10 currencies they considered, even after taking into account transaction costs. Then, it is safe to say that even with risk-free rates, deviations from CIP are not eliminated or eroded away.

6.0 Conclusion

The negative dynamic links between credit default swaps (corporate and sovereign) and stock markets are not new in the literature. However, the dynamic interactions between sovereign credit default swaps and cross-currency basis swap markets and, most especially, between the cross-currency basis swap and stock markets have surprisingly received much less attention in the literature even though an understanding of the dynamic linkages between these asset markets across countries could be helpful in the financial markets for the purposes of cross-assets portfolio selection and management, diversification and funding activities.

Using standard impulse responses and Granger causality analysis, this study empirically investigates the dynamic interdependencies between stock, cross-currency swap and credit default swap markets for four major economies – UK, Eurozone, Japan, and Australia between 2008 and 2019. All the four economies are chosen based on data availability and, most importantly, because almost all of them, particularly the Eurozone, Japan and the UK, have the largest and most liquid cross-currency basis swaps markets. Unlike other studies, we use stock market indices, rather than individual stocks, to enable us to capture more broadly the performance of stock markets in these economies. Additionally, we focus on sovereign CDS markets as sovereign reference entities represent the most liquid segment of the CDS market.

We find evidence that stock market returns and changes in sovereign CDS spreads exhibit inverse dynamic relations wherein a positive shock to the CDS market, which raises the CDS spreads, cumulatively deteriorates stock market performance. Also, a favorable shock that raises stock market performance accumulatively lessens CDS spreads, implying a feedback mechanism in the lead-lag dynamic relations which provide evidence that, more often than not, information first manifests in equity markets before propagating to the CDS markets.

Importantly, we document some striking new results. First, the four economies analyzed suggest some consensus on the existence of some dynamic relations among the three asset markets and provide evidence for significant dynamic co-movements of the three markets in majority of the countries analyzed for the entire period. Second, we discover that a positive shock that raises stock market performance would lower CDS spreads and induce tighter CCBS spreads.

Conversely, a positive shock that tightens CCBS spreads lowers CDS spreads and improves stock market returns. Also, positive shocks that elevate CDS spreads widen CCBS spreads and decrease stock market performance. The magnitude and persistence of these feedback dynamics differ from case to case and are strongest, most persistent and statistically significant for the Eurozone and Japan. Altogether, our results reveal that, in dynamic relations, the stock market predominantly leads the CCBS and sovereign CDS markets. This suggests that information of relevance in the financial markets is first reflected in the stock markets before they propagate to these other asset markets, implying that the stock market seems to be more sensitive to news than other asset markets. Put differently, the stock market does not adjust simultaneously with the other markets in response to news or market events. It possibly adjusts first before the adjustment is propagated to other markets.

Our subsample robustness analysis suggests that the dynamics across these asset markets generally intensify during turbulent periods. Furthermore, results in the turbulent periods give rise to insights that are consistent with those for the entire period, suggesting that outcomes for the entire period largely reflect outcomes for the turbulent periods. Hence, entire period results may not exactly carry over into all sub-periods. At the same time, we once again find evidence that the stock market is influential in leading other asset markets in turbulent periods, but also post turbulence. Compared to the other asset markets, the leading role of the stock market is strongest during turbulence. In our event study focusing on the Eurozone and UK, we look at how Brexit has influenced the dynamic relations amongst asset markets. We show that most asset markets that led other asset markets prior to Brexit became insignificant post Brexit while those that had no leading influence on other asset markets prior to Brexit became more significantly influential post Brexit. Overall, our robustness analysis and event study provide insights into the intertemporal stability of dynamic linkages amidst the three asset markets. In most sub-periods, there is a robust lead-lag link from the stock market to other asset markets. There is evidence that the stock market is influential and significantly leads the CDS and CCBS market during the crisis and post turbulence to some extent. The leading role of stock market in comparison to both other markets is most visible in the turbulent periods.

Our results provide some fresh perspective on debates around the role that asset markets play in the diffusion of shocks to other asset markets within economies. For example, our findings would imply that, among other factors, the stock market also played a role in the significant deviations from covered interest parity observed over time and especially during the crisis. As our results suggest, more often than not, there is evidence that bearish stock market performance in the economies studied precedes wider cross-currency basis swap spreads because the stock market performance leads changes in cross-currency basis swap markets. Massively deteriorating stock market performance, especially in the Eurozone and Japan which recorded the highest declines in stock performance during turbulence among the four economies, led to heightened risk sentiment and all sorts of uncertainty which contributed to limited access to dollar funding liquidity for institutions associated with these economies. Such significantly reduced access to dollar funding liquidity reflected in the inflated Libor – OIS spreads, led to a surge in currency swap deals. This increased the demand for synthetic dollars (and supply of other currencies) in the swap market which raised the implied dollar cost of synthetic dollars, culminating in wider bases of the currencies associated with these economies.

Taking everything into consideration, our results illustrate the importance of knowing the interconnectedness of asset markets over time, particularly in working out the asset market from which financial shocks propagate to other asset markets. Although our analysis captures the intertemporal dynamics among the three markets, we are constrained by a lack of data for a significant period for other developed and emerging market economies. Therefore, two areas for further research are suggested in the study. First, on the back of data availability, is to extend our analysis to study the dynamics of the asset markets in the broader developed economies and emerging market economies, both in a country-specific setting as has been done in this paper and using more generic panel approaches. Second, which is more theoretical, would be to build more formal, extensive and rigorous models that theoretically explain the dynamics of the three asset markets jointly.

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Appendix

Fig 9: One-year rolling correlations of stock market returns and changes in the CDS and CCBS spreads

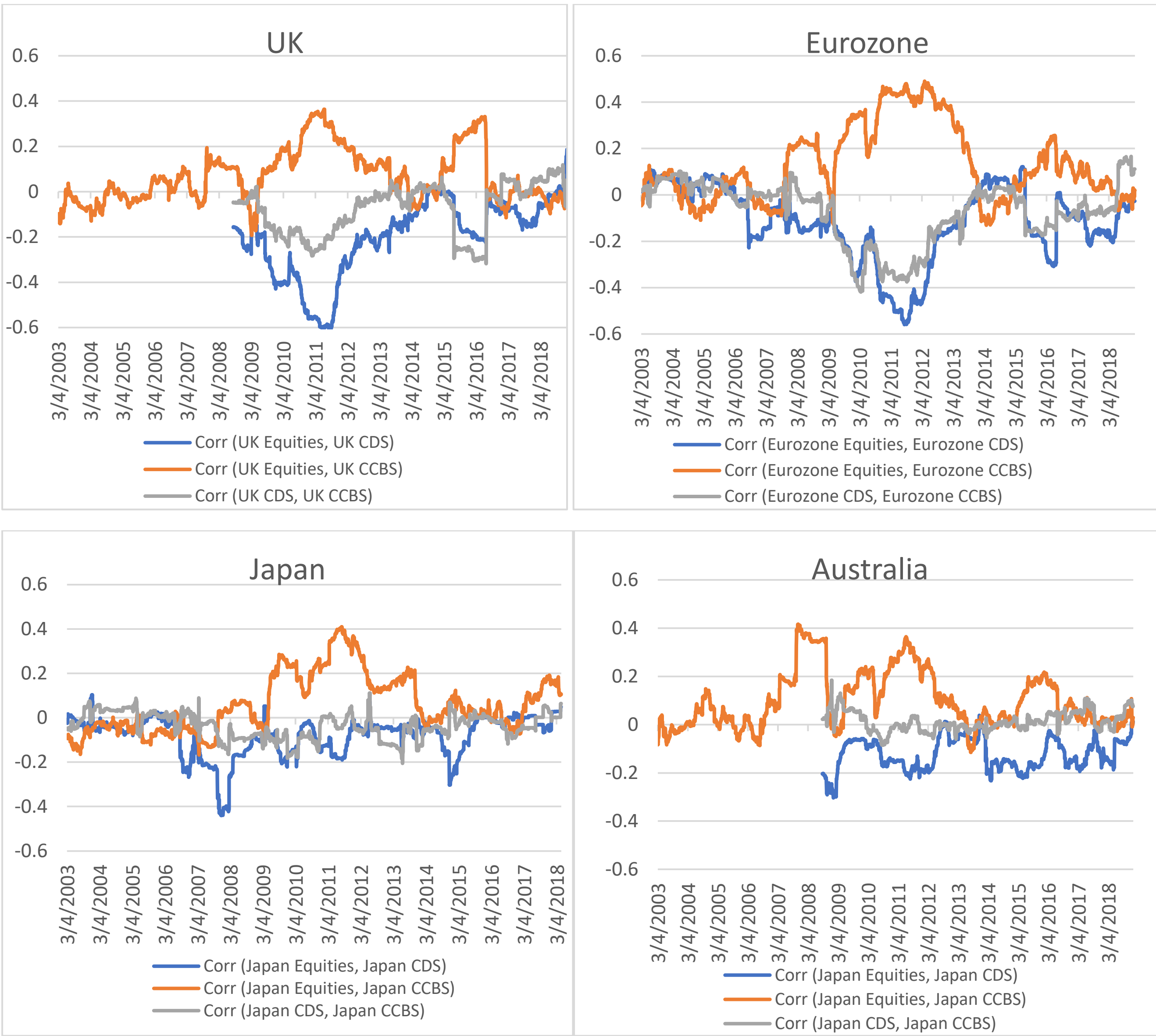


Fig 10: Accumulated impulse responses to 1 standard deviation shock for the whole sample period (2008 – 2019)

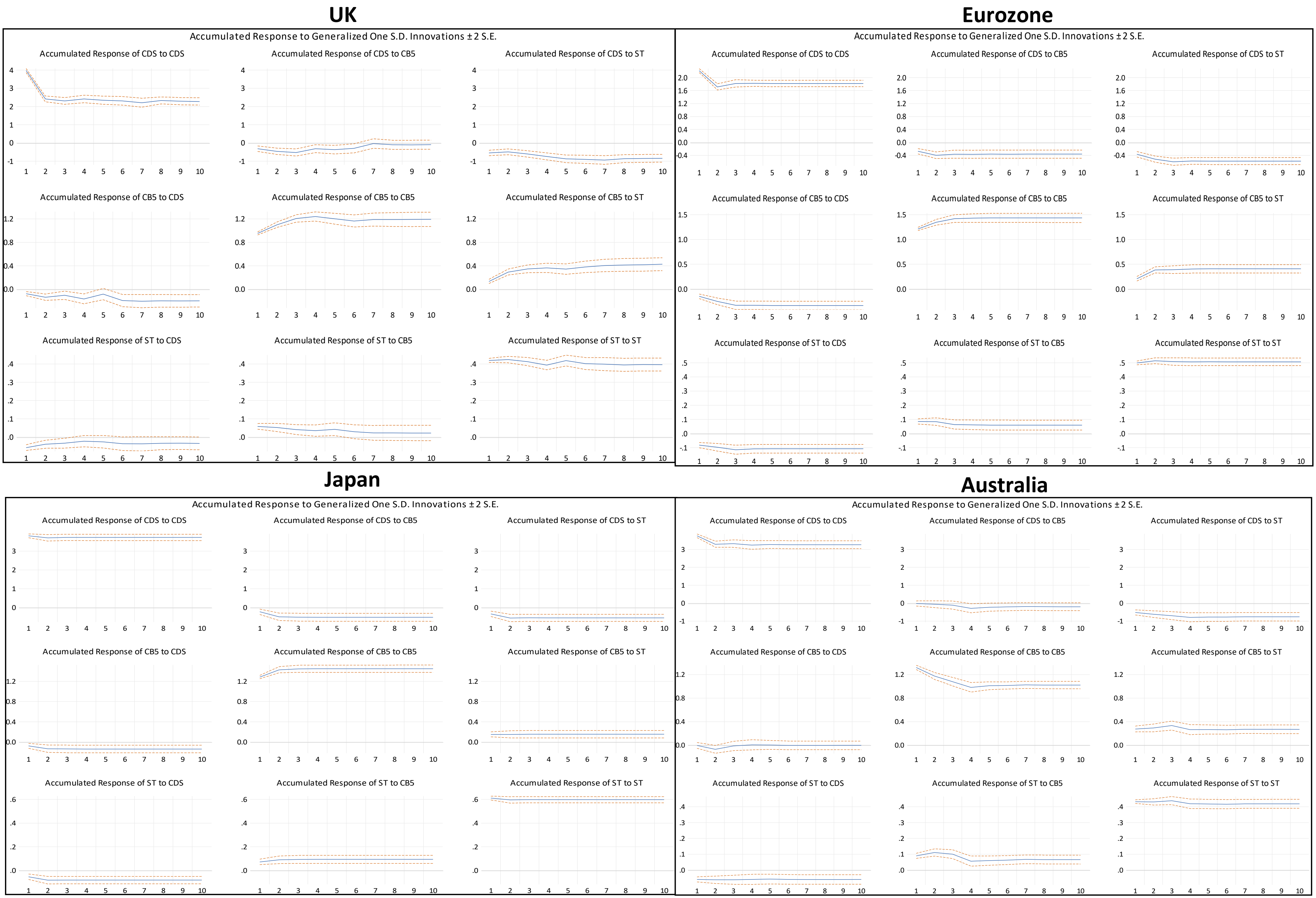
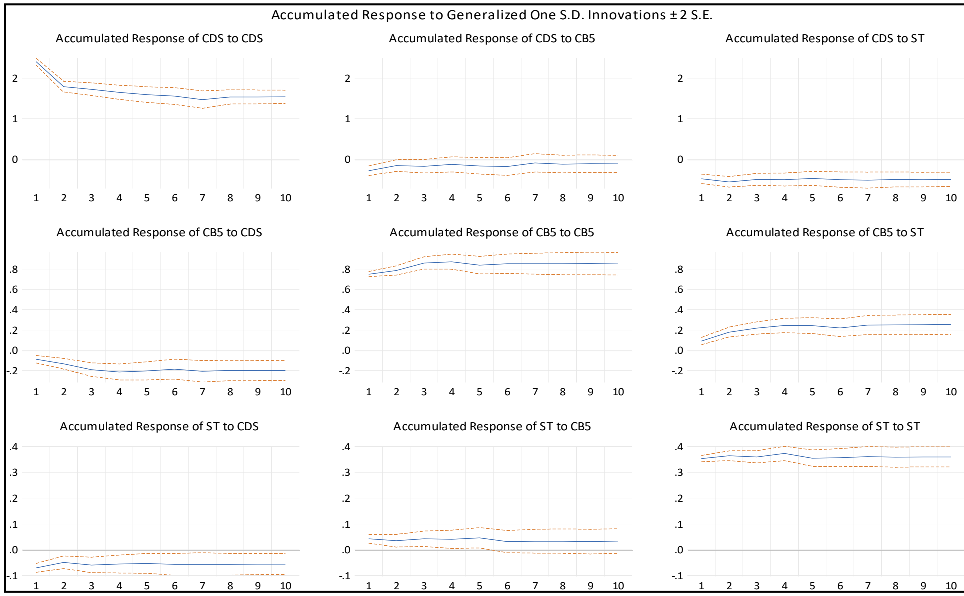
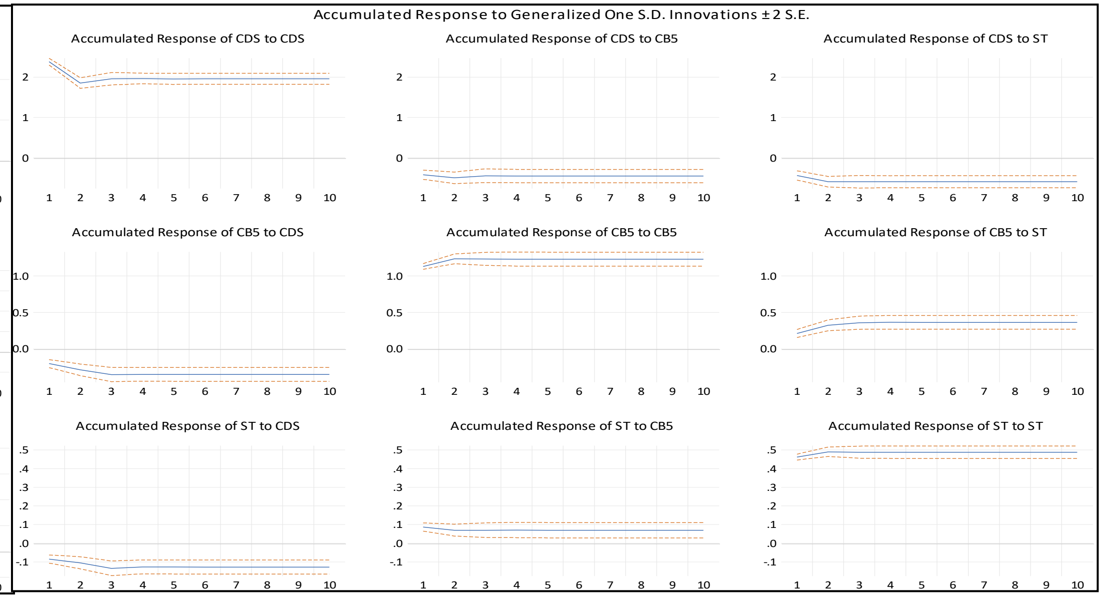


Fig. 11: Accumulated impulse responses to 1 std dev shock for Brexit Event study – Before Brexit (2008 – June 22, 2016) and Post Brexit (June 23, 2016 - 2019)

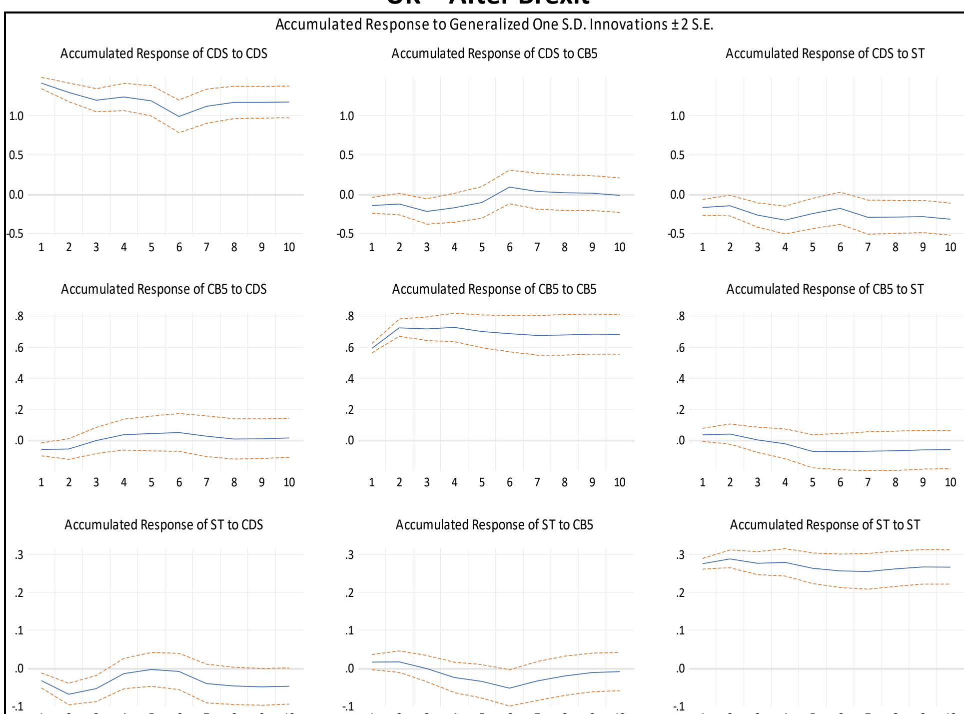
UK – Before Brexit



Eurozone – Before Brexit



UK – After Brexit



Eurozone – After Brexit

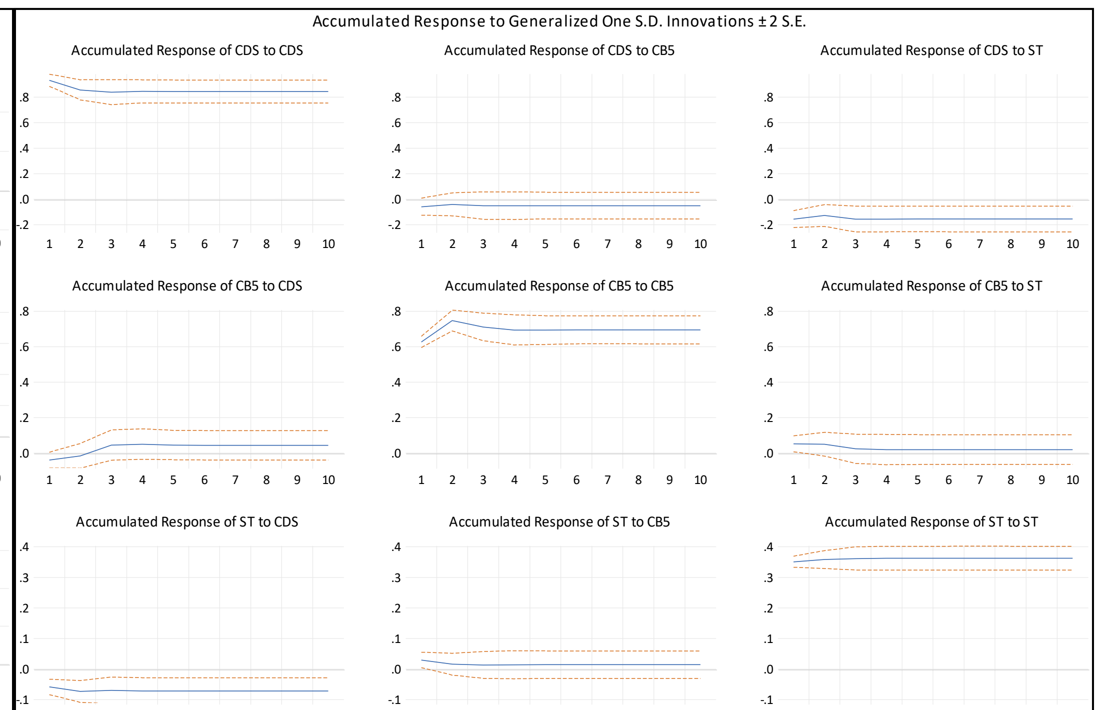
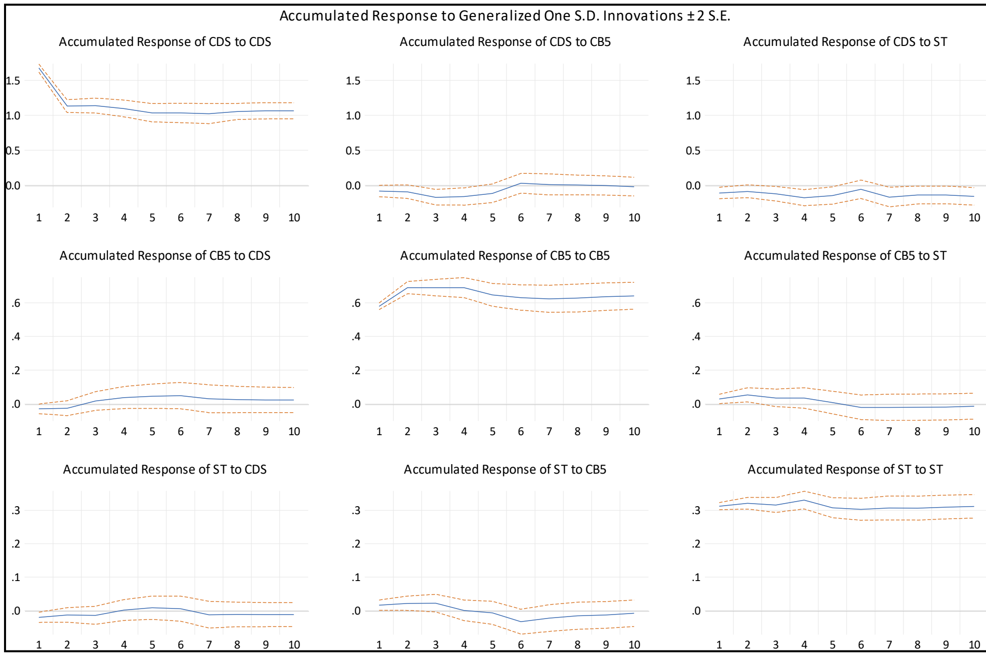
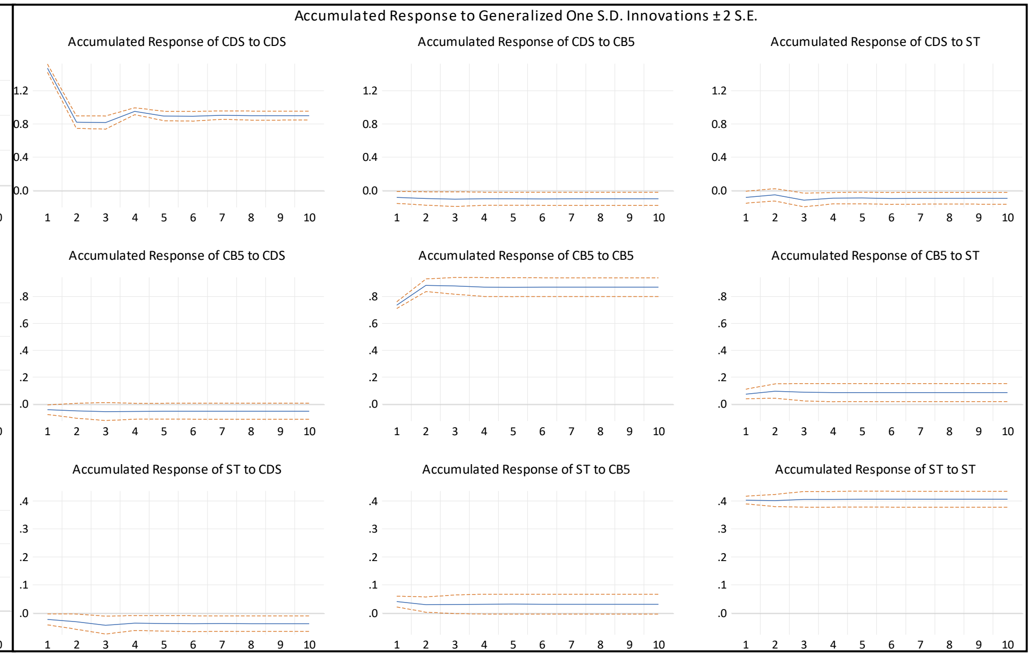


Fig 12: Accumulated impulse responses to 1 std dev shock for post crisis (post GFC and eurozone crises) subsamples

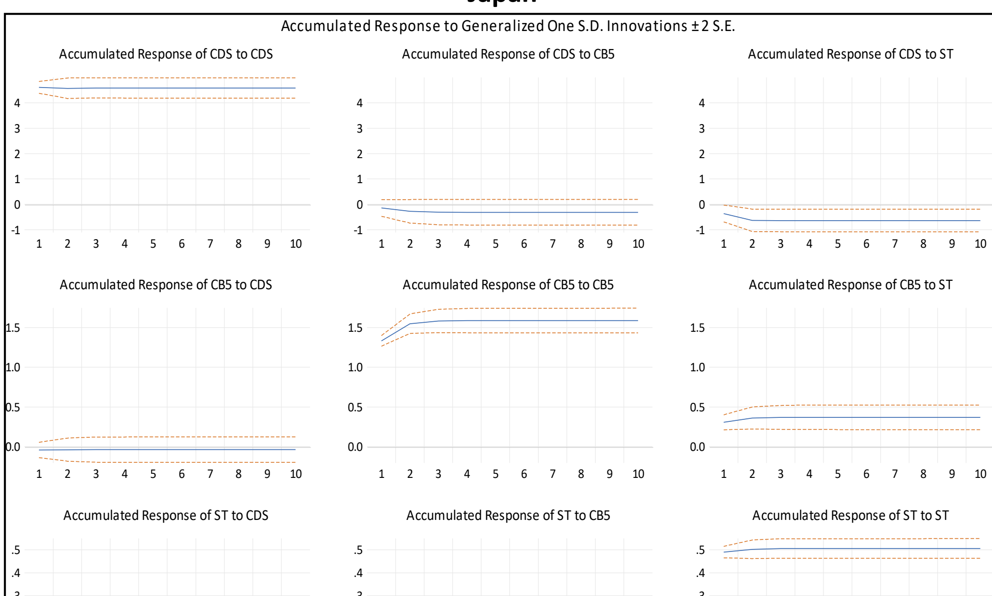
UK



Eurozone



Japan



Australia

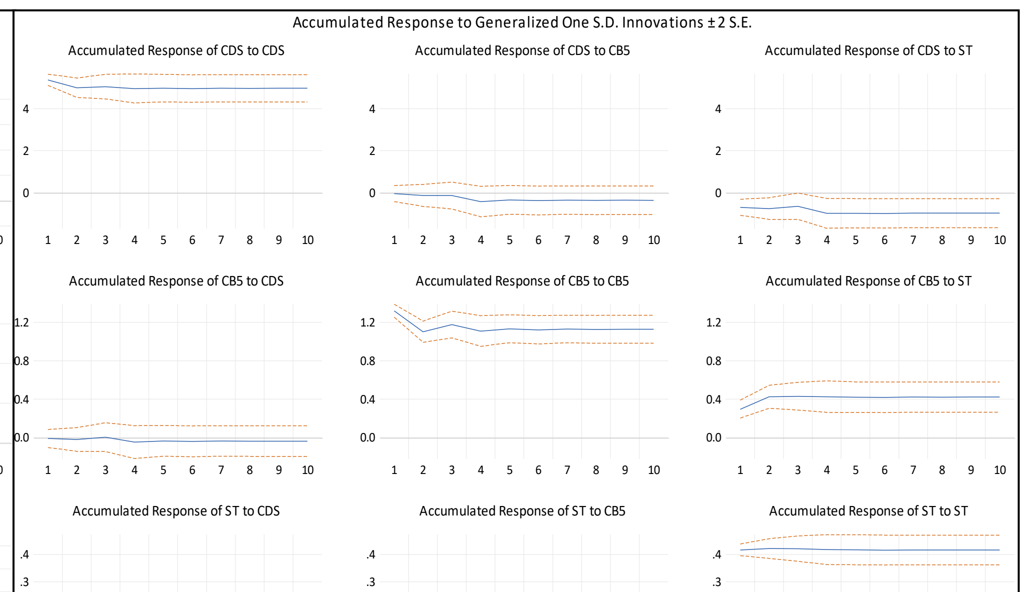


Fig. 13: Accumulated impulse responses to 1 std dev shock during the Eurozone crisis (2010 – 2012)

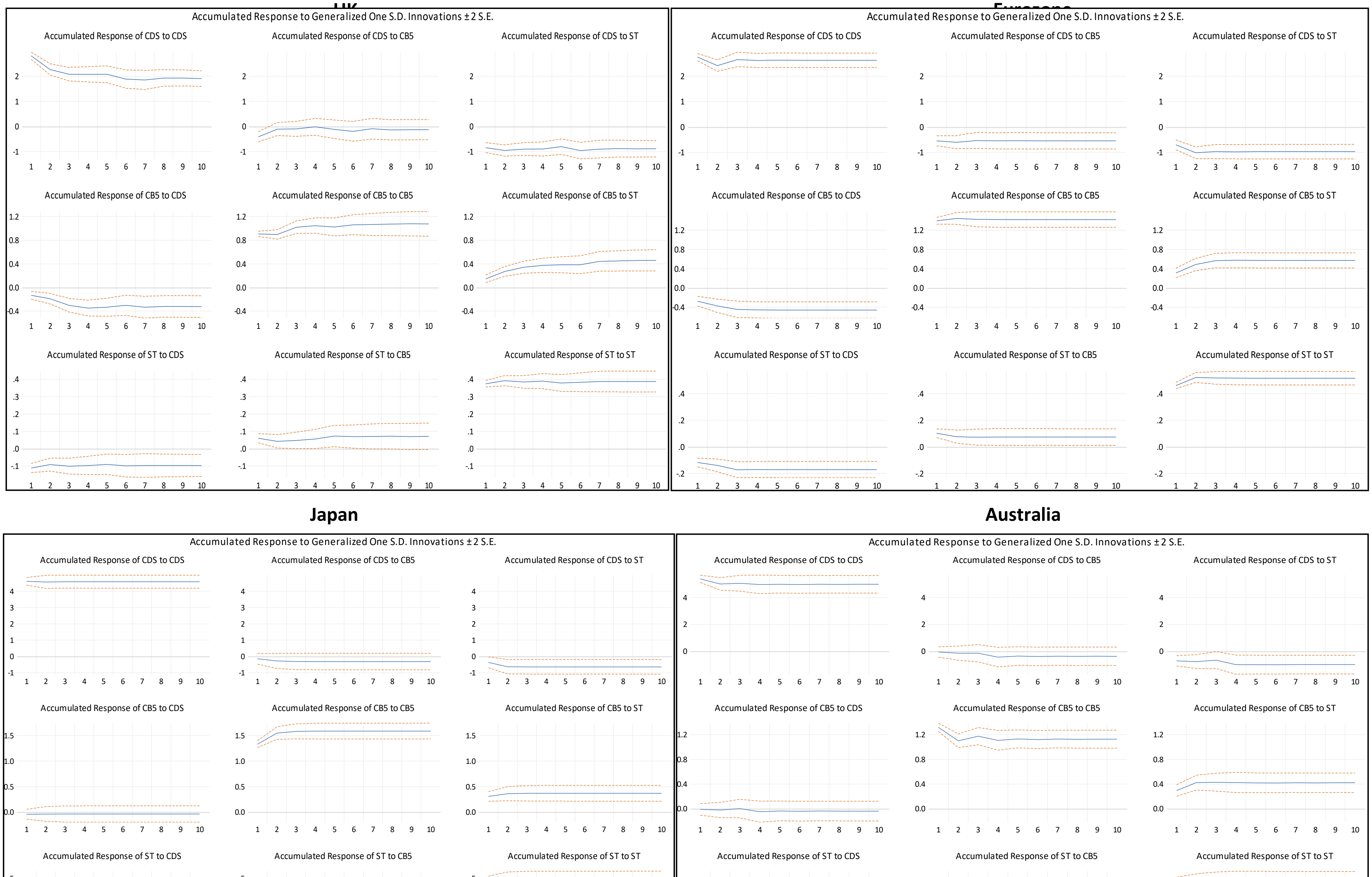
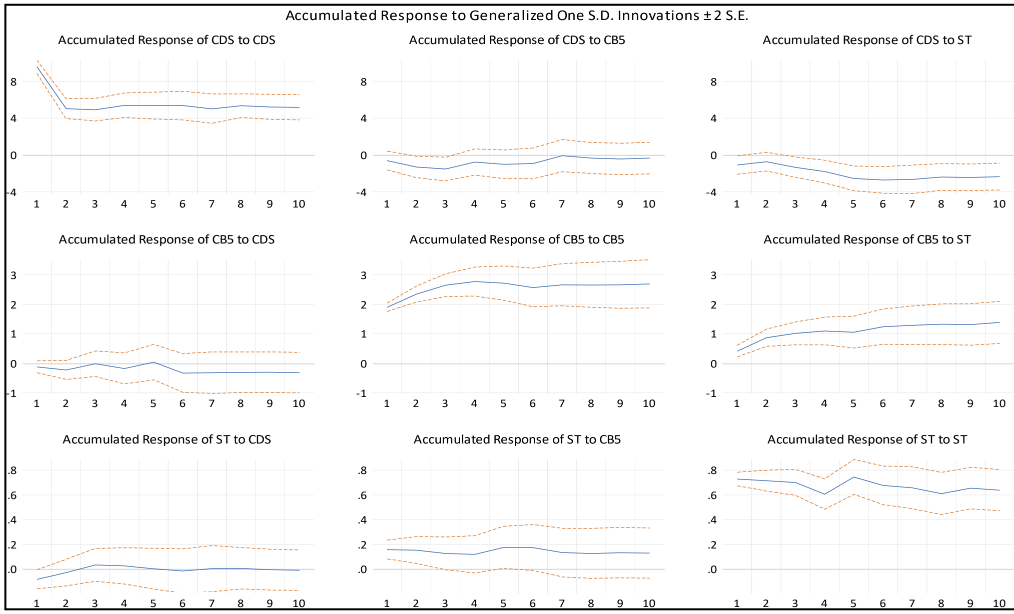
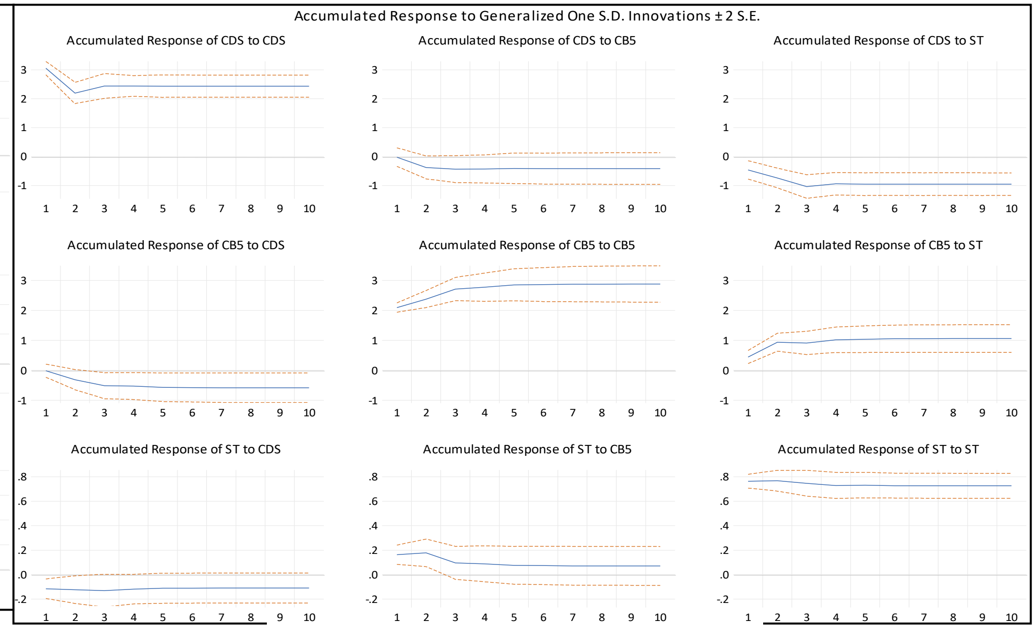


Fig. 14: Accumulated impulse responses to 1 std dev shock at the height of Global financial crisis (2008 – 2009

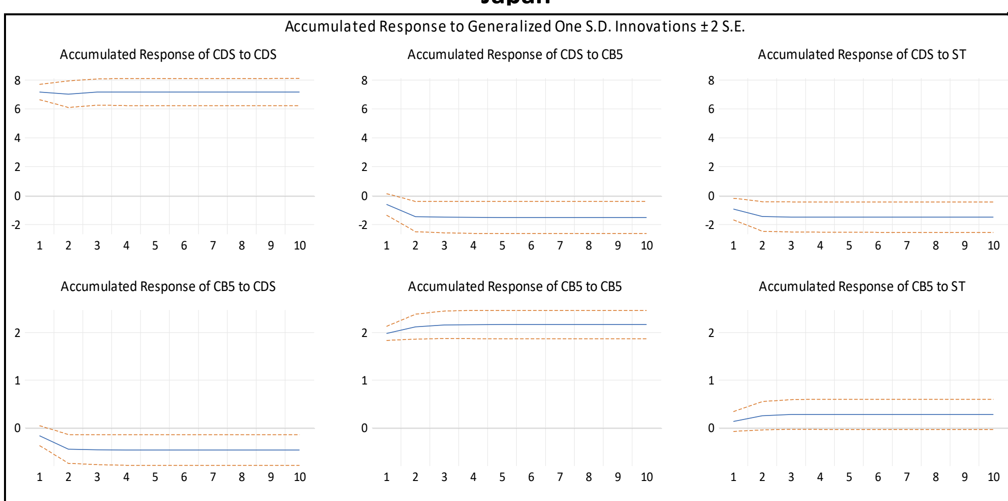
UK



Eurozone



Japan



Australia