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Corporate bond market interdependence: Credit spread correlation between and within U.S. and Canadian corporate bond markets

par

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Préambule

La gestion financière responsable vise la maximisation de la richesse relative au risque dans le respect du bien commun des diverses parties prenantes, actuelles et futures, tant de l'entreprise que de l'économie en général. Bien que ce concept ne soit pas en contradiction avec la définition de la théorie financière moderne, les applications qui en découlent exigent un comportement à la fois financièrement et socialement responsable. La gestion responsable des risques financiers, le cadre réglementaire et les mécanismes de saine gouvernance doivent pallier aux lacunes d'un système parfois trop permissif et naïf à l'égard des actions des intervenants de la libre entreprise.

Or, certaines pratiques de l'industrie de la finance et de dirigeants d'entreprises ont été sévèrement critiquées depuis le début des années 2000. De la bulle technologique (2000) jusqu'à la mise en lumière de crimes financiers [Enron (2001) et Worldcom (2002)], en passant par la mauvaise évaluation des titres toxiques lors de la crise des subprimes (2007), la fragilité du secteur financier américain (2008) et le lourd endettement de certains pays souverains, la dernière décennie a été marquée par plusieurs événements qui font ressortir plusieurs éléments inadéquats de la gestion financière. Une gestion de risque plus responsable, une meilleure compréhension des comportements des gestionnaires, des modèles d'évaluation plus performants et complets intégrant des critères extra-financiers, l'établissement d'un cadre réglementaire axé sur la pérennité du bien commun d'une société constituent autant de pistes de solution auxquels doivent s'intéresser tant les académiciens que les professionnels de l'industrie. C'est en mettant à contribution tant le savoir scientifique et pratique que nous pourrons faire passer la finance responsable d'un positionnement en périphérie de la finance fondamentale à une place plus centrale. Le développement des connaissances en finance responsable est au cœur de la mission et des intérêts de recherche des membres du Groupe de Recherche en Finance Appliquée (GReFA) de l'Université de Sherbrooke.

Cette étude analyse les liens statistiques de dépendance entre le risque de crédit des titres obligataires américains et canadiens au cours des années 2000. Nos résultats montrent que les titres canadiens et américains sont peu dépendants en temps normal, mais qu'ils deviennent significativement plus dépendants durant la crise de 2007-2009. Alors que la crise a eu pour effet d'augmenter significativement les liens de dépendance entre les titres américains, selon les secteurs et les classes de risque, les liens de dépendance des titres canadiens sont demeurés remarquablement stables temporellement. Nos résultats montrent aussi que l'augmentation de la dépendance entre les marchés américains persiste même après la période de crise de 2007-2009. Nos résultats suggèrent donc que la crise a moins influencé les marchés canadiens qu'américains, et que ces derniers offrent depuis une diversification moins efficace pour les investisseurs.

CORPORATE BOND MARKET INTERDEPENDENCE: CREDIT SPREAD CORRELATION BETWEEN AND WITHIN U.S. AND CANADIAN CORPORATE BOND MARKETS

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Abstract

This study investigates the correlation and interdependence between and within the U.S. and Canadian corporate bond markets. The empirical framework adopted allows credit spreads to depend on common systematic risk factors derived from structural models and incorporates dynamic conditional correlations (DCC) between spreads. Results show that there is a surprisingly weak correlation between the two markets in normal times. However, during crises, there is a sudden and strong increase in the correlation between U.S. and Canadian credit spreads. The analysis of credit spread correlation within each market also shows an unusual increase in credit spread correlations between sectors and between risk classes in the U.S. during the 2007-2009 global financial crisis. This increase persists over the post-crisis period. By contrast, in Canada, credit spread correlations between sectors remain remarkably stable over time, suggesting an interdependence of credit spreads within the Canadian market.

Keywords: Credit risk; credit spreads; dynamic conditional correlation; interdependence of financial markets.

JEL: C32; G12; G15; G32; G33.

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1. Introduction

This study investigates credit spread[1] correlation and interdependence between and within U.S. and Canadian corporate bond markets, where interdependence is defined as a strong and stable correlation over time between the two markets in all states of the world (i.e. in normal times and during periods of shocks and post-shocks) (Forbes and Rigobon, 2002). The issue of correlation is of central importance in credit risk assessment. Correlations between asset classes or between markets are crucial inputs for portfolio and risk management and are an essential tool in portfolio and asset allocation decisions. Moreover, any unusual changes in credit spread correlation has a significant influence on the pricing and hedging of credit derivatives. These changes can lead to substantial and sudden losses and can even jeopardize the stability of the financial system.

The behavior of credit spread correlations in the U.S. and Canada is particularly interesting because the Canadian corporate bond market is closely linked to its U.S. counterpart (Mittoo and Zhang, 2010). Canadian investors and firms rely heavily on the U.S. bond market and, since 1993, about 48% of public Canadian debt has been issued in the U.S. Moreover, since the elimination of the Foreign Property Rule early in 2005, Maple Bonds, defined as Canadian-dollar-denominated bonds issued by foreign borrowers (mainly from the U.S.) in the domestic Canadian market, has shown particularly rapid growth. This development, combined with the geographical proximity and economic ties between the two countries, may have heightened the interdependence between financial markets and, more specifically, between corporate bond markets. Lastly, by contrast to the U.S., very few studies examine the Canadian corporate bond market because of its small

[1] Credit spreads are generally regarded as proxies for both changes in the probability of future default and in recovery rates (e.g. Collin-Dufresne et al., 2001).

size[2], its lower liquidity[3] and the fact that it consists primarily of high-quality bonds[4]. However, the Canadian corporate bond market has become more active in recent years.[5] This increased level of activity has been accompanied by the development of new products and can lead to higher credit risk, especially during financial crises, because of the assumed close link between the Canadian and U.S. corporate bond markets.

The literature on transmission processes between financial markets has investigated two correlation mechanisms: cyclical correlation and direct or event correlation. Cyclical correlation stands for a state of 'continuous', 'normal-period' relation between markets. Kallberg and Pasquariello (2008) and Baele and Inghelbrecht (2010) assume that cyclical correlations are due to fundamentals. On the corporate bond market, cyclical correlation refers to credit spread correlation across obligors due to systematic common factors (see, for e.g., Giesecke, 2004). A number of studies have investigated the relationship between credit spreads and the business cycle and find that credit spreads are strongly related to general macro-economic factors such as the level of default-free interest rates (see, for e.g., Duffee, 1998 or Longstaff and Schwartz, 1995). Due to their joint dependence on varying common variables, credit spreads across firms are smoothly correlated through time. In contrast, direct or event correlation is characterized by strong and sudden changes in measured market linkages. On the corporate bond market, direct or event correlation refers to how a firm's credit spread is affected by the credit quality of other firms. As emphasized by Giesecke (2004)**,** the sudden large changes in spreads across several issuers are not independent from one another. For example, a sudden spread change in one issue, possibly due to a rating downgrade, a news announcement, or a default, can lead to a simultaneous

[2] Anderson, Parker, and Spence (2003) argue that the small issue size is a product of the small number of Canadian institutional managers and the smaller average size of assets under management. Further, the smaller asset size, combined with the regulatory constraints on a single-name exposure, limit the size of corporate bond issues that can be placed on the Canadian market at any one time.

[3] Mittoo and Zhang (2010) show that the Canadian bond market is less liquid than the U.S. market because most Canadian investors follow a buy-and-hold investment strategy. The secondary market trading of corporate bonds is thin for all corporate bonds.

[4] The Canadian high-yield bond market is still in its infancy and only accounts for about 3% of the annual corporate debt issuance in Canada.

[5] The Canadian bond market grew rapidly in the 1990s. At the end of 2012, the outstanding amount of Canadian domestic corporate debt securities was US$200 billion, up from US$48 billion in 1990 [Bank for International Settlements, Securities statistics and syndicated loans, Table 16B (http://www.bis.org/statistics/secstats.htm)].

market-wide response in spreads. Direct correlation is therefore a potential source of contagion. A recent example would be the default of Lehman Brothers and the associated immediate spread widening on debt in the U.S. and around the world. One explanation for this type of correlation is the existence of close direct ties between firms which are, generally, of legal (e.g. parent–subsidiary), financial (e.g. trade credit), or business nature (e.g. buyer–supplier). In this paper, we provide a credit spread correlation model that takes into account the two correlation mechanisms and in which we emphasize the direct ties between firms' credit spreads.

In the credit risk literature, there are two main approaches to describe credit spread correlations: the intensity-based approach[6] and the structural approach[7]. Unlike intensity-based models, structural models provide an intuitive framework for identifying the state variables, which are the theoretical determinants of credit spread changes, and offer a prediction for whether changes in these state variables are positively or negatively correlated with changes in credit spreads. For example, Collin-Dufresne et al. (2001) identify at least four theoretical determinants of credit spreads changes, namely the risk-free rate, the slope of the yield curve rate, the market value of the firm's assets, and the volatility of market value of the firm's assets.

Our study focuses on the structural approach and contributes to the literature in several ways. First, our research examines credit spread correlation, which complements studies by Zhou (2001), Giesecke (2004) and Giesecke and Goldberg (2004) that focus on *default* correlations under the multi-firm structural credit model. In addition, unlike Zhou (2001), who focuses on cyclical correlation, we take, as Giesecke (2004) and Giesecke and

[6] In the intensity-based approach, correlation between credit spreads is introduced by the correlation between intensity processes (see, for e.g., Jarrow et al., 2000). This is done by allowing intensities of different firms to be driven by common variables, which reflect the observed credit spread correlation across firms as a result of the dependence on general macro-economic factors. The drawback of this approach is that event correlations cannot be captured while intensities vary smoothly. In recent papers (see, for e.g., Driessen. 2005) based on Jarrow and Yu, 2001), a stronger degree of credit spread correlation can be imposed by letting intensities experience correlated jumps. The main problem then lies in the calibration of the jump components.

[7] Structural default models are built on the original insights of Black and Scholes (1973), who demonstrate that equity and debt can be valued using contingent-claims analysis. Introduced by Merton (1974) and further investigated by, among others, Longstaff and Schwartz (1995) and Collin-Dufresne et al. (2001) structural models posit some firm value process and assume that default is triggered when firm value falls below some threshold. This default threshold is a function of the amount of debt outstanding.

Goldberg (2004), a comprehensive approach that examines both cyclical and direct correlations. Our investigation is motivated by prior research (see, for e.g., Collin-Dufresne et al., 2001; Giesecke, 2004 and Giesecke and Goldberg, 2004) that suggest that cyclical default correlation does not account for all credit risk dependence between firms, including credit spread correlation across firms which is a significant component of overall risk. Second, unlike Giesecke (2004) and Giesecke and Goldberg (2004), who introduce direct or event correlation in their model through a copula function, we estimate credit spread correlation coefficients with a dynamic conditional correlations (GARCH-DCC) model which takes into account the common systematic risk factors derived from credit risk structural models. Our choice of the GARCH-DCC approach, which is widely used in the finance literature, is especially motivated by the work of Forbes and Rigobon (2002) that shows that interdependence measured by return correlation is potentially influenced by the presence of conditional heteroskedasticity in the return series. This phenomenon is well taken into account by the GARCH-DCC model. Additionally, due to the documented fat tail, or leptokurtic, characteristic of credit spreads (see, for e.g., Pedrosa and Roll, 1998), we use the multivariate Student-t distribution-based estimation procedure. The Student-t distribution is more consistent with financial reality than the normal distribution because it endows extreme quantiles with larger probabilities. Third, unlike previous studies (see, for e.g., Bekaert et al., 2014; Aloui et al., 2011; Baele and Inghelbrecht,2010; Caporale et al., 2005 and Forbes and Rigobon, 2002) that generally consider correlation in the context of cross-market co-movement in stock returns, we investigate both credit spread interdependence between and within the U.S. and Canadian corporate bond markets. More specifically, we examine whether strong and stable correlations exist between and within U.S. and Canadian credit spreads in normal times and during periods of shocks and post-shocks.

Our work, which is based on Bank of America (BofA) Merrill Lynch daily option-adjusted spreads for U.S and Canadian corporate bond indexes from January 2001 through January 2013, yields important empirical findings. First, for both countries, we find that credit spreads are strongly related to common default risk factors derived from structural models, such as the level and slope of the default-free term structure, the equity market returns and volatility. Due to their joint dependence on varying common variables, credit spreads across sectors or risk classes are correlated through time. Second, the analysis of direct credit spread correlation coefficients between the U.S. and Canada are very low, albeit significantly different from zero. However, a closer examination on sub-periods reveals that, with the exception of the correlation between industrial-sector credit spreads in both countries, the correlation between U.S. and Canadian credit spreads is not significant for the 2001-2007 (pre-crisis) and 2010-2013 (post-crisis) periods. Interestingly, we observe an upward trend in correlation coefficients which is particularly important over the 2007-2009 (crisis) period. Overall, our results suggest that, in normal times, both markets display greater independence, but they are more strongly correlated during a crisis. These results are consistent with a segmentation of the U.S. and Canadian markets during the pre-crisis and post-crisis periods, but support an integration of the two markets during the financial subprime crisis. Third, the analysis of credit spread correlations within each market shows that credit spreads between the financial sector and the industrial sector are highly correlated. This link, which is stronger in Canada than in the U.S., can be explained largely by a strong reliance on bank intermediation in Canada. We also note a relatively high correlation between U.S. investment- and speculative-grade credit spreads. Our analysis of three distinct sub-periods reveals an upward trend for credit spread correlations across sectors and across risk classes within the U.S., especially during the 2007-2009 financial crisis. This phenomenon persists over the post-crisis period and suggests a structural break in the time series of correlation coefficients, consistent with no interdependence between credit spreads within the U.S. corporate bond market. By contrast, in Canada, credit spread correlations across sectors remain remarkably stable over time, suggesting an interdependence of credit spreads within the Canadian market.

The remainder of the paper is organized as follows. Section 2 presents a summary of the literature on credit spread correlations. Section 3 outlines the methodological framework used for modelling credit spread correlations and for investigating the interdependence between and within U.S. and Canadian corporate bond markets. Section 4 describes the data. Section 5 presents and discusses our empirical results. Section 6 concludes the paper.

2. Related literature

The empirical literature on cyclical credit spread correlations finds that credit spreads are strongly related to common systematic risk factors derived from credit risk structural models (Cremers et al., 2008; Landschoot, 2008; Campbell and Taksler, 2003; Collin-Dufresne et al., 2001; Longstaff and Schwartz, 1995 and Duffee, 1998) and to macro-economic factors (Chan and Marsden, 2014; Pu and Zhao, 2012; Koopman et al., 2009; Hackbarth et al., 2006 and Jarrow and Turnbull, 2000). A number of studies find strong relationships between default-free interest rates and credit spreads. For example, Duffee (1998), based on monthly U.S. corporate bond data from 1985 to 1995, finds that the change in the three-month Treasury yield and the change in the slope of the term structure are negatively correlated with changes in credit spreads. Similar results are also reported by Litterman and Scheinkman (1991), Longstaff and Schwartz (1995), and recently by Landschoot (2008), which confirm that the two most important factors driving credit spreads are the changes in the level and slope of the term structure of interest rates.

The relation between stock returns and credit spreads has been widely investigated at both the individual firm level (see, for e.g., Kwan, 1996) and portfolio level (see, for e.g., Blume, Keim, and Patel, 1991). The main conclusion of these studies is that credit spreads are sensitive to stock returns. Shane (1994) uses monthly U.S. corporate bond data over the period 1982-1992 and finds that credit spreads have a significant negative correlation with the returns on an equity index. Similarly, Collin-Dufresne et al. (2001), Campbell and Taksler (2003), and Cremers et al. (2008) also show that yield spread changes are significantly negatively related to stock market returns. However, credit spreads seem to be an increasing function of equity volatility. For example, Collin-Dufresne et al. (2001), and Campbell and Taksler (2003) find that increases in implied volatility dramatically impact credit spreads.

More recent research examines the links between credit spreads and business cycles or macroeconomic conditions (see, for e.g., Chan and Marsden, 2014; Dionne and al., 2011; Tang and Yan, 2010; Landschoot, 2008 or Jarrow and Turnbull, 2000). For instance, Jarrow and Turnbull (2000) suggest that incorporating macroeconomic variables can improve the reduced-form model for credit risk. Landschoot (2008) indicates that credit spreads behave cyclically over time; credit spreads are expected to widen during periods of economic downturn as investors become more risk-averse. In Tang and Yan (2010), the link between spreads and aggregate factors is explored further by modeling firm characteristics to directly depend on macroeconomic conditions. Finally, Dionne and al. (2011) use a model of default spreads with Markov-switching macroeconomic factors and find that macroeconomic factors are linked to sharp increases in spreads, indicating that spread variations can be related to macroeconomic undiversifiable risk. These results are confirmed by Chan and Marsden (2014) who use market variables under a Markov regime-switching model. All of these studies suggest that credit spreads are affected by common financial and/or economic factors, which generate the cyclical correlation between them.

Unlike the empirical literature on corporate credit spread correlation due to common factors in the economy (i.e. cyclical credit spread correlation), relatively few empirical studies have been conducted on measuring direct correlation, particularly using corporate credit spreads (see, for e.g., Altera and Schülerb, 2012). Most studies consider interdependence in the context of cross-market correlation in stock returns (Bekaert et al., 2014; Jung and Maderitsch, 2014; Aloui et al., 2011; Samarakoon, 2011 and Baele and Inghelbrecht, 2010). For example, Jung and Maderitsch (2014) analyze the structural stability of volatility spillovers of stock markets in Hong Kong, Europe and the U.S. from 2000 through 2011. The authors use realized-volatility time series for the three markets and employ a Heterogeneous Autoregressive Distributed Lag Model and find no break in volatility spillovers, which is consistent with an interdependence between the three markets. Using two shock models to examine the transmission of shocks between the U.S. and emerging markets, Samarakoon (2011) finds similar results. Aloui and al. (2011) use a multivariate copula approach to examine the co-movement between four emerging markets (Brazil, Russia, India and China) and the U.S. during the 2007-2009 global financial crisis, and show strong evidence of the extreme interdependence between each of these markets and the U.S..

As in recent papers (see, for e.g., Pragidis et al., 2015; Kenourgios and Dimitriou, 2015 and Papavassiliou, 2014), our study uses a dynamic conditional correlation model

(GARCH-DCC model) framework proposed by Engle (2002) to investigate credit spread interdependence between and within U.S. and Canadian corporate bond markets.

3. Methodology

3.1 Credit spread correlation

In this section, we develop our framework to examine correlation between and within the U.S. and Canadian corporate bond markets. Our credit spread correlation model considers credit spreads as a function of common default risk factors derived from structural models, such as the level and the slope of the default-free term structure, the equity market returns and volatility, all of which introduce cyclical correlation in the model. Due to their joint dependence on varying common variables, credit spreads across sectors or risk classes are correlated through time. In addition, direct credit spread correlations associated with the direct linkages between corporate bonds are introduced by the DCC process, which describes the non-linear dependence structure between credit spreads. More specifically, the GARCH-DCC model framework has three components (equations) to describe credit spreads, variances and conditional correlations: a conditional mean component, a GARCH component and a DCC component. Specifically, we assume that credit spreads on the two markets are driven, on the one hand, by observable factors such as the equity market return, the equity market volatility, the risk-free rate or the slope of the yield curve, and, on the other hand, by unobservable factors related to the specificity of each market.

Let $\left(\Delta C\mathrm{S}_{\mathrm{t}}^{\mathrm{US}}, \Delta C\mathrm{S}_{\mathrm{t}}^{\mathrm{CA}}\right)'$ be a vector composed of daily changes in credit spreads for the U.S. and the Canadian markets. For instance, to examine credit spread correlation *between* the U.S. and Canadian corporate bond markets, we estimate the following model:

$$\begin{cases} \Delta CS_t^{US} = \omega_{US} + \theta_{US}\Delta CS_{t-1}^{US} + \phi_1^{US} R_{m,t-1}^{US} + \phi_2^{US}\Delta\sigma_t^{US} + \phi_3^{US}\Delta r_t^{US} + \phi_4^{US}\Delta Slop_t^{US} + \phi_5^{US} R_{m,t-1}^{CA} + \phi_6^{US}\Delta\sigma_t^{CA} + \phi_7^{US}\Delta r_t^{CA} + \phi_8^{US}\Delta Slop_t^{CA} + \varepsilon_t^{US} \\ \Delta CS_t^{CA} = \omega_{CA} + \theta_{CA}\Delta CS_{t-1}^{CA} + \phi_1^{CA} R_{m,t-1}^{CA} + \phi_2^{CA}\Delta\sigma_t^{CA} + \phi_3^{CA}\Delta r_t^{CA} + \phi_4^{CA}\Delta Slop_t^{CA} + \phi_5^{CA} R_{m,t-1}^{US} + \phi_6^{CA}\Delta\sigma_t^{US} + \phi_7^{CA}\Delta r_t^{US} + \phi_8^{CA}\Delta Slop_t^{US} + \varepsilon_t^{CA} \end{cases} \quad (1)$$

where $R_{\mathrm{m,t}}^{\mathrm{i}}, \Delta\sigma_{\mathrm{t}}^{\mathrm{i}}, \Delta r_{\mathrm{t}}^{\mathrm{i}}, \Delta Slop_{\mathrm{t}}^{\mathrm{i}}, \text{with } \mathrm{i} \in \{\mathrm{US, CA}\}$ denote, respectively for the U.S. and Canadian markets, the equity market returns, the equity market volatility, the risk-free rate and the slope of the yield curve. While some variables are included directly, others are variations (Δ) between *t*-1 and *t*. As recommended by Kwan (1996), we use lagged equity market returns. Moreover, we assume that credit spread variations follow a multivariate

Student-t (υ) joint distribution with a time-dependent conditional variance-covariance matrix H_t:

$$\begin{pmatrix} \varepsilon_t^{US} \\ \varepsilon_t^{CA} \end{pmatrix} \sim \upsilon \text{ and } \mathrm{H_t} = \begin{pmatrix} \mathrm{h_t^{US}} & \mathrm{h_t^{USCA}} \\ \mathrm{h_t^{CAUS}} & \mathrm{h_t^{CA}} \end{pmatrix}$$

The conditional variance-covariance matrix (H_t) can be written as a product of matrices:

$$H_t \equiv D_t R_t D_t$$

where $D_t = diag\left\{\sqrt{h_t^{US}}, \sqrt{h_t^{CA}}\right\}$ is a diagonal matrix of time-varying standard deviations generated from the estimation of univariate GARCH (1,1) processes:

$$h_t^i = \mathrm{s_i} + \alpha_i (\varepsilon_{t-1}^i)^2 + \beta_i h_{t-1}^i \text{ with } \mathrm{i} \in \{\mathrm{US, CA}\} \tag{2}$$

R_t is the conditional correlation matrix of the standardized disturbances ε_t, with:

$$\mathrm{R_t} = \begin{pmatrix} 1 & \mathrm{q_{USCA}}_t \\ \mathrm{q_{CAUS}}_t & 1 \end{pmatrix}$$

Matrix $\mathrm{R_t}$ is decomposed into a product of matrices:

$$R_t \equiv Q_t^{*-1} Q_t Q_t^{*-1} \tag{3}$$

with $Q_t = (1 - \lambda_1 - \lambda_2)\overline{Q} + \lambda_1 \tilde{\varepsilon}_{t-1} \tilde{\varepsilon}'_{t-1} + \lambda_2 Q_{t-1}$, and where Q_t is the positive definite matrix containing the conditional variances-covariances for ε_t, and Q_t^{*-1} is the inverted diagonal matrix with the square root of the diagonal elements of Q_t:

$$Q_t^{*-1} = \begin{pmatrix} 1/\sqrt{\mathrm{q_{USUS}}_t} & 0 \\ 0 & 1/\sqrt{\mathrm{q_{CACA}}} \end{pmatrix}$$

λ_1 and λ_2 are parameters that govern the dynamics of conditional correlations. They are nonnegative and satisfy the following constraint: $0 \leq \lambda_1 + \lambda_2 < 1$. Essentially, equation (3) relies on an autoregressive moving average type process to capture short-term deviations in the correlation around its long-run (unconditional) level. Finally, the dynamic conditional correlations (the key element of interest in R_t) are given by the following equation:

$$\rho_{USCA,t} = \frac{q_{USCA,t}}{\sqrt{q_{USUS,t}\, q_{CACA,t}}} \quad (4)$$

We test whether conditional correlations are constant using the Wald test, where the null hypothesis, H_0, is defined as $\lambda_1 = \lambda_2 = 0 \Rightarrow Q_t = \overline{Q}$. Under H_0, the test statistic follows a Chi2 distribution with two degrees of freedom.

Overall, we examine *between* correlations for the following three credit spread pairs: i) U.S. financial sector vs Canadian financial sector, ii) U.S. industrial sector vs Canadian industrial sector, and iii) U.S. investment-grade vs Canadian investment-grade.

We also investigate credit spread correlations *within* the U.S. and Canadian corporate bond markets. These correlations are calculated between pairs of credit spreads within each market. Specifically, we examine *within* correlations for the following three credit spread pairs (1, 2): i) U.S. financial sector vs U.S. industrial sector, ii) U.S. investment-grade vs U.S. speculative-grade, and iii) Canadian financial sector vs Canadian industrial sector. In a more general setting, for both between- and within- analyses, we use the (1, 2) pairwise notation in our result tables.

3.2 Credit spread interdependence

There is disagreement in the literature regarding the interdependence of markets (see, for e.g., Jung and Maderitsch, 2014; Samarakoon, 2011; Baele and Inghelbrecht, 2010; Corsetti et al., 2005 or Rigobon, 2002). We follow the narrow approach of Forbes and Rigobon (2002), according to which interdependence is defined as a structural stability of the correlation coefficient in all states of the world. According to the authors, if there is no significant increase in the co-movement between two markets following a shock, it suggests that there is a strong and stable linkage between the two markets in all states of the world. In other words, interdependence is defined as the absence of a structural break in the time series of correlation coefficients. As highlighted by Forbes and Rigobon (2002), although this definition of interdependence is restrictive, it has the advantage of providing a straightforward framework to test if interdependence occurs. Specifically, we can compare linkages between two markets (such as cross-market correlation coefficients) during a relatively stable period (generally measured as a historic average) with linkages during the shock (crisis) and post-shock periods.

To examine the interdependence of credit spreads between and within the U.S. and Canadian corporate bond markets, we therefore estimate between-correlations before, during and after the subprime financial crisis.[8] To do so, we divide our sample into three sub-periods based on the NBER's defined contraction period: 1) December 2001 to November 2007 (pre-crisis), 2) December 2007 to June 2009 (subprime financial crisis), and 3) July 2009 to January 2013 (post-crisis). We then estimate our regression model (GARCH-DCC) for the three sub-periods. This split allows us to examine directly, via the evolution of DCC coefficients, whether cross-market linkages during the subprime crisis differ from those during the other two periods (i.e. if there are structural breaks).

If there is interdependence, the means of DCC coefficients between credit spreads before ($\hat{\rho}_{12,1}$), during ($\hat{\rho}_{12,2}$) and after ($\hat{\rho}_{12,3}$) the financial crisis should be equal. The condition for a structural stability of the correlation coefficients, following Forbes and Rigobon (2002), is therefore that $\hat{\rho}_{12,1} = \hat{\rho}_{12,2} = \hat{\rho}_{12,3}$. More specifically, our interdependence test is a t-test with unequal variances in which correlation coefficients are conditional on credit spread volatility. As shown by several empirical studies (see, for e.g., Forbes and Rigobon, 2002; Corsetti et al., 2005; Samarakoon, 2011 and Jung and Maderitsch, 2014), estimates of correlation coefficients tend to increase and be biased upward during crises when markets are more volatile. Tests for interdependence based on cross-market correlation coefficients can then be biased and inaccurate due to heteroskedasticity. To avoid this bias, we test the stability of correlation coefficients before, during, and after the subprime crisis with two distinct t-tests, described below.

The first test tests the null hypothesis (H_0) that the means of credit spread correlations (estimated with DCC) *before* (pre-crisis) and *during* the financial subprime crisis period do not differ significantly from one another:

$$\begin{cases} H_0 : \hat{\rho}_{12,1} = \hat{\rho}_{12,2} \\ H_a : \hat{\rho}_{12,1} \neq \hat{\rho}_{12,2} \end{cases}$$

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8 The period covered by our study is marked by two financial crises that resulted in contractions of activities, as identified by the NBER: i) March 2001 to November 2001 (bursting of the technological bubble) and ii) December 2007 to June 2009 (subprime financial crisis). However, because our interdependence test requires a pre-crisis period, we have to remove the technological bubble crisis sub-period.

The second test tests the null hypothesis (H'$_0$) that the means of credit spread correlations (estimated with DCC) *during* and *after* (post-crisis) the financial subprime crisis do not differ significantly from one another:

$$\begin{cases} H'_0 : \hat{\rho}_{12,2} = \hat{\rho}_{12,3} \\ H'_a : \hat{\rho}_{12,2} \neq \hat{\rho}_{12,3} \end{cases}$$

Interdependence is observed if there is a stable credit spread correlation before, during and after the financial subprime crisis.

4. Data

We use BofA Merrill Lynch daily option-adjusted spread (OAS) for corporate bond indexes from January 2001 through January 2013 (3,010 observations). BofA Merrill Lynch has two main indexes: the BofA Merrill Lynch Investment-Grade corporate bond index and the BofA Merrill Lynch High-Yield corporate bond index. The first index tracks the performance of corporate issuers' public debt for three business sectors: financial, industrial and utilities. However, for both countries, utilities issue much less bonds than financial and industrial firms and we therefore focus on the financial and industrial sectors.[9,10] Our final data set consists of seven indices for the U.S. and Canadian bond markets: i) the BofA Merrill Lynch US Investment-Grade Corporate Index, ii) the BofA Merrill Lynch US Financial Corporate Index, iii) the BofA Merrill Lynch US Industrial Corporate Index, iv) the BofA Merrill Lynch US High-Yield Bond Index, v) the BofA Merrill Lynch Canada Investment-Grade Corporate Index, vi) the BofA Merrill Lynch Canada Financial Corporate Index, and vii) the BofA Merrill Lynch Canada Industrial Corporate Index.[11]

To describe the dependence of credit spreads on the state of the economy (i.e. cyclical correlation), we focus on systematic risk factors derived from structural models. Specifically, we use market proxy variables derived from credit risk structural models, including the level and the slope of the default-free term structure, the equity market return

[9] BofA Merrill Lynch high-yield corporate bonds index does not include the sector composition indexes.
[10] Although the index for utilities is computed, its liquidity is very low for the Canadian market.
[11] Since the Canadian high-yield bond market is illiquid and only accounts for about 3% of the annual corporate debt issuance in Canada, we choose not to investigate Canadian high-yield corporate bonds.

and its volatility. These market variables are the daily return for the S&P500 (U.S.) or S&P-TSX (Canada) index, the implied volatility for the VIX (U.S.) or the VIXC (Canada), the 3-month U.S. or Canadian T-bill rate and the slope of the U.S. or Canadian yield curve, which is estimated by the spread between the 10-year government benchmark bond and the 3-month Treasury bill rate. Table I describes and summarizes the predicted sign of the correlation between changes in credit spreads and changes in the state variables, while table II presents the correlation matrix of the state variables.

[Insert Tables I and II here]

5. Empirical results and discussion

5.1. Descriptive statistics and stylized facts

Following several previous studies (see, for e.g., Landschoot, 2008; Collin-Dufresne et al., 2001; Longstaff and Schwartz, 1995 and Duffee, 1998, we use credit spread changes (as opposed to levels).[12] To assess the distributional characteristics and stochastic properties of credit spreads, we first examine descriptive statistics, as reported in Table III. Statistics show that all the data series of credit spread changes are positively skewed and exhibit excess kurtosis, which indicates that spread changes are not normally distributed. The Jarque-Bera statistics are highly significant for all credit spread series and confirm that the assumption of normality is not supported. This confirms our choice of a fat-tailed distribution in the specification of the model. Furthermore, the ARCH LM tests are highly significant, which indicates the presence of ARCH effects in all the series. Our choice of a GARCH-DCC approach with a Student-t (fat-tailed distribution) therefore is in line with the stylized facts observed from the credit spread changes.

[Insert Table III here]

5.2 General estimation results

Results compiled in Panel A of Tables IV, V, VI and VII, for both the U.S. and Canada, show that credit spreads are strongly related to common default risk factors derived from structural models. Due to their joint dependence on varying common variables, credit spreads across sectors or risk classes are smoothly correlated through time,

[12] This choice seems well justified. The untabulated augmented Dickey–Fuller (ADF) test shows that the existence of a unit root is strongly rejected for each series of credit spreads.

which is the cyclical credit spread correlation. Further, conditional variance parameters are for the most part significant, as observed in Panel B of Tables IV, V, VI and VII. This corroborates the presence of conditional heteroskedasticity in credit spread series, and also supports our choice for the GARCH-DCC model. Moreover, as can be seen in the results compiled in Panel C of Tables IV, V, VI and VII, the tests carried out ex post show that the fit with a Student-t distribution is excellent, as evidenced by the parameter of the joint distribution, υ, which is statistically significant and greater than 2. This result validates our assumption that υ follows a multivariate t-Student distribution and is consistent with the stylised facts observed, and thus confirms the presence of fat tails (rare events) in the distributions of credit spreads on the Canadian and U.S. markets.

[Insert Tables IV, V, VI and VII here]

Panel D of Tables IV, V, VI and VII show that the estimated conditional correlation parameters are positive and significant. This confirms that cyclical credit spread correlation models based only on observable systematic risk factors (e.g. common systematic risk factors derived from credit risk structural models) omit one significant factor of credit spread co-movement, which is a significant component of overall risk. Finally, the results for the time-invariance of DCC coefficients compiled in Panel E of Tables IV, V, VI and VII enable us to reject the null hypothesis at all conventional levels. These results indicate that the assumption of time-invariant conditional correlations is too restrictive for the data. Credit spread correlations between and within the U.S. and Canadian corporate bond markets are therefore not constant over time.

5.3 Credit spread correlation

5.3.1 Credit spread correlation between the U.S. and Canadian corporate bond markets

Results from Panel D of Table IV present credit spread correlations (DCC) between the U.S. and Canadian markets. Our results show that credit spread correlations between the U.S. and Canadian markets are relatively weak. The intensity of the relationship between the two markets is low, both for the industrial sector (DCC coefficient of 0.17) and for the financial sector (0.15). Moreover, we note that credit spread correlation between investment-grade bonds between the U.S. and Canadian markets is also weak, with a coefficient of 0.17, which is of similar magnitude than for the two sectors.

5.3.2 Credit spread correlation within the U.S. and Canadian corporate bond markets

Results in Panel D of Table V present the credit spread correlations (DCC) within the U.S. and Canadian markets. Within both countries, we observe that credit spreads between the financial and industrial sectors are strongly correlated. The correlation is stronger in Canada (DCC coefficient of 0.68) than in the U.S. (0.51) which can be explained by the relatively high reliance on bank loans by non-financial firms in the Canadian market. Furthermore, we note a relatively high correlation between investment-grade and speculative-grade credit spreads (0.48) in the U.S. In sum, these results show that credit spread correlation *within* each market is stronger than correlation *between* the two markets.

5.4 Credit spread interdependence

5.4.1 Credit spread interdependence between the U.S. and Canada

Earlier results (see Table IV) showed that credit spread correlation between U.S. and Canada is low but significantly different from zero. To investigate the interdependence between U.S. and Canadian credit spreads, we estimate DCC coefficients for three sub-periods around the subprime crisis. Results in Panel D of Table VI reveal that, for the financial sector or for investment-grade securities, mean credit spread correlations between the U.S. and Canadian markets are low and not significant during the first (pre-crisis) and third (post-crisis) sub-periods. In both cases, we observe a significant peak during the second sub-period which corresponds to the financial crisis. Specifically, for the financial sector (investment-grade securities), mean credit spread correlation between the U.S. and Canada goes from a statistically non-significant 0.05 (0.07) before the crisis to a significant 0.33 (0.20) during the crisis and a non-significant 0.06 (0.08) after. For the industrial sector, mean credit spread correlation between the U.S. and Canada is remarkably stable over the three sub-periods, going from a statistically significant 0.17 before the crisis to 0.18 during the crisis and back to 0.17 after. Interdependence test results for between-correlations are available in Table VIII. We see that mean spread correlation for the financial sector between the U.S. and Canadian markets (see table VI) during the crisis is significantly different from before the crisis, and correlation after the crisis is significantly different from average correlation during the crisis. These results confirm the significant peak in credit spread correlation for the financial sector between the U.S. and Canadian corporate bond markets during the financial crisis. Similar results are obtained for mean credit spreads between the U.S. and Canadian investment-grade corporate bond markets However, as expected, we don't observe a statistically significant difference between average correlation before, during and after the financial crisis.

[Insert Table VIII here]

Overall, with the exception of industrial-sector credit spreads, mean credit spread correlations between the U.S. and Canadian corporate bond markets are stable over time. Our results therefore suggest that, in "normal" times (i.e. pre-crisis and post-crisis), both markets display greater independence, but are more strongly correlated during a period of crisis. These results are consistent with a segmentation of the U.S. and Canadian markets during the pre- and post-crisis periods, but support an integration of the two markets during the financial subprime crisis period.

5.4.2 Credit spread interdependence within the U.S. and Canada

5.4.2.1 U.S. credit spreads

The analysis of mean credit spread correlations within each market for the three sub-periods, available in Panel D of Table VII, reveals an upward trend across sectors and across risk classes within the U.S., particularly over the 2007-2009 period (crisis). Specifically, within the U.S., we observe an almost 50% increase in mean credit spread correlation across sectors over time, going from 0.44 before the crisis to 0.65 during and 0.64 after the crisis. Interdependence test results in Panel B of Table VIII indicate that this large mean credit spread correlation during the crisis is significantly different from pre-crisis average correlation. However, average post-crisis credit spread correlation is not statistically different from average crisis correlation.

We also observe an increase of 0.15 in the mean credit spread correlation between investment-grade and speculative-grade within the U.S. during the financial crisis. Specifically, we see that DCC goes from 0.40 pre-crisis to 0.55 during the crisis. This higher mean correlation persists over the post-crisis period, with a DCC coefficient of 0.56.

Interdependence test results in Table VIII show that average correlation during the crisis is indeed statistically significantly different from the average pre-crisis correlation. However, average post-crisis correlation is not significantly different from the average during-crisis correlation. These results highlight the persistence of high mean credit spread correlation within the U.S. bond market in the post-crisis period and suggest a structural break in the time series of correlation coefficients due to contagion within the U.S., as documented, among others, by Longstaff (2010). Our results are therefore consistent with the absence of credit spread interdependence within the U.S. corporate bond market.

5.4.2.2 Canadian credit spreads

Within the Canadian market, we observe mean credit spread correlation across sectors appears very stable over time, going from 0.72 pre-crisis to 0.71 during the crisis and 0.71 post-crisis. Therefore, despite the high level of mean credit spread correlation between sectors in normal times, financial-sector and industrial-sector credit spreads continue to be highly correlated during and after the crisis. Test results in Panel B of VIII confirm that the average credit spread correlation between the two sectors is very stable over time. Specifically, mean credit spread correlations are not statistically significantly different from one sub-period to another. These results suggest the presence of credit spread interdependence between sectors in the Canadian corporate bond market.

5.4.3 Robustness test

To examine the robustness of our results, we estimate our model on different subdivisions of the sample period, to ensure that results don't depend on our definition of pre-crisis, crisis and post-crisis periods. Specifically, we increase the length of the crisis sub-period from January 2007 to December 2009 (vs December 2007 to June 2009) since, as highlighted by Longstaff (2010), the subprime crisis actually began in early 2007. The pre-crisis period then covers the period from January 2001 to December 2006, and the post-crisis period covers the period from January 2010 to January 2013 (end of our sample). Untabulated results are very similar to the results obtained previously.

6. Conclusions and implications

This study investigates credit spread correlation and interdependence between and within U.S. and Canadian corporate bond markets. The empirical framework adopted herein allows for credit spreads to depend on common systematic risk factors derived from credit risk structural models and incorporates DCC between credit spreads. Based on daily OAS for bond indexes from January 2001 through January 2013, our results show that there is a surprisingly weak correlation between the U.S. and Canada in normal periods. However, during the financial crisis, there is a sudden and strong increase in the correlation between U.S. and Canadian credit spreads. Overall, our results suggest that, in normal times, both markets display greater independence but are more strongly correlated during period of crisis. The analysis of credit spread correlation within each market also shows an unusual increase in credit spread correlations across sectors and risk classes in the U.S. during the 2007-2009 financial crisis. This phenomenon persists over the post-crisis period and suggests a structural break in the time series of correlation coefficients, consistent with the absence of credit spread interdependence within the U.S. corporate bond market. By contrast, in Canada, credit spread correlations across sectors remain remarkably stable over time, suggesting an interdependence of credit spreads within the Canadian market.

Our study can be useful to portfolio managers in developing their risk management strategies. Correlations across individual positions, asset classes or markets are crucial inputs for portfolio management and are therefore very important for risk management. A higher degree of correlation can, for example, reduce diversification benefits. As demonstrated by Longstaff (2010), who examines the subprime crisis episode, default correlations can increase in an unusual way and high credit spreads can be envisaged in a period of market stress. Great losses can occur from holding a portfolio without considering time-varying correlation. Moreover, an unexpected increase in correlation can affect the pricing and hedging of credit derivatives, which provide insurance against spread variations for many underlying instruments. If investors can sense the interacting dynamics among markets in advance, then adjusting and hedging activities can be implemented in time, yielding successful and profitable performances.

One limitation of our research is our assumption that the conditional distribution of the innovation follows a multivariate t distribution. The use of a copula function, for example, would allow consideration of the marginal distributions and the dependence structure both separately and simultaneously.[13] We leave this question and tests to future research.

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[13] For example, Gumbel and Clayton copulas are two asymmetric copulas which imply a higher dependence at right and left tails respectively.

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Table I - States variables and expected signs for credit spreads

Variables	Description	Sign
Stock market variables		
$R^{i}_{m,t}$	Daily equity market return based on the S&P500 Index for the U.S. and S&P/TSX for Canada	-
$\Delta\sigma^{i}_{t}$	Daily change in the implied volatility based on the VIX for the U.S. and VIXC for Canada	+
Interest rate variables		
Δr^{i}_{t}	Daily change in the 3-month Treasury bill yield (U.S. and Canada)	-
$\Delta Slop^{i}_{t}$	Daily change in the slope of the government yield curve estimated by the spread between the 10-year government bond yield and the 3-month Treasury bill yield (U.S. and Canada)	-

Table II - Correlation matrix of state variables

This table presents the correlation matrix for the state variables defined in Table I. The sample period is from January 2 2001 through January 31 2013. The total number of observations is 3010.

	$R^{US}_{m,t-1}$	$\Delta\sigma^{US}_{t}$	Δr^{US}_{t}	$\Delta Slop^{US}_{t}$	$R^{CA}_{m,t-1}$	$\Delta\sigma^{CA}_{t}$	Δr^{CA}_{t}	$\Delta Slop^{CA}_{t}$
$R^{US}_{m,t-1}$	1.000							
$\Delta\sigma^{US}_{t}$	-0.825	1.000						
Δr^{US}_{t}	0.172	-0.165	1.000					
$\Delta Slop^{US}_{t}$	0.239	-0.185	0.541	1.000				
$R^{CA}_{m,t-1}$	0.736	-0.617	0.159	0.165	1.000			
$\Delta\sigma^{CA}_{t}$	-0.432	0.440	-0.134	-0.083	-0.507	1.000		
Δr^{CA}_{t}	0.078	-0.064	0.238	-0.063	0.133	-0.079	1.000	
$\Delta Slop^{CA}_{t}$	0.227	-0.193	-0.084	0.497	0.118	-0.069	-0.694	1.000

Table III - Summary statistics for credit spread changes

This table presents summary statistics on changes in daily option-adjusted credit spread (OAS) indexes for U.S. and Canadian corporate bonds by credit quality (investment- and speculative-grade) and sector (financial-sector and industrial-sector bonds). The sample period is from January 02, 2001 through January 31, 2013 (i.e. 3010 observations). Parameter Rho represents first-order serial correlation coefficients. J-B is the normality Jarque-Bera test and ARCH test is the Lagrange multiplier test for autoregressive conditional heteroskedasticity.

Credit spread changes (bps)	U.S.									Canada								
	Mean	Std. Dev.	Min	Max	Rho*	Skewness	Kurtosis	J-B test*	ARCH test*	Mean	Std	Min	Max	Rho*	Skewness	Kurtosis	J-B test*	ARCH test*
Financial-Sector	0.03	4.6	-89	74	0.20	1.45	117.47	1644319	75.89	-0.01	2.1	-27	23	-0.18	0.43	29.24	86452	18.19
Industrial-Sector	-0.01	2.3	-16	44	0.22	3.65	59.18	402492	20.68	-0.03	1.4	-12	11	-0.20	0.70	12.21	10879	51.10
Investment-Grade	0.01	2.8	-33	46	0.19	3.20	59.90	411178	82.77	-0.02	1.6	-14	14	-0.17	0..69	15.89	21084	39.90
Speculative-Grade	-0.19	11.2	-88	145	0.14	1.52	26.06	67860	7.12	-	-	-	-	-	-	-	-	-

Note: The null hypotheses of no autocorrelation, normality and homoscedasticity at the 1% levels of significance are rejected for all categories of credit spread changes series.

Table IV - Credit spread correlations between the U.S. and Canadian corporate bond markets

This table presents credit spread correlations between the U.S. and Canadian corporate bond markets. Credit spread correlation coefficients are estimated with a GARCH-DCC model with multivariate Student-t distribution. In Panel A (conditional mean), for market i, i=1,2, $R^{i}_{m,t-1}$, $\Delta\sigma^{i}_{t}$, Δr^{i}_{t} and $\Delta Slop^{i}_{t}$ represent the state variables, namely the lagged index return, the change in the implied market volatility, the change in the interest rate, and the change in the slope of the yield curve, respectively. ΔCS^{i}_{t} denotes credit spread changes and ω_{i} represents the constant term of the regression. In Panel B, $\zeta_i = (s_i, \alpha_{\mathrm{i}}, \beta_{\mathrm{i},})$ is the 1x3 vector of parameters for the conditional variance (GARCH(1,1)). In Panel C, ν is the parameter for the multivariate Student-t distribution and in Panel D, $\varsigma_i = (\lambda_1, \lambda_2, \rho_{12})$ is the 1x3 vector of parameters of dynamic conditional correlations (DCC) and two parameters that govern the dynamics of conditional correlations. In Panel E, the estimation of parameters for the Wald test is done using a two-step maximum likelihood estimation method. In all panels, the estimated coefficient mean values are presented, with t-statistics in parentheses. Numbers in bold indicate that the coefficients are significant at the 10% level.

	Financial-sector		**Industrial-sector**		**Investment-grade**	
	U.S.	Canada	U.S.	Canada	U.S.	Canada
Panel A: Conditional mean						
ω_{i}	-0.03 (-1.41)	0.01 (0.40)	**-0.06** (-2.70)	-0.03 (-1.55)	**-0.06** (-2.63)	-0.01 (-0.51)
U.S. variables						
ΔCS^{US}_{t-1}	**0.23** (11.22)	-	**0.33** (16.25)	-	**0.24** (11.22)	-
$R^{US}_{m,t-1}$	**-0.25** (-6.67)	**-0.08** (-2.67)	**-0.26** (-8.56)	**-0.05** (-1.93)	**-0.29** (-8.94)	**-0.07** (-2.57)
$\Delta\sigma^{US}_{t}$	**0.20** (7.10)	-0.02 (-0.90)	**0.14** (6.52)	0.00 (0.12)	**0.16** (6.93)	-0.02 (-0.98)
Δr^{US}_{t}	**-4.71** (-4.52)	0.39 (0.44)	**-7.08** (-8.36)	**-2.28** (-3.16)	**-6.16** (-6.94)	-1.01 (-1.31)
$\Delta Slop^{US}_{t}$	**-2.77** (-3.42)	-0.92 (-1.38)	**-5.66** (-8.53)	**-2.07** (-3.36)	**-4.55** (-6.65)	**-1.32** (-2.20)

.

Table IV continued

	Financial-sector		Industrial-sector		Investment-Grade	
	U.S.	Canada	U.S.	Canada	U.S.	Canada
Panel A (continued): Conditional mean						
Canada variables						
ΔCS_{t-1}^{CA}	-	**-0.15** (-7.00)	-	**-0.14** (-6.34)	-	**-0.16** (-7.40)
$R_{m,t-1}^{CA}$	-0.04 (-1.00)	-0.05 (-1.42)	0.00 (0.00)	-0.02 (-0.66)	0.02 (0.46)	-0.04 (-1.31
$\Delta \sigma_{t}^{CA}$	0.03 (0.96)	0.01 (0.43)	0.02 (0.94)	0.00 (-0.01)	0.02 (0.70)	0.01 (0.58)
Δr_{t}^{CA}	-1.81 (-1.58)	**-1.70** (-1.73)	-1.16 (-1.16)	0.51 (0.55)	-0.09 (-0.09)	-0.95 (-1.05)
$\Delta Slop_{t}^{CA}$	-1.28 (-1.20)	**-2.15** (-2.48)	-1.11 (-1.25)	-0.20 (-0.23)	-0.57 (-0.62)	-1.16 (-1.45)
Panel B: Conditional variance						
α_i	**0.16** (2.91)	**0.17** (2.99)	**0.49** (6.57)	**0.24** (4.60)	**0.01** (3.41)	**0.42** (4.01)
β_i	**0.80** (6.90)	**0.74** (6.44)	**0.43** (4.75)	**0.70** (3.98)	**0.97** (6.37)	**0.53** (4.91)
s_i	0.59 0.69	0.11 (0.17)	**0.47** (2.26)	0.13 (0.39)	0.18 (0.20)	**1.29** (2.06)
Panel C: Distribution parameter						
ν	**2.22** (31.87)		**2.36** (29.12)		**2.23** (42.65)	
Panel D: DCC						
ρ_{12}	**0.15** (4.96)		**0.17** (5.95)		**0.17** (5.97)	
λ_1	**0.09** (2.54)		**0.05** (2.06)		**0.16** (2.30)	
λ_2	**0.74** (9.18)		**0.72** (5.68)		**0.49** (2.15)	
Panel E: Wald test			H_0: $\lambda_1 = \lambda_2 = 0$			
chi2 (Prob.)	**91.27** (0.0000)		**80.95** (0.000)		**37.24** (0.0000)	

Table V - Credit spread correlations within the U.S. and Canadian corporate bond markets

This table presents credit spread correlations within the U.S. and Canadian corporate bond markets. Credit spread correlation coefficients are estimated with a GARCH-DCC model with multivariate Student-t distribution. In Panel A (conditional mean), for market i, i=1,2, $R^i_{m,t-1}$, $\Delta\sigma^i_t$, Δr^i_t and $\Delta Slop^i_t$ represent the state variables, namely the lagged index return, the change in the implied market volatility, the change in the interest rate, and the change in the slope of the yield curve, respectively. ΔCS^i_t denotes credit spread changes and ω_i represents the constant term of the regression. In Panel B, $\zeta_i = (s_i, \alpha_i, \beta_i)$ is the 1x3 vector of parameters for the conditional variance (GARCH(1,1)). In Panel C, ν is the parameter for the multivariate Student-t distribution and in Panel D, $\varsigma_i = (\lambda_1, \lambda_2, \rho_{12})$ is the 1x3 vector of parameters of dynamic conditional correlations (DCC) and two parameters that govern the dynamics of conditional correlations. In Panel E, the estimation of parameters for the Wald test is done using a two-step maximum likelihood estimation method. In all panels, the estimated coefficient mean values are presented, with t-statistics in parentheses. Numbers in bold indicate that the coefficients are significant at the 10% level.

	Sectors				**Risk classes**	
	U.S.		Canada		U.S.	
	Financial	Industrial	Financial	Industrial	Invesment	Speculative
Panel A: Conditional mean						
ω_i	**-0.05**	**-0.04**	0.01	-0.03	**-0.06**	**-0.56**
	(-1.96)	(-2.04)	(0.09)	(-1.56)	(-3.00)	(-6.99)
U.S. variables						
ΔCS^{US}_{t-1}	**0.19**	**0.22**	**0.13**	**0.13**	**0.19**	**0.12**
	(10.19)	(12.27)	(12.27)	(10.99)	(9.88)	(9.13)
$R^{US}_{m,t-1}$	**-0.28**	**-0.24**	**-0.09**	**-0.06**	**-0.26**	**-1.41**
	(-7.48)	(-8.54)	(-2.81)	(-2.41)	(-8.57)	(-11.43)
$\Delta\sigma^{US}_t$	**0.18**	**0.11**	-0.03	0.00	**0.14**	**0.55**
	(6.00)	(5.13)	(-1.44)	(-0.26)	(5.92)	(6.09)
Δr^{US}_t	**-5.63**	**-5.56**	-0.73	**-1.37**	**-6.61**	**-84.73**
	(-5.43)	(-7.12)	(-0.85)	(-2.03)	(-7.58)	(-26.42)
$\Delta Slop^{US}_t$	**-3.05**	**-4.28**	-0.97	**-1.51**	**-4.20**	**-74.93**
	(-3.70)	(-6.79)	(-1.49)	(-2.67)	(-6.15)	(-29.49)

Table V continued

	Sectors				Risk classes	
	U.S.		Canada		U.S.	
	Financial	Industrial	Financial	Industrial	Invesment	Speculative
Panel A (continued): Conditional mean						
Canada variables						
ΔCS_{t-1}^{CA}	-	-	**-0.17** (-9.54)	**-0.18** (-10.30)	-	-
$R_{m,t-1}^{CA}$	-0.02 (-0.50)	-0.02 (-0.05)	-0.04 (-1.08)	-0.01 (-0.31)	-0.04 (-1.12)	-0.16 (-1.28)
$\Delta\sigma_{t}^{CA}$	0.06 (1.50)	0.02 (0.90)	0.02 (0.90)	0.00 (-0.09)	0.03 (1.02)	0.37 (1.31)
Δr_{t}^{CA}	-1.91 (-1.63)	-1.66 (-1.19)	-1.29 (-1.34)	0.63 (0.74)	-0.49 (-0.49)	-8.07 (-1.13)
$\Delta Slop_{t}^{CA}$	-1.13 (-1.05)	-1.57 (-1.22)	**-2.26** (-2.63)	-0.57 (-0.75)	-0.06 (-1.00)	-5.45 (-1.62)
Panel B: Conditional variance						
α_i	**0.07** (1.80)	**0.17** (1.73)	**0.06** (4.56)	**0.27** (4.78)	**0.01** (3.67)	**0.04** (4.08)
β_i	**0.86** (11.62)	**0.59** (7.37)	**0.89** (5.79)	**0.60** (5.04)	**0.97** **(6.93)**	**0.88** (8.01)
s_i	0.74 (0.51)	0.83 (0.48)	0.57 (1.12)	0.50 (1.54)	0.80 (0.86)	0.41 (1.52)
Panel C: Distribution parameter						
v	**2.00** (41.97)		**2.28** (26.34)		**2.21** (51.21)	
Panel D: DCC						
ρ_{12}	**0.51** (25.19)		**0.68** (41.74)		**0.48** (19.76)	
λ_1	**0.91** (8.13)		**0.07** (1.66)		**0.14** (3.21)	
λ_2	**0.02** (1.71)		**0.49** (1.79)		**0.69** (7.09)	
Panel E: Wald test			H_0: $\lambda_1 = \lambda_2 = 0$			
chi2 (Prob.)	**69.34** (0.000)		**26.24** (0.000)		**187.66** (0.000)	

Table VI - Credit spread correlations between the U.S. and Canadian corporate bond markets conditional on the sub-period

This table presents credit spread correlations between the U.S. and Canadian corporate bond markets for three sub-periods: 1) from December 2001 to November 2007 (pre-crisis), 2) from December 2007 to June 2009 (crisis) and 3) from July 2010 to January 2013 (post-crisis). Credit spread correlation coefficients are estimated with a GARCH-DCC model with multivariate Student-t distribution. In Panel A (conditional mean), for market i, i=1,2, $R^{i}_{m,t-1}$, $\Delta\sigma^{i}_{t}$, Δr^{i}_{t} and $\Delta Slop^{i}_{t}$ represent the state variables, namely the lagged index return, the change in the implied market volatility, the change in the interest rate, and the change in the slope of the yield curve, respectively. ΔCS^{i}_{t} denotes credit spread changes and ω_{i} represents the constant term of the regression. In Panel B, $\zeta_i = (s_i, \alpha_i, \beta_i)$ is the 1x3 vector of parameters for the conditional variance (GARCH(1,1)). In Panel C, ν is the parameter for the multivariate Student-t distribution and in Panel D, $\varsigma_i = (\lambda_1, \lambda_2, \rho_{12})$ is the 1x3 vector of parameters of dynamic conditional correlations (DCC) and two parameters that govern the dynamics of conditional correlations. In Panel E, the estimation of parameters for the Wald test is done using a two-step maximum likelihood estimation method. In all panels, the estimated coefficient mean values are presented, with t-statistics in parentheses. Numbers in bold indicate that the coefficients are significant at the 10% level.

	Financial-Sector						**Industrial-Sector**						**Investment-Grade**					
	Pre-crisis		Crisis		Post-crisis		Pre-crisis		Crisis		Post-crisis		Pre-crisis		Crisis		Post-crisis	
	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada
Panel A: Conditional mean																		
ω_i	**-0.05**	-0.03	0.01	-0.05	**-0.25**	0.01	**-0.05**	**-0.04**	-0.04	0.06	**-0.14**	**-0.09**	**-0.07**	**-0.03**	-0.05	-0.01	**-0.16**	-0.03
	(-2.83)	(-159)	(0.62)	(-1.19)	(-3.86)	(0.92)	(-1.73)	(-1.97)	(-1.11)	(139)	(-3.71)	(-2.71)	(-2.67)	(-1.87)	(-1.01)	(-0.34)	(-3.73)	(-1.21)
U.S. variables																		
ΔCS^{US}_{t-1}	**-0.07**	-	**0.43**	-	**0.26**	-	**0.11**	-	**0.56**	-	**0.30**	-	0.03	-	**0.55**	-	**0.23**	-
	(-2.27)		(9.79)		(7.19)		(3.86)		(14.07)		(7.92)		(1.08)		(15.46)		(7.13)	
$R^{US}_{m,t-1}$	**-0.17**	0.01	**-0.32**	**-0.37**	**-0.62**	0.01	**-0.35**	-0.01	**-0.15**	**-0.13**	**-0.31**	-0.03	**-0.31**	0.01	**-0.23**	**-0.20**	**-0.40**	-0.05
	(-4.63)	(0.46)	(-3.79)	(-4.99)	(-4.98)	(0.21)	(-7.77)	(-0.82)	(-2.79)	(-2.88)	(-4.77)	(-1.01)	(-8.07)	(-0.82)	(-3.57)	(-3.17)	(-5.11)	(-0.88)
$\Delta\sigma^{US}_{t}$	**0.07**	0.01	**0.24**	0.05	**0.33**	0.05	**0.11**	0.03	**0.11**	0.05	**0.13**	0.05	**0.09**	0.02	**0.16**	0.02	**0.26**	**0.05**
	(2.53)	(0.29)	(3.93)	(1.59)	(5.25)	(1.34)	(3.01)	(0.86)	(2.79)	(1.49)	(3.80)	(1.64)	(2.73)	(0.99)	(3.59)	(1.62)	(6.08)	(1.68)
Δr^{US}_{t}	-1.12	-0.59	**-8.14**	0.37	**-17.14**	0.33	**-7.62**	**-3.08**	**-10.01**	**-2.97**	**-4.19**	-2.11	**-5.14**	**-1.83**	**-9.79**	0.90	**-13.14**	0.77
	(-1.04)	(-0.45)	(-4.01)	(0.31)	(-2.45)	(0.85)	(-5.43)	(-2.83)	(-6.33)	(-3.24)	(-5.96)	(-1.01)	(-4.17)	(-1.77)	(-5.81)	(1.17)	(-3.37)	(0.25)
$\Delta Slop^{US}_{t}$	**-1.84**	**-1.77**	**-3.81**	-0.21	**-5.77**	-0.63	**-7.77**	**-4.02**	**-6.47**	**-2.65**	**-3.01**	-0.98	**-4.51**	**-2.59**	**-6.96**	0.126	**-3.81**	-0.87
	(-2.69)	(-2.33)	(-2.85)	(-0.29)	(-2.93)	(-0.99)	(-6.98)	(-5.01)	(-5.18)	(-2.33)	(-2.84)	(-1.13)	(-4.37)	(-3.22)	(-4.77)	(1.04)	(-3.19)	(-1.07)

Table VI continued

	Financial-Sector						Industrial-Sector						Investment-Grade					
	Pre-crisis		Crisis		Post-crisis		Pre-crisis		Crisis		Post-crisis		Pre-crisis		Crisis		Post-crisis	
	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada
Canada variables																		
ΔCS_{t-1}^{CA}	-	**-0.39**	-	**0.23**	-	**-0.06**	-	**-0.27**	-	0.01	-	**-0.18**	-	**-0.36**	-	**0.20**	-	**-0.13**
		(-13.30)		(4.24)		(-1.68)		(-9.17)		(0.23)		(-3.97)		(-12.02)		(4.33)		(-3.37)
$R_{m,t-1}^{CA}$	-0.01	**-0.11**	-0.03	0.02	-0.03	-0.05	0.02	-0.02	0.01	0.02	-0.13	-0.05	0.01	-0.04	-0.07	-0.05	0.05	-0.08
	(-0.44)	(-2.77)	(-0.88)	(0.17)	(-0.18)	(-0.73)	(0.87)	(-0.50)	(0.37)	(0.81)	(-1.64)	(-0.77)	(0.36)	(-1.13)	(-1.19)	(-0.89)	(0.60)	(-1.56)
$\Delta\sigma_t^i$	0.02	0.00	0.03	0.05	0.20	0.05	0.01	0.01	0.01	**0.05**	0.07	0.10	0.09	0.01	-0.01	**0.07**	0.13	0.021
	(0.89)	(0.11)	(0.77)	(1.17)	(1.46)	(1.26)	(0.17)	(0.33)	(0.50)	(2.51)	(1.59)	(0.63)	(1.41)	(0.21)	(-0.03)	(1.89)	(1.56)	(0.78)
Δr_t^i	-0.63	-0.23	-0.24	**-6.75**	-3.09	-2.66	0.67	1.50	-2.61	1.14	-4.33	0.04	0.87	0.61	0.37	**-3.14**	-4.27	**-4.25**
	(-0.85)	(-0.28)	(-0.17)	(-2.58)	(-1.45)	(-0.82)	(0.53)	(1.15)	(-1.19)	(0.93)	(-1.25)	(0.01)	(0.63)	(0.47)	(0.22)	(-1.88)	(-1.41)	(-1.97)
$\Delta Slop_t^i$	-0.59	-0.51	1.70	**-4.82**	-3.03	**-5.07**	0.42	1.69	-2.13	-0.22	-2.13	**-2.67**	0.31	0.17	0.10	**-3.09**	-3.75	**-4.31**
	(-0.47)	(-0.35)	(0.52)	(-1.99)	(-1.22)	(-3.58)	(0.18)	(1.16)	(-1.10)	(-0.83)	(-1.47)	(-2.17)	(0.38)	(0.22)	(0.17)	(-2.09)	(-1.44)	(-2.77)
Panel B: Conditional variance																		
α_i	**0.23**	**0.26**	**0.27**	**0.42**	**0.18**	**0.06**	**0.15**	**0.06**	**0.37**	**0.30**	**0.33**	**0.29**	**0.42**	**0.24**	**0.06**	**0.31**	**0.10**	**0.18**
	(1.93)	(1.86)	(2.25)	(2.53)	(2.04)	(1.85)	(3.83)	(3.58)	(2.79)	(2.44)	(2.63)	(1.71)	(4.33)	(3.71)	(1.71)	(1.94)	(1.84)	(1.89)
β_i	**0.62**	**0.62**	**0.63**	**0.51**	**0.79**	**0.89**	**0.69**	**0.81**	**0.43**	**0.43**	**0.51**	**0.55**	**0.50**	**0.72**	**0.83**	**0.49**	**0.83**	**0.62**
	(4.65)	(4.81)	(4.21)	(1.91)	(1.87)	(1.90)	(3.61)	(3.55)	(2.54)	(1.92)	(1.85)	(1.82)	(3.87	(2.97)	(3.44)	(2.95)	(2.08)	(1.69)
s_i	0.51	1.35	0.88	2.28	0.50	0.51	0.10	0.02	0.18	0.68	0.69	0.19	0.11	0.19	0.51	1.01	0.02	0.57
	(0.17)	(0.24)	(1.18)	(0.77)	(0.11)	(0.25)	(0.63)	(0.09)	(0.33)	(0.76)	(1.61)	(0.25)	(0.42)	(0.77)	(0.79)	(0.33)	(0.01)	(0.98)
Panel C: Distribution parameter																		
ν	**2.09**		**2.33**		**2.39**		**2.32**		**2.37**		**2.35**		**2.23**		**2.04**		**2.40**	
	(22.14)		(12.49)		(12.08)		(25.12)		(10.69)		(12.81)		(24.01)		(28.19)		(10.13)	
Panel D: DCC																		
ρ_{12}	0.05		**0.33**		0.06		**0.17**		**0.18**		**0.17**		0.07		**0.20**		0.08	
	(1.17)		(6.11)		(1.18)		(3.87)		(3.92)		(2.03)		(1.01)		(3.87)		(1.35)	
λ_1	**0.14**		**0.10**		**0.14**		**0.10**		**0.05**		**0.03**		**0.03**		**0.51**		**0.03**	
	(1.81)		(1.83)		(1.85)		(1.88)		(1.86)		(1.92)		(1.78)		(1.89)		(1.83)	
λ_2	**0.74**		**0.59**		**0.42**		**0.59**		**0.81**		**0.81**		**0.85**		**0.22**		**0.83**	
	(2.79)		(1.87)		(1.72)		(1.91)		(9.03)		(8.98)		(8.88)		(1.77)		(10.21)	
Panel E: Wald test H_0: $\lambda_1 = \lambda_2 = 0$																		
chi2	**69.03**		**13.30**		**12.89**		**13.88**		**121.18**		**133.08**		**142.97**		**13.85**		**203.19**	
(Prob.)	(0.000)		(0.002)		(0.002)		(0.002)		(0.000)		(0.000)		(0.000)		(0.002)		(0.000)	

Table VII - Credit spread correlations within the U.S. and Canadian corporate bond markets conditional on the sub-period

This table presents credit spread correlations within the U.S. and Canadian corporate bond markets for three sub-periods: 1) from December 2001 to November 2007 (pre-crisis), 2) from December 2007 to June 2009 (crisis) and 3) from July 2010 to January 2013 (post-crisis). Credit spread correlation coefficients are estimated with a GARCH-DCC model with multivariate Student-t distribution. In Panel A (conditional mean), for market i, i=1,2, $R^i_{m,t-1}$, $\Delta\sigma^i_t$, Δr^i_t and $\Delta Slop^i_t$ represent the state variables, namely the lagged index return, the change in the implied market volatility, the change in the interest rate, and the change in the slope of the yield curve, respectively. ΔCS^i_t denotes credit spread changes and ω_i represents the constant term of the regression. In Panel B, $\zeta_i = (s_i, \alpha_i, \beta_i)$ is the 1x3 vector of parameters for the conditional variance (GARCH(1,1)). In Panel C, ν is the parameter for the multivariate Student-t distribution and in Panel D, $\varsigma_i = (\lambda_1, \lambda_2, \rho_{12})$ is the 1x3 vector of parameters of dynamic conditional correlations (DCC) and two parameters that govern the dynamics of conditional correlations. In Panel E, the estimation of parameters for the Wald test is done using a two-step maximum likelihood estimation method. In all panels, the estimated coefficient mean values are presented, with t-statistics in parentheses. Numbers in bold indicate that the coefficients are significant at the 10% level.

	Sectors												**Risk classes**					
	Pre-crisis				**Crisis**				**Post-crisis**				**Pre-crisis**		**Crisis**		**Post-crisis**	
	U.S.		Canada		U.S.		Canada		U.S.		Canada		U.S.		U.S.		U.S.	
	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Invest.	Specu.	Invest.	Specu.	Invest.	Specu.
Panel A: Conditional mean																		
ω_i	**-0.06**	-0.06	-0.04	**-0.06**	0.07	-0.02	-0.01	0.08	**-0.30**	**-0.14**	-0.06	**-0.12**	**-0.05**	**-0.52**	**-0.10**	**-0.38**	**-0.18**	**-0.97**
	(-2.29)	(-1.09)	(-0.59)	(-2.19)	(1.11)	(-0.39)	(-0.49)	(1.41)	(-3.92)	(-3.71)	(-1.33)	(-3.29)	(-2.04)	(-4.98)	(-1.91)	(-1.82)	(-3.44)	(-6.11)
U.S. variables																		
ΔCS^{US}_{t-1}	**-0.08**	0.05	-	-	**0.37**	**0.49**	-	-	**0.20**	**0.23**	-	-	-0.01	**0.12**	**0.46**	**0.27**	**0.17**	**0.04**
	(-2.38)	(1.53)			(9.12)	(12.23)			(5.19)	(6.81)			(-0.31)	(6.08)	(12.98)	(9.12)	(6.11)	(1.80)
$R^{US}_{m,t-1}$	**-0.18**	**-0.30**	0.01	-0.02	**-0.32**	**-0.13**	**-0.51**	**-0.15**	**-0.67**	**-0.69**	-0.05	-0.06	**-0.25**	**-1.42**	**-0.23**	**-1.77**	**-0.43**	**-1.66**
	(-4.73)	(-7.71)	(0.14)	(-0.51)	(-3.77)	(-2.65)	(-6.17)	(-3.07)	(-5.78)	(-4.83)	(-0.63)	(-1.51)	(-6.33)	(-9.21)	(-3.35)	(-6.14)	(-5.32)	(-6.19)
$\Delta\sigma^{US}_t$	0.02	**0.06**	0.00	0.01	**0.22**	**0.10**	-0.01	-0.02	**0.34**	**0.15**	-0.02	0.00	**0.06**	**0.62**	**0.14**	**0.79**	**0.19**	**0.39**
	(0.79)	(1.96)	(0.07)	(0.25)	(3.46)	(2.78)	(-0.45)	(-0.51)	(5.41	(4.54)	(-0.33)	(0.03)	(2.32)	(5.19)	(2.93)	(4.77)	(4.87)	(2.04)
Δr^{US}_t	-1.51	**-4.61**	-0.81	**-2.67**	**-10.06**	**-6.26**	-1.20	-1.30	**-14.74**	-3.07	-0.54	-0.66	**-4.78**	**-87.23**	**-9.89**	**-90.33**	**-12.22**	**-116.01**
	(-1.31)	(-4.68)	(-0.51	(-2.89)	(-5.69)	(-4.90)	(-0.53)	(-1.17)	(-2.04)	(-0.71)	(-0.17)	(-0.19)	(-4.87)	(-18.03)	(-6.57)	(-15.33)	(-2.87)	(-8.31)
$\Delta Slop^{US}_t$	**-1.89**	**-4.97**	**-2.51**	**-3.85**	**-4.77**	**-4.38**	-0.38	-0.83	**-4.89**	**-2.68**	-0.52	-0.19	**-4.31**	**-80.03**	**-8.11**	**-81.12**	**-3.48**	**-64.14**
	(-2.70)	(-5.95)	(-2.45)	(-4.26)	(-5.59)	(-3.82)	(-078)	(-0.54)	(-2.56)	(-2.91)	(-0.63)	(-0.14)	(-5.17)	(-26.17)	(-4.27)	(-15.19)	(-2.89)	(-14.30)

Table VII continued

	Sectors												Risk classes					
	Pre-crisis				Crisis				Post-crisis				Pre-crisis		Crisis		Post-crisis	
	U.S.		Canada		U.S.		Canada		U.S.		Canada		U.S.		U.S.		U.S.	
	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Fin.	Ind.	Invest.	Specu.	Invest.	Specu.	Invest.	Specu.
Canada variables																		
ΔCS_{t-1}^{CA}	-	-	**-0.36**	**-0.31**	-	-	**0.11**	-0.03	-	-	**-0.16**	**-0.22**	-	-	-	-	-	-
			(-15.19)	(-12.29)			(2.41)	(-0.65)			(-4.83)	(-6.57)						
$R_{m,t-1}^{CA}$	-0.01	0.01	-0.06	-0.01	-0.02	-0.01	-0.11	0.03	-0.05	-0.06	0.03	-0.06	-0.02	-0.06	-0.06	0.02	0.05	-0.32
	(-0.14)	(0.66)	(-1.12)	(-0.09)	(-0.11)	(-0.10)	(-0.35)	(-0.33)	(-0.21)	(-1.19)	(-0.69)	(-0.41)	(-0.26)	(-0.34)	(-0.63)	(0.15)	(0.88)	(-1.14)
$\Delta\sigma_t^{CA}$	-0.01	0.03	0.02	0.03	0.06	0.01	**0.08**	**0.06**	0.19	0.02	-0.04	-0.07	0.07	0.22	0.01	0.21	0.09	0.61
	(-0.21)	(0.92)	(0.20)	(0.44)	(1.21)	(0.42)	(1.80)	(2.49)	(1.55)	(0.53)	(-0.36)	(-0.56)	(1.50)	(1.11)	(0.32)	(1.33)	(0.73)	(1.01)
Δr_t^{CA}	-0.17	0.21	0.29	-0.71	-0.15	-1.02	-4.63	-1.90	-1.71	-3.81	-1.71	-0.61	1.19	2.49	-1.20	-14.33	-4.78	-35.01
	(-0.19)	(0.29)	(0.26)	(-0.33)	(-0.09)	(-0.82)	(-1.63)	(-1.33)	(-0.98)	(-1.49)	(-0.89)	(-0.81)	(1.21)	(0.46)	(-0.83)	(-1.58)	(-0.63)	(-1.18)
$\Delta Slop_t^{CA}$	-0.47	-0.39	-0.68	-0.83	-1.77	-1.01	-1.82	-1.83	-1.51	-5.29	**-4.66**	**-2.63**	0.26	1.14	-0.30	-5.83	-1.95	-35.14
	(-0.42)	(-0.12)	(-0.55)	(-1.46)	(-0.64)	(-1.04)	(-0.59)	(-1.21)	(-0.63)	(-1.39)	(-2.87)	(-2.51)	(0.22)	(0.13)	(-0.11)	(-0.69)	(-1.20)	(-1.52)
Panel B: Conditional variance																		
α_i	**0.17**	**0.31**	**0.05**	**0.26**	**0.27**	**0.28**	**0.03**	**0.31**	**0.18**	**0.22**	**0.17**	**0.02**	**0.30**	**0.05**	**0.04**	**0.03**	**0.02**	**0.27**
	(1.70)	(1.81)	(4.34)	(3.33)	(1.93)	(1.44)	(2.23)	(1.66)	(2.50)	(2.14)	(1.87)	(2.04)	(4.41)	(3.10)	(1.75)	(1.80)	(2.00)	(2.85)
β_i	**0.70**	**0.46**	**0.80**	**0.67**	**0.56**	**0.43**	**0.93**	**0.48**	**0.70**	**0.40**	**0.75**	**0.89**	**0.66**	**0.86**	**0.82**	**0.96**	**0.94**	**0.53**
	(5.58)	(4.71)	(2.63)	(3.42)	4.32	(1.99)	(2.16)	(1.71)	(1.76)	(1.79)	(1.74)	(1.77)	(3.88)	(4.13)	(3.92)	(5.07)	(2.24)	(1.74)
s_i	1.65	1.67	0.17	0.23	0.81	0.84	0.13	**2.48**	0.57	**0.91**	0.18	0.06	0.07	0.12	0.70	0.55	0.36	0.63
	(0.05)	(0.39)	(0.30)	(0.71)	(0.86)	(0.53)	(1.01)	(1.94)	(0.29)	(2.32)	(0.54)	(0.14)	(0.23)	(1.04)	(0.31)	(1.10)	(0.36)	(0.68)
Panel C: Distribution parameter																		
ν	**2.03**		**2.31**		**2.31**		**2.30**		**2.32**		**2.26**		**2.32**		**2.10**		**2.33**	
	(51.02)		(26.54)		(26.77)		(23.07)		(26.25)		(20.32)		(15.23)		(29.42)		(26.22)	
Panel D: DCC																		
ρ_{12}	**0.44**		**0.72**		**0.65**		**0.71**		**0.64**		**0.71**		**0.40**		**0.55**		**0.56**	
	(14.23)		(38.32)		(22.25)		(20.44)		(22.45)		(22.53)		(12.23)		(14.25)		(15.22)	
λ_1	**0.69**		**0.10**		**0.15**		**0.02**		**0.02**		**0.05**		**0.18**		**0.16**		**0.10**	
	(5.32)		(2.02)		(1.88)		(2.71)		(1.86)		(1.70)		(2.63)		(1.73)		(2.12)	
λ_2	**0.23**		**0.35**		**0.69**		**0.96**		**0.05**		**0.23**		**0.42**		**0.69**		**0.61**	
	(2.44)		(1.83)		(5.87)		(6.83)		(1.71)		(1.80)		(1.69)		(3.57)		(381)	
Panel E: Wald test									H_0: $\lambda_1 = \lambda_2 = 0$									
chi2	**388.68**		**27.19**		**121.19**		**130.22**		**25.41**		**24.93**		**33.24**		**46.68**		**49.23**	
(Prob.)	(0.000)		(0.001)		(0.000)		(0.000)		(0.001)		(0.001)		(0.000)		(0.000)		(0.000)	

Table VIII – Credit spread interdependence

This table summarize the results of credit spread interdependence tests. Panel A presents the results for the interdependence between U.S. and Canadian corporate credit spreads, while Panel B presents the results for interdependence within the U.S. and Canada. The first t-test compares the average credit spread correlation (DCC) before the crisis vs during the crisis. The second t-test compares the average credit spread correlation during the crisis vs after the crisis. $\widehat{\rho}_{12,1}$, $\widehat{\rho}_{12,2}$ and $\widehat{\rho}_{12,3}$ represent the average DCC for the pre-crisis period, the crisis period and the post-crisis period, respectively.

Panel A: Credit spread interdependence between the U.S. and Canadian corporate bond markets

	Pre-crisis vs crisis $H_0 : \widehat{\rho}_{12,1} = \widehat{\rho}_{12,2}$		Crisis vs post-crisis $H_0 : \widehat{\rho}_{12,2} = \widehat{\rho}_{12,3}$		Interdependence
	t-stat	p-value	t-stat	p-value	
U.S. Financial-sector vs Canada Financial-sector	6.9836	0.0000	6.7293	0.0000	No
U.S. Industrial-sector vs Canada Industrial-sector	0.9732	0.2023	0.9119	0.1923	Yes
U.S. Investment-Grade vs Canada Investment-Grade	3.8563	0.0002	3.56321	0.0005	No

Panel B: Credit spread interdependence within the U.S. and Canadian corporate bond markets

	Pre-crisis vs crisis $H_0 : \widehat{\rho}_{12,1} = \widehat{\rho}_{12,2}$		Crisis vs post-crisis $H_0 : \widehat{\rho}_{12,2} = \widehat{\rho}_{12,3}$		Interdependence
	t-stat	p-value	t-stat	p-value	
U.S. Financial-sector vs U.S. Industrial-sector	5.7239	0.0000	0.9873	0.1824	No
U.S. Investment-Grade vs U.S. Speculative-Grade	4.2535	0.0001	0.94241	0.1945	No
Canada Financial-sector vs Canada Industrial-sector	0.0872	0.5132	0.5772	0.7266	Yes