Counterparty Risk in Exchange Traded Notes (ETNs): Theory and Evidence

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This Draft: October 1, 2012

Abstract

In this paper we address the issue of counterparty credit risk in Exchange Traded Notes (ETNs). An ETN is a tracking product which is designed as an unsecured debt security and is therefore subject to the issuer's default risk. We describe a standard reduced-form pricing framework to gauge the theoretical effect credit risk should have on ETNs. We then derive firm-specific, real market credit risk measures using Credit Default Swap (CDS) data to construct model-implied risk-adjusted ETN prices. Our results indicate that a substantial credit risk discount should be priced into ETNs. In sharp contrast, however, based on real market ETN quotes, we found no evidence for credit risk pricing by market players.

1   Introduction

The financial market turmoil over the past few years has highlighted the central role that counterparty credit risk plays in securities trading. Both academic and popular literature have dedicated much attention to risks associated with the most dominant derivatives in over-the-counter (OTC) markets, such as Credit Default Swaps (CDS) and Interest Rate Swaps (IRS). A few examples include: Arora, Gandhi and Longstaff (2012); Duffie and Zhu (2011); and Gregory (2010), which provides an excellent summary of the topic. However, in addition to these predominant and central securities, counterparty risk plays a crucial role in other, less obvious domains of financial markets. In this paper we address the role of

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counterparty credit risk in Exchange Traded Notes (ETNs), a relatively new financial vehicle with a fast growing market share.

An ETN is a type of a tracking product. As such, it is a security traded in the secondary market that is designed to track a given index or market benchmark. ETNs are unique in their structure in that they are set as a debt security with a payoff that is linked to the performance of a pre-specified underlying index or market benchmark. ETNs are generally issued by a single bank as senior, unsecured, unsubordinated debt securities, and are not asset-backed. They are backed only by the full faith and credit worthiness of the underwriting bank. Therefore, as unsecured promissory obligations, holders of this product are directly exposed to the credit risk of the underwriting entity. To the best of our knowledge, this issue of credit risk embedded in ETN securities has so far received no attention in the academic literature. The purpose of this paper is to fill this gap in the literature.

ETNs are often lumped together with Exchange Traded Funds (ETF), since they are both exchange-traded products that track an underlying index. However, their similarity stops there. The underlying structure and tracking mechanism for ETFs is fundamentally different from those for ETNs and the two should not be confused. An ETF is structured as an open-end fund that holds the underlying assets of the index that it is designed to track. Each ETF share represents a unit of ownership on the underlying basket of securities and is, therefore, backed by real assets. As such, ETFs are not subject to any issuer's risk of default, as the issuer functions only as a fund sponsor and portfolio manager with no ownership rights on the underlying funds. On the other hand, as explained above, ETNs are designed as unsecured debt securities, and are thus subject to default risk.

We address two main questions in this study. First, we investigate the theoretical relevance of counterparty credit risk to ETN products, and study the magnitudes of the theoretical discounts that should be priced into ETNs because of this risk. Second, based on our answer to the first question, we explore to what extent, if at all, credit risk is indeed priced into ETN products and taken into account by market participants.

The risk of a large ETN issuer defaulting is not merely theoretical. During the credit crisis in 2008 this risk became extremely relevant when the very survival of major financial institutions was in jeopardy, many of which had outstanding ETN obligations. In fact, the worst-case scenario unfolded when Lehman Brothers collapsed and its line of three *Opta* ETN securities stopped trading around its time of default. Consequently, these ETNs were delisted from the stock exchange about a month later. Holders of Lehman Brothers ETNs eventually recovered around 9 percent of their ETNs' intrinsic value after joining a long list of

creditors with claims on Lehman's assets.[1] Similarly, in the case of the Bear Stearns collapse, ETN holders were hours from the same fate, when JP Morgan stepped in, purchased the investment bank, and honored all Bear Stearns' debt obligations.

To date, ETNs in the US are not subject to any statutory regulation requiring the disclosure of their use of proceeds, the issuer's hedging of its ETN obligations, or of any other risk management policy that is adopted by the issuer. Moreover, there are no regulatory guidelines as to how the issuer is allowed to use ETN proceeds, and as mentioned before, the issuer is not obligated to use them to secure its obligations. The notes are issued under a senior debt indenture and as such all proceeds, from a regulatory point of view, merely become part of the issuer's general capital base. The lack of a specific regulatory infrastructure for ETNs is not unique to the US; most other countries have a similar regulatory framework.

Notably, in sharp contrast to the US, an interesting counter-example is Israel. Over the past several years the Israel Securities Authority has increasingly imposed greater disclosure requirements and new regulatory obligations on ETNs. For example, one of the basic regulatory requirements is that all ETN proceeds must be isolated from the issuer's general capital and deposited in a Special Purpose Vehicle (SPV) with a dedicated external trustee overseeing its activity. Additionally, each ETN must file monthly, quarterly and annual reports that provide a detailed description of how the proceeds are managed and specify their sources of potential risk. Both market risk and counterparty credit risk factors are addressed in these reports along with quantitative measures that gauge these risks, such as VaR for measuring market risk, and CDS prices of relevant counterparties to which the SPV is exposed for measuring counterparty credit risk. These tight regulations are enforced in order to increase transparency, protect investors' interests, and guarantee market stability. However, as mentioned above, this is not the case in the US and in most other countries.

In order to understand better the potential role counterparty risk plays in ETN products, we explore both theoretical and empirical aspects of the topic. We adopt the following strategy for our analysis. First, on the theoretical level, we use a standard reduced-form pricing framework to incorporate credit risk into ETN prices. This serves as our benchmark model. We then extract firm-specific default intensities from CDS quotes for all ETN issuers and apply them to our benchmark model. In this way we construct theoretical risk-adjusted ETN price estimates that internalize the risk of default based on real market measures for default risk. These risk-adjusted price estimates then serve as a basis for evaluating the theoretical relevance of credit risk to ETNs and allow for measuring the magnitude of its potential impact on ETN prices.

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[1] See *"Moody's Global Credit Policy"*, February 2009.

Second, on the empirical level, we investigate to what extent market participants take into account the risk of default in their ETN trading activity. To do so, we examine how consistent real ETN market prices are with those implied by our benchmark model that incorporates credit risk, as described above. On the basis of this analysis, we study the time series of ETN premiums and discounts compared to their theoretical risk-adjusted prices, and draw conclusions about the efficiency or inefficiency of the ETN market. Consequently, we are able to determine the extent to which market participants behave rationally.

Briefly, we find that indeed a significant default risk component ought to be priced into ETNs. Our benchmark model implies extended periods of time where discounts should amount to more than 50 basis points, with variation naturally depending on the issuing entity and the particular date. At the height of the financial distress in 2009 and 2011, our estimated theoretical discounts exceeded 100 basis points for some ETNs. In sharp contrast, however, real market ETN quotes have rarely indicated evidence for pricing credit risk by market participants. In fact, ETNs have often traded with positive premiums for an extended period.

Our research and findings make an important contribution to the discussion on regulatory policy. They emphasize that the ETN industry requires closer regulatory treatment and that market forces do not fully reflect the risks embedded in these products. Some regulators have already stressed this issue; see for example Minenna (2011). We argue in favor of more transparency requirements and the disclosure of clear-cut and unambiguous quantitative measures that have the potential to provide investors in complex financial products, such as ETNs, with better tools to evaluate associated risks. These estimates could include CDS spreads or Value-at-Risk-type, for example.

This paper also contributes to the extensive literature on credit risk in bond pricing and on counterparty credit risk in derivatives contracts. A number of papers closely related to our paper address questions such as to what extent credit risk determines bond prices in real markets; what portion of corporate yield spreads is directly attributed to default risk; and how much of the spread stems from other factors, such as liquidity and taxes. Important examples include Jones, Mason, and Rosenfeld (1984); Longstaff and Schwartz (1995); Duffie and Singleton (1997); Duffie (1999); Elton, *et al.* (2001); Collin-Dufresne, Goldstein, and Martin (2001); Eom, Helwege, and Huang (2004); Liu, Longstaff, and Mandell (2004); Longstaff, *et al.* (2005).

Additionally, a large number of papers have studied both from theoretical and empirical perspectives the effect credit risk has on derivatives pricing. See for example: Cooper and

Mello (1991); Litzenberger (1992); Sorensen and Bollier(1994); Duffie and Huang (1996); Minton (1997); Huge and Lando (1999); Gupta and Subrahamanyam (2000); Jarrow and Yu (2001); Hull and White (2001); Levy (2010); and Arora, Gandhi and Longstaff (2012). For a more general discussion on counterparty risk for OTC instruments and derivatives in general see Canabarro and Duffie (2003), and additional references therein.

However, in contrast to the extensive existing literature on credit risk for other financial instruments, ETNs have not received much attention in the academic literature, partially because they are a relatively new type of investment vehicle. Most surprisingly, their exposure to credit risk has not been addressed at all. This topic has, however, received some attention in the media and in other professional forums. For example, all ETN prospectuses explicitly present this product as an unsecured debt security. Similarly, once ETNs started registering with the NYSE, the exchange published documents explaining the structure and risks associated with them.[2] Finally, a number of articles on Bloomberg, the Wall Street Journal, Morningstar, and financial blogs discussed this issue on various occasions, especially at the time of the Lehman collapse.[3] Most recently, the US Securities and Exchange Commission (SEC) distributed a letter to certain financial institutions requesting clarifications regarding their structured notes policies. Some of the main issues emphasized in this letter are the issuer's use of proceeds, the purpose of the issuer's structured notes program, the reason for offering them, and the issuer's credit risk.[4] Motivated by these sources, we address this gap in the academic literature and investigate the impact of credit risk on ETN securities.

The remainder of this paper is organized as follows. In the next section we describe the mechanics of ETN products and discuss their relevant maturity for default risk. In Section 3 we describe our benchmark model for incorporating credit risk into ETNs. Section 4 expands the model and discusses several versions most suitable for short-term credit risk. Section 5 briefly describes the pricing model for CDS contracts as an introduction to Section 6, in which we describe our econometric procedure of fitting parameters for the default risk process. In Section 7 we describe our data, followed by Sections 8 and 9 where we present and

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[2]See "*What You Should Know About Exchange Traded Notes*", 2008, at: www.nysedata.com.

[3]See for example: "*Exchange-Traded Notes Top $10 Billion as Banks Offer New Bets on Indexes*", Bloomberg.com, April 21, 2010; "*Trouble at Barclays Raises ETN Worries, Potential for Steep Loses if Bank Defaults*", WSJ.com, January 23, 2009; "*Understanding Exchange-Traded Commodities & Notes*", by Gordon Rose, Morningstar, July 6, 2011; "*ETNs Demystified*", by John Gabriel, Morningstar, January 14, 2009; "*ETNs: Useful, but Watch Out for Counter Party Risk*", SeekingAlpha.com, January 27, 2007; "*ETN Credit Risk Is Minimal*", SeekingAlpha.com, March 9, 2010; "*ETNs – Riskier Than They Look*", InvestWithAnEdge.com, January 27, 2009; and more.

[4]See: Wall Street Journal, "*SEC Wants Clearer 'Notes'*", April 13, 2012, by Andrew Ackerman.

analyze our results. Section 10 is dedicated to a discussion on several alternative measures of short-term credit risk and Section 11 concludes.

2 Mechanics of ETNs

The appropriate pricing framework for ETNs depends on the mechanics that underlie this type of security. ETNs typically have very long maturities, usually more than 30 years from their day of issuance; however, they contain a special early redemption mechanism that distinguishes their structure from plain vanilla bonds. This mechanism allows dealers to redeem existing units at their intrinsic value directly with the issuing entity on any given date. Discipline of the redemption process is critical to support ETN market prices to remain as close as possible to the underlying index that they are designed to track. Any deviation between the underlying index and the price of the ETN can be exploited for arbitrage profits by redeeming the ETN and taking advantage of the gap in prices.[5] It is this redemption process that essentially transforms ETN securities from long-term obligations into short-term notes.

An early redemption order is not executed immediately. The redemption process requires an early notification to the issuing entity and the redemption value is determined on that date. It is only several days later that redemption payments are made, with some variation between issuers, but typically within a week (5 business days). Thus, from the day of redemption notification until the final redemption date: a) final payments are fixed, as determined on the early notification date; and b) the holder of the ETN is exposed to default risk. Essentially, it is these two factors that constitute the default risk that should be priced into ETN securities. Put differently, for the purpose of pricing default risk into ETNs, the early redemption option in fact transforms the ETN into an equivalent short-term note with an effective maturity date of approximately a week.[6] The rationale is as follows: If the risk of default was priced into an ETN for a period longer than a week, the ETN would have a greater price discount, compensating the owner of the ETN for default risk for a period longer than a week. In this

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[5]ETN issuers explicitly commit in their prospectuses only to redeem existing notes at their face value and do not mention an obligation to issue new notes at their intrinsic value. However, from conversations with market practitioners, it is their common practice to allow the creation of new units upon request. Thus, in practice, an arbitrage mechanism is available to take advantage of both positive and negative price deviations.

[6]Another way of interpreting this instrument would be to treat it as a long-term puttable debt security with an embedded American option that can be redeemed anytime until maturity. The embedded American put option would have a processing time of a week. The two approaches yield the same result and are thus identical.

case, the holder of an ETN could redeem the note immediately, exploiting the price gap of the increased discount. In other words, while the holder would be exposed to default risk for only one week (until redemption payments were made), he would nevertheless be compensated for holding the security for a period longer than a week. If such arbitrage opportunities are excluded, then any investor in ETNs would be compensated for the minimum amount of time he must hold the security — the time of the redemption process.

Notice that while the redemption option essentially converts ETNs into very short-term debt securities with a maturity of about a week, this does not imply that credit risk is a negligible issue. Several studies have shown that given the fact that investors cannot have perfect accounting information about the issuer's assets and instead rely on periodic reports or incomplete information, defaultable debt securities would still have a positive credit spread as maturity approaches zero (see: Duffie and Lando (2001); Yu (2005)). In other words, uncertainty and noisy information about the true financial adequacy of the issuing firm implies bounded positive credit spreads even at zero maturity. We account for this issue in our estimation process. We start with a benchmark model that ignores the effect of imperfect accounting information. Then, we consider another approach to account for uncertainty regarding the issuing firm's value.

3   Benchmark Model for ETNs

Modeling the price of an ETN with credit risk is very similar to pricing any other defaultable bond. We start with a standard reduced form model, following the specific framework suggested by Longstaff, *et al.* (2005), which builds on prior work by Duffie and Singleton (1997, 1999), Duffee (1998), Lando (1998), and others. Let r_t denote the riskless rate and λ_t the intensity of the Poisson process governing the default. Each of the processes r_t and λ_t is stochastic and evolves independently. We make the assumption that the ETN holder recovers a fixed fraction $1-R$ of the face value of the note in the case of default. Additionally, we denote by IND_t the intrinsic face value of the ETN on date t, which is determined by the underlying index minus investor fees as specified in each ETN's prospectus. Last, we denote by ΔT the length of the ETN redemption process, which is the relevant horizon for default risk as explained above. We assume that the risk-neutral dynamics of the default process λ_t is specified by the following mean reverting square-root diffusion process,

$$d\lambda = (\alpha - \beta\lambda)\,dt + \sigma\sqrt{\lambda}dW_t \tag{1}$$

where α, β and σ are positive constants, and W_t is a standard Brownian motion. Given the default process, it is straightforward to represent the price of an ETN at time t, P_t, as simple

expectations under the risk neutral probability. That is,

$$
\begin{aligned}
P_t \;=\; IND_t \times \Bigg\{ &E_t\left[\exp\left(-\int_t^{t+\Delta T}(r_u+\lambda_u)\,du\right)\right] \\
&+ E_t\left[(1-R)\int_t^{t+\Delta T}\lambda_u\exp\left(-\int_t^u(r_v+\lambda_v)\,dv\right)du\right]\Bigg\}
\end{aligned}
\tag{2}
$$

If the ETN holder redeemed the security on day t, he would be paid the intrinsic value IND_t at time $t+\Delta T$, which is the redemption payment date. As explained above, if arbitrage profits are excluded, then ΔT is the relevant time horizon for default risk for ETNs. Thus, the first term in equation (2) is the present value of the promised face-value payment of the ETN as determined on notification date t after accounting for the probability of default. The second term is the present value of recovery payments in the event of default.

One advantage of this framework is that the expectation terms in equation (2) admit closed form solutions given the square-root dynamics of the default intensity process. Longstaff, *et al.* (2005) showed that based on standard results such as those in Duffie, Pan, and Singleton (2000), equation (2) can be written as,

$$
\begin{aligned}
P_t \;=\; IND_t \times \big(&A\left(t+\Delta T\right)\exp\left(B\left(t+\Delta T\right)\lambda\right)Z\left(t+\Delta T\right) \\
&+ (1-R)\int_t^{t+\Delta T}\exp\left(B\left(u\right)\lambda\right)Z\left(u\right)\left(G\left(u\right)+H\left(u\right)\lambda\right)du \big)
\end{aligned}
\tag{3}
$$

where λ denotes the current (time t) value of the intensity process and,

$$
\begin{aligned}
A\left(u\right) &= \exp\left(\frac{\alpha\left(\beta+\phi\right)}{\sigma^2}\left(u-t\right)\right)\left(\frac{1-\kappa}{1-\kappa e^{\phi(u-t)}}\right)^{\frac{2\alpha}{\sigma^2}} \\[2mm]
B\left(u\right) &= \frac{\beta-\phi}{\sigma^2}+\frac{2\phi}{\sigma^2\left(1-\kappa e^{\phi(u-t)}\right)} \\[2mm]
Z\left(u\right) &= E_t\left[\exp\left(-\int_t^u r_v dv\right)\right] \\[2mm]
G\left(u\right) &= \frac{\alpha}{\phi}\left(e^{\phi(u-t)}-1\right)\exp\left(\frac{\alpha\left(\beta+\phi\right)}{\sigma^2}\left(u-t\right)\right)\left(\frac{1-\kappa}{1-\kappa e^{\phi(u-t)}}\right)^{\frac{2\alpha}{\sigma^2}+1} \\[2mm]
H\left(u\right) &= \exp\left(\frac{\alpha\left(\beta+\phi\sigma^2\right)}{\sigma^2}\left(u-t\right)\right)\left(\frac{1-\kappa}{1-\kappa e^{\phi(u-t)}}\right)^{\frac{2\alpha}{\sigma^2}+2} \\[2mm]
\phi &= \sqrt{2\sigma^2+\beta^2} \\[2mm]
\kappa &= \frac{\left(\beta+\phi\right)}{\left(\beta-\phi\right)}
\end{aligned}
$$

Based on the closed form solution in equation (3) and given the set of parameters α, β, σ, the realization of λ_t, and the discount factor $Z(u)$, one can construct for each date t a corresponding theoretical ETN price that incorporates credit risk. Notice that based on equation (3), the discount of the ETN price is given simply by the expression,

$$
\begin{aligned}
D_t \quad &\equiv \quad A\left(t + \Delta T\right) \exp\left(B\left(t + \Delta T\right)\lambda\right) Z\left(t + \Delta T\right) \\
&+ \left(1 - R\right) \int_t^{t+\Delta T} \exp\left(B\left(u\right)\lambda\right) Z\left(u\right)\left(G\left(u\right) + H\left(u\right)\lambda\right) du
\end{aligned}
\tag{4}
$$

This expression converges to zero as ΔT converges to zero. In the case of ETNs the relevant time horizon for default risk is very short (approximately 1 week), which implies that ETN price discounts may be very close to zero. However, as mentioned earlier, this result changes once incomplete accounting information is taken into account, which is a more realistic description of credit markets. We discuss this issue next.

4   Incomplete Accounting Information

The above benchmark ETN model might underestimate the risk of default in cases where investors cannot observe the issuer's assets directly. In reality, accounting information is not fully transparent; noisy or delayed accounting reports and other barriers to information do not allow for full disclosure of the issuer's current asset value or nearness to default. This issue was particularly relevant in the years 2007-2011, which were characterized by high levels of uncertainty and extreme volatility in credit markets. As mentioned above, Duffie and Lando (2001) and Yu (2005) showed that incomplete accounting information has a strong effect on short-term maturities. Uncertainty increases credit spreads and default probabilities for the short-end of the term-structure, and they are bounded from below with positive values at zero maturities. Hence, in a realistic setting, imperfect reporting must be considered when gauging short-term risk of default.

We offer the following adjustment to account for this isssue. Investors face imperfect information about the current situation of the firm's assets. It is only additional information that may arrive in the future that will provide full disclosure. Therefore, the relevant time horizon for pricing the risk of default extends beyond the maturity of the note. In other words, short-term maturities share the same uncertainty set as longer maturities do, since information regarding current assets might be revealed only past the maturity date. This fact manifests itself in price discounts that are fixed for the very short-end of the term-structure until a certain maturity date threshold. This threshold could be the time of a consecutive quarterly report or a firm announcement. Thus, in our estimation process we extend the

maturity date beyond the 1-week horizon for ETNs to achieve a more realistic price discount. In practice, we use equation (4) with maturities of one month and one quarter, to construct an interval that captures the effect of delayed accounting reports and news. That is, we use $\Delta T = 30$ days and $\Delta T = 90$ days as lower and upper bounds for an interval that contains the true price discount.

In conclusion, we carry out our analysis using 3 different estimates. Our benchmark estimate is the 1-week discount resulting from equation (4). This estimate is valid for a setting with perfect accounting information. Since this assumption is unrealistic, we extend the time horizon to 30 days and 90 days to create an interval that better captures the true short-term price discount. These are our second and third estimates.

5   CDS Model for Parameter Estimation

Any one of the three estimates we suggest for the short-term price discount requires knowledge about the underlying default intensity λ_t. To estimate the default intensity we use CDS data. All ETN issuers in our sample are major financial institutions and therefore experience very active CDS trading. The probability that the underwriting firm may default follows the same intensity process as we described above in equation (1), since it is the same entity. Following Longstaff, *et al.* (2005), it is straightforward to represent the value of the fixed CDS spread S_t determined at time t for a contract maturing at $t + \Delta\tau$ by,

$$S_t = \frac{E\left[R \int_t^{t+\Delta\tau} \lambda_u \exp\left(-\int_t^u (r_v + \lambda_v)\, dv\right) du\right]}{E\left[\int_t^{t+\Delta\tau} \exp\left(-\int_t^u (r_v + \lambda_v)\, dv\right) du\right]} \tag{5}$$

Again, given the square-root dynamics of the the default intensity process, we can represent equation (5) using the following closed form solutions for the expectations terms:

$$S_t = \frac{R \int_t^{t+\Delta\tau} \exp\left(B\left(u\right)\lambda\right) Z\left(u\right)\left(G\left(u\right) + H\left(u\right)\lambda\right) du}{\int_t^{t+\Delta\tau} A\left(u\right)\exp\left(B\left(u\right)\lambda\right) Z\left(u\right) du} \tag{6}$$

where $A\left(u\right), B\left(u\right), Z\left(u\right), G\left(u\right)$ and $H\left(u\right)$ are the same expressions as defined above. On the basis of this closed form solution, we can now use real CDS quotes to fit parameters α, β and σ that characterize the square-root process, and estimate a vector of realizations of λ_t's for our sample, where $t = 1...N$. This set of parameters and estimates will subsequently be used to construct risk adjusted ETN prices based on equation (4), that is, D_t. We next describe our econometric approach for estimating the parameters of the process and the realizations of λ_t.

6 Estimation Strategy

The main problem in estimating the parameters of the default intensity process, λ_t, is that the time series of its realizations is not directly observable. It is only indirectly known through its transformation in the observable CDS prices, as expressed in equations (5) and (6). Therefore, we apply the Expectation Maximization (EM) algorithm of Dempster *et al.* (1977), which has become a popular method for calculating maximum likelihood estimates for incomplete data.

The EM algorithm consists of two steps. In the first step, we invert the closed form solution of the transformed data, i.e., CDS spreads as specified in equation (6). By this inversion we create an equation that specifies the default process, λ_t, as a function of CDS spreads and the parameters α, β and σ. Then, based on the observed CDS spreads and a first guess for the parameters α, β and σ, we estimate the vector $(\lambda_1...\lambda_N)$, that is, one iteration for the time series of the default process. In the second step, using the estimated vector $\left(\widehat{\lambda}_1...\widehat{\lambda}_N\right)$ which we obtained in the first step, we maximize the likelihood function associated with the default process with respect to the parameter vector (α, β, σ), under the assumption that the previously unknown time series of the default process $(\lambda_1...\lambda_N)$ is now known by $\left(\widehat{\lambda}_1...\widehat{\lambda}_N\right)$. These two steps are repeated until the parameter vector converges, which is ensured by the fact that the likelihood function increases in each iteration.

In order to carry out the likelihood estimation in the second step of the EM algorithm as described above, we need the transition densities between two consecutive sampling points — that is, the density of $\lambda_{t+\Delta t}$ given λ_t, where Δt denotes the time distance between two sampling points. Feller (1951) showed that the transition densities of the default process are given by,

$$f\left(\lambda_{t+\Delta t}|\,\lambda_t, \theta\right) = c \cdot e^{-(u_t + v_{t+\Delta t})} \left(\frac{v_{t+\Delta t}}{u_t}\right)^{\frac{q}{2}} I_q\left(2 \cdot \sqrt{u_t \cdot v_{t+\Delta t}}\right) \tag{7}$$

where θ is the parameter vector to be estimated, $\theta = (\alpha, \beta, \sigma)$; $I_q\left(\cdot\right)$ is the modified Bessel function of the first kind and order q; and the following set of definitions,

$$
\begin{aligned}
c &= \frac{2\beta}{\sigma^2 \left(1 - \exp\left(-\beta\Delta t\right)\right)} \\
u_t &= c\lambda_t \exp\left(-\beta\Delta t\right) \\
v_{t+\Delta t} &= c\lambda_{t+\Delta t} \\
q &= \frac{2\alpha}{\sigma^2} - 1 \; .
\end{aligned}
$$

Based on the transition densities as specified in equation (7), it is now straightforward to

present the log-likelihood function as,

$$\ln L(\theta) = \qquad (8)$$

$$(N-1)\ln(c) + \sum_{t=1}^{T}\left[-(u_t + v_{t+\Delta t}) + 0.5q\ln\left(\frac{v_{t+\Delta t}}{u_t}\right) + \ln\left(I_q\left(2\cdot\sqrt{u_t\cdot v_{t+\Delta t}}\right)\right)\right]$$

where N denotes the number of observations. Based on equation (8), the estimate for the log-likelihood function is maximized in the second step of the EM algorithm by maximizing $\ln L(\theta)$ with respect to the parameter set $\theta = (\alpha, \beta, \sigma)$.

Finally, we define a few additional technical specifications regarding our parametrization. Throughout our estimation process we hold the recovery rate R constant at 40%, as commonly used in academic research and by market practitioners. Additionally, we assume the term-structure for the risk-free interest rate, r_t, is constant. Pan and Singleton (2008), based on Duffie and Singleton (2003), showed that CDS premiums are not sensitive to the level of interest rates. (We refer the reader to an extended discussion therein.) Therefore, we replace the stochastic risk-free rate in our model with a flat term-structure. We use 30-day Libor rates as the risk-free rate.

7   Data

We focused our analysis on the largest ETN issuers that also experience active trading for their CDS contracts: Barclays Bank PLC, which issues ETNs under *iPath*; Deutsche Bank AG, which issues ETNs under *PowerShares*; Morgan Stanley, which issues ETNs under *Market Vectors*; and UBS, which issues ETNs under *E-TRACS*. We collected data for all ETNs issued by these four firms from January 2006, when the first ETNs began trading, through December 2011. We downloaded our data from the TradeStation historical data platform. This sample includes 1-minute intraday transaction quotes for ETNs and 1-minute intraday indicative NAV quotes (INAV). The indicative quotes are posted by the exchange every 15 seconds and represent the underlying intrinsic value of the corresponding ETN. In other words, they represent the intraday underlying payment obligation of the issuing firm for each ETN, after accounting for fees, as determined in their prospectuses. Hence, our sample contains quotes for both market prices and intrinsic face values for the ETNs.

Using our 1-minute sample, for each day, for each ETN, we matched a pair of ETN and INAV quotes that were recorded at exactly the same minute, generally around 2:00 PM Eastern Standard Times. This pair constitutes our representative daily observation. We downloaded high frequency 1-minute quotes and not regular end-of-day prices to confirm that our daily

pairs of observations for ETN and INAV quotes overlap exactly in their time. If end-of-day quotes were used, we could not have ensured that we are comparing synchronized quotes. For example, if the last transaction for a specific ETN on a given trading day took place at 11:00 AM while its INAV quote was from 4:00 PM, these two quotes would be mismatched and the calculated premium or discount would be biased. To avoid such situations, we used intraday data, allowing a more refined treatment of the data to make sure our quotes are synchronized.

Since many ETNs started trading much later than January 2006, our sample in many cases begins later in time with varying start dates depending on the specific day of issuance of the particular ETN. Also, many ETNs experience very little trading activity, which makes their analysis much less meaningful. Therefore, we filtered our sample to include only ETNs that traded with a volume greater than 100,000 units per day. Our final sample includes the 17 most liquid ETNs and covers various market benchmarks, among them: oil, agriculture, metals, and other indices. A full description of our final sample is presented in Table 1.

In addition, we downloaded from Bloomberg CDS quotes for the four underwriting firms for the period from January 2000 through December 2011. We focused on 5-year contracts, which are considered the most liquid ones. Additionally, we selected CDS contracts only for senior, unsecured, unsubordinated debt, which is the type of debt ETNs satisfy. For Barclays Bank PLC, Deutsche Bank AG, and UBS, the contracts are denominated in euros, whereas for Morgan Stanley they are denominated in US dollars. Since we used our CDS data only for the purpose of fitting the parameters of the default intensity process, the currency denomination is not relevant as long as the CDS currency denomination matches that of its underlying bonds. We confirmed that this is indeed the case. See Figure 1 for the time series of CDS spreads.

8 Results

We divided our discussion on our estimation results into three sub-sections. We begin by discussing the set of results for the predicted price discounts, D_t, based on our benchmark model and implied by equation (4). We then report our second set of predicted price discounts using the extended versions, which account for incomplete accounting information by using an extended range of 30-day to 90-day maturity horizon. Finally, we present ETN real market premiums and discounts implied by real ETN prices and their INAVs. We compare real premiums and discounts with the predicted ones obtained in the first section.

8.1   Benchmark Model

Table 2 presents comparative summary statistics for the credit risk price discount D_t, as defined in equation (4), for all four issuers in our sample. We report all three estimates for our benchmark model: the original 1-week maturity, and the two extended maturity versions, with lower and upper bounds around the 30-day and 90-day horizons.

Mean predicted discounts using the original 1-week maturity are between 2 and 4 basis points for all issuers. Maximum values vary from one issuer to another. For Barclays, Deutsche Bank, and UBS, maximum discounts are around 10 basis points; and for Morgan Stanley around 45 basis points. Mean estimates increase as we increase the maturity horizon to 30 days and 90 days. For the 30-day lower bound, mean discounts are around 10 basis points for most issuers, and around 20 basis points for Morgan Stanley. For the 90-day upper bound, mean discounts are around 25 basis points for most issuers, and around 56 basis points for Morgan Stanley. Maximum values surpass 100 basis points, and for Morgan Stanley they surpass the 550 basis point level.

Note that discounts for the 30-day maturity are about four times as high as the 1-week maturity. Similarly, the 90-day maturity is around three times as high as the 30-day maturity. This means that credit risk price discounts increase linearly with time to maturity ΔT for our estimates, with a coefficient equal to 1.

The time series for all three measures are plotted in Figure 2. For Barclays, Deutsche Bank, and UBS, lower bound estimates generated by the 30-day discount mostly lie between 10 and 30 basis points after 2007. The upper bound 90-day discount mostly lies between 30 and 100 basis points after 2007. For Morgan Stanley the lower bound estimate of the 30-day discount mostly lies between 30 and 50 basis points; the upper bound 90-day discount mostly lies between 50 and 200 basis points during the same period, with highest levels exceeding 400 basis points.

In summary, our results imply that predicted price discounts are substantial and have ranged between 30 and 100 basis points since 2007. At the height of the credit events, predicted discounts reached levels of over 100 basis points for extended periods.

8.2   Real Market ETN Discounts

Table 4 provides summary statistics for real market premiums and discounts for all ETNs in our sample, grouped by issuer. In sharp contrast to the predicted results described above, there is very little evidence for consistent discounts. In fact, in many cases ETNs exhibit

periods of substantial price premiums. ETNs issued by Barclays mostly experience an average premium ranging from −5 basis points (discounts) to 7 basis points. There are two exceptions for Barclays, GAZ and INP, that experience a huge premium, with 221 and 159 basis points on average, respectively. At their peak, these two ETNs premiums were close to 3,000 basis points (a 30% premium), and at their low, a discount of 205 and 613 basis points, respectively. For the rest of Barclays' ETNs, maximum and minimum premiums range from −164 basis points to 185 basis points.

Similarly, for ETNs issued by Deutsche Bank, premiums and discounts are mostly around zero on average, with a slight tendency to be positive. Their premiums range from −347 to 328 basis points. One exception is the case of the ETN DAG, which experiences a higher premium on average (47 basis points) and is more volatile, with maximum and minimum premiums of 1,340 and −382 basis points, respectively.

Last, ETNs issued by UBS and Morgan Stanley have slightly positive price premiums of a few basis points on average. One exception in this case is the ETN CNY that has a discount of 14 basis points on average, with premiums ranging from −591 to 167 basis points.

Given the above evidence, we tested the hypothesis that average discounts for all ETNs are zero. The second block of results in Table 4 displays our t-test results. Indeed, confidence intervals for most ETNs' average discounts are non-negative at the 95% confidence level. In fact, the confidence intervals for some of Barclays' ETNs indicate very high positive average premiums — in the range of 200 basis points (GAZ, INP). The only exceptions are OIL, VXX and VXZ for Barclays, and CNY for Morgan Stanley, with slightly negative average discounts of a few basis points.

In addition to these summary statistics, we also present in Appendix 1 the time series for real market premiums plotted against our estimated theoretical ones for all ETNs in our sample. For the sake of the coherence of our discussion, we choose to compare only our middle size predicted discounts D_t, which are the ones implied by the 90-day horizon.[7] Two key features are common in most cases. First, premiums and discounts are very volatile for real market quotes, and often switch signs on a daily basis. However, they are all arranged as "noise" around the zero-line. This is consistent with our description above that in most cases their average is close to zero (see Table 4). Second, our theoretical premium estimates are always negative and bound real market premiums from below. That is, real market premiums rarely reach the levels of our theoretical discounts. There are a few exceptions to these two key

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[7]The three measures are highly correlated. Hence they represent the trend over time with some gap between them.

features (e.g., DAG and INP), but this is not the norm. We thus conclude that even though a significant discount ought to be priced into ETNs due to default risk, in reality, this is not done.

In addition to underpriced credit risk in ETNs, Appendix 1 displays another key feature: very little apparent correlation between the behavior of real market premiums and their theoretical predictions. In the next section we test for any such correlations.

9 Real & Implied Discount Correlation

To test for a potential relationship between real market discounts and our theoretical implied discounts, we ran two regressions: one using levels of real and theoretical premiums and another using their daily changes as follows:

$$D_{i,t} = \alpha + \beta \widetilde{D}_{i,t} + \varepsilon_{i,t} \tag{9}$$

and

$$\Delta D_{i,t} = \delta + \gamma \Delta \widetilde{D}_{i,t} + \mu_{i,t} \tag{10}$$

where $D_{i,t}$ and $\widetilde{D}_{i,t}$ are real discounts and theoretical discounts for ETN i at date t, correspondingly;[8] and $\Delta D_{i,t}$ and $\Delta \widetilde{D}_{i,t}$ are daily changes to real and theoretical discounts for ETN i at date t, respectively.

As a first step, we test that all our underlying variables are stationary, to exclude the case of spurious regressions and, thus, to make sure that our coefficient estimates for equations (9) and (10) are meaningful. In the next step we report regression results for all cases where unit roots were excluded.

Table 5 reports test statistics for Dicky-Fuller unit root tests. We reject the null hypothesis that our series contain a unit root at high significance levels for all ETN real discounts $(D_{i,t})$, for all ETN daily changes to real discounts $(\Delta D_{i,t})$, and for all daily changes to our theoretical discounts $(\Delta \widetilde{D}_{i,t})$. However, for levels of theoretical discounts $(\widetilde{D}_{i,t})$ we reject the unit root hypothesis for only 11 ETNs out of 17 at the 5% significance level, as reported in the fourth column in Table 5. For the remaining six ETNs, we cannot reject the hypothesis (DJP, OIL, VXX, VXZ, MLPI and XVIX). Thus, we conclude that for these six ETNs the discounts and theoretical discounts are not correlated.

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[8]See previous footnote for the choice of price discount measure. Also, as we mentioned earlier, the three measures of D_t for 1 week, 30 days, and 90 days are all linearly dependent by the time-to-maturity factor ΔT. Therefore, the choice of maturity does not make a difference for purpose of regression analysis.

Based on our results for the unit root tests, we continue to the next step and report estimation results for the 11 stationary ETNs for their levels regression, as specified in equation (9), and for all 17 ETNs for their daily changes regression, as specified in equation (10).

Table 6 presents regression results for the levels regression. Out of the 11 stationary ETNs, only nine have significant slope coefficients (β) at the 10% significance level. Of these, only seven ETNs have positive slopes. Surprisingly, the remaining two ETNs have significant negative slopes (DAG and DZZ). However, slope coefficients as well as adjusted R^2 values for most ETNs are extremely low, indicating very little correlation and explanatory power. The only two exceptions are CNY and INP. We thus conclude that in most cases there is very weak evidence for any correlation between the levels of real and theoretical ETN discounts.

Similarly, Table 7 presents our regression results for the daily changes regression as specified in equation (10). Again, only five ETNs have significant slope coefficients, out of which four have positive slopes (γ) and one has a negative slope (DGP). However, just as in the previous case for the levels regression, adjusted R^2 values are extremely low, indicating very little explanatory power. Thus, we conclude that the evidence for correlation between credit risk and ETN real discounts is very weak.

10   Alternative Measures for Credit Risk

In this section we study the robustness of our estimates and evaluate the methodology we chose compared to alternative market-implied measures for the same short-term credit risk: commercial paper, Libor-OIS spread, and short-term CDS data. In the next sub-sections we discuss credit risk spreads implied by these measures, compare them to our results, and discuss potential caveats and limitations associated with each alternative measure.

10.1   Commercial Paper

Commercial paper is a short-term debt security with maturities that range from one day to 270 days and are primarily issued by financial institutions. As debt securities, they are subject to default risk. Their implied credit spreads could be perceived as another estimate for the compensation the market demands for the issuer's default risk until maturity. The relevant time horizon for counterparty credit risk in ETNs is one week (as discussed earlier); therefore, one could potentially estimate that the relevant theoretical credit spread that should be priced into each ETN is identical to the one implied by 1-week commercial paper for the same issuer. Unfortunately, historical data for single issuer commercial paper yields is

not easily available and we were unable to locate such data for the four financial institutions in our sample: Barclays, Deutsche Bank, Morgan Stanley, and UBS. However, Bloomberg generates several indices for commercial paper historical yields for various maturities and various credit ratings. We focus on 1-week maturity yields for three credit rating groups, as they are defined by Bloomberg: Top-Top rated, Top rated, and Low rated. We use indices for non-asset-backed commercial paper only.

The time series for credit spread indices for all three credit rating classes are plotted in Figure 4. It is clear that all credit spreads for the 1-week maturity are very low. As can be seen in Figure 4, indicative yields for Top-Top and Top rated commercial paper rarely exceed the range of 10-20 basis points. These spreads translate into a pricing discount of no more than one basis point for a note with one week to maturity. At the height of the credit events in 2007-2008, commercial paper spreads reached levels of 100 and 400 basis points several times. These spreads translate into weekly price discounts of approximately 2 and 8 basis points, respectively. The Low rated commercial paper frequently reached spreads of 100 basis points, and at the height of credit events in 2007-2009, they experienced spreads between 200-400 basis points for extended periods. However, even these highest rates translate into weekly price discounts in the range of only 4 to 8 basis points.

The magnitudes of these weekly price discounts implied by commercial paper do not support our estimates based on the 5-year CDS data we used. These results may suggest that our estimates amplify the impact of credit risk. Moreover, credit spreads implied by commercial paper suggest that, in fact, the impact of counterparty credit risk on ETN pricing is negligible, or at least econometrically inseparable from the daily ETN premium and discount noise observed in the data around its face value. However, there are several problems with using commercial paper rates to gauge the price of short-term credit risk.

First, the available commercial paper data is only aggregate data, and it is unclear to what extent even Low rated commercial paper yields accurately represent the credit risk of our four individual financial firms. Figure 1 presents CDS spreads for these issuers. Note that CDS spreads vary from one underlying entity to another. Additionally, since 2007 their spreads have rarely dropped below 100 basis points, and have mostly traded in the range of 100-200 basis points. These are substantially higher spreads than those of Low rated commercial paper.

Second, commercial papers are typically purchased at issuance and are held until maturity; there is little trading activity for outstanding commercial paper series. Moreover, commercial papers are typically issued via dealers who charge fees which vary, depending on the

issuer's credit history, issuance size, and market conditions. Dealers also typically purchase positions that do not sell in the market (see Kacperczyk and Schnabl (2009)). This trading environment creates biases in reported prices, both because of illiquidity issues and the fact that some price components remain unobserved and unknown.

Third, and most importantly, starting in mid-2007 the Federal Reserve made massive efforts to prevent the collapse of the commercial paper market, intervening with substantially influential policies. For example, in September 2007 the Federal Reserve initiated a short-term lending program (TAF) to support short-term liquidity needs of financial firms. In September 2008 the Federal Reserve Bank of Boston launched a program that indirectly provided guarantees for commercial paper (AMLF program). Finally, in October 2008 the Federal Reserve announced that it would purchase commercial paper directly from eligible issuers at a set rate (CPFF program). With these policies the Fed essentially stepped in and supported the demand for commercial paper by replacing investors that had left the market. For an extensive review of these policies and their consequences see Kacperczyk and Schnabl (2009). These massive interventions undoubtedly altered the "market price" of risk and it is highly questionable to what extent commercial paper rates during these years reflect the risk of default.

10.2   Libor-OIS Spread

The Libor spread is an additional measure relevant to short-term credit risk. Libor is the interest rate at which banks lend funds to one another or borrow funds from one another. Libor is often measured as a spread from other risk-free benchmark rates in the market. One widely used risk-free benchmark rate is the Overnight Indexed Swap (OIS) rate, which is an interest rate swap where the periodic floating rate of the swap is the federal funds overnight rate for every day of the swap period. In other words, it is the conversion of the floating federal funds overnight rate into a fixed rate over the life of the swap. The federal funds overnight rate is the risk-free cost of borrowing for the banking system from the central bank, and thus expresses the cost of risk-free liquidity. The spread between Libor and OIS is the banks' additional cost of borrowing above the basic cost of liquidity. Therefore, it is considered to be a measure of health of the banking system as it measures how likely borrowing banks will default. Put differently, Libor-OIS spread reflects counterparty credit risk premiums in contrast to liquidity risk premiums.

We used 1-week Libor-OIS spreads, i.e., the difference between 1-week Libor rates and 1-week OIS rates, as a proxy for 1-week credit risk spreads of the banking system. Again, we are interested in comparing this measure with our estimates which we based on 5-year CDS

contracts. The time series for Libor-OIS spreads are plotted in Figure 5. As can be seen, Libor-OIS spreads are very similar in magnitude to those of commercial paper as presented in the previous section and in Figure 4. Libor-OIS spreads are mostly around 10-20 basis points. Only at the height of the credit events in 2008-2009 did Libor-OIS spreads reach the level of 100 basis points, with a brief peak at 400 basis points. As we explained earlier, these rates translate into price discounts of no more than several basis points for the 1-week maturity.

Indeed, Libor-OIS spreads are not consistent with the estimates we calculated based on CDS prices. However, similar to the case of commercial paper, Libor rates have limited informative value as they are a composite of rates quoted by 16 different banks, and as such, need not represent the credit risk of any single defaultable entity. Moreover, Libor rates have been highly criticized over the past few years with allegations that they have been subject to manipulation, and that reported rates by the Libor contributing banks do not represent actual rates of borrowing.[9] Therefore, the reliability of this measure is highly questionable in gauging the credit risk of the banking system in general, and even more so for firm-specific credit risk.

10.3   Additional CDS Maturities

Ideally, the most accurate measure for the 1-week credit spread for an individual issuer would be its 1-week CDS premium. However, CDS contracts do not trade with such short maturities. Nevertheless, they do trade with maturities shorter than 5 years, where the shortest maturities are 6 months and 1 year. These contracts started trading much later than the 5-year maturity and their liquidity has not picked up as that of the 5-year maturity. For these reasons we base our analysis on 5-year contracts. However, as a robustness test for our results we examined how close the default intensities implied by the 6-month and 1-year maturities are compared to those implied by the 5-year contracts. This comparison has implications for both our benchmark model estimates and our lower bound intensity-approach estimates, as they both build on extracting the default intensity λ_t from CDS prices. Note that while data were not always available for these short CDS maturities, we used the best available data we could locate for purposes of comparison.

We used the following methodology. We repeated the same estimation process for the default intensity as described in Section 6, this time using historical data for 6-month and 1-year CDS contracts. Therefore, all together, for each date t in our sample we now have three estimated

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[9]See: "*Cleaning up LIBOR*", The Economist, April 14, 2012.

default intensities: $\widehat{\lambda}_t^{0.5}, \widehat{\lambda}_t^1$ and $\widehat{\lambda}_t^5$, for the 6-month, 1-year, and 5-year CDS maturities, respectively. We then compared the time series for the three estimated intensities. The results are reported in Figure 6. As can be seen, for the 6-month and 1-year tenors the intensities rarely diverge from one another and, in fact, they almost coincide. This means that the very short end of the default intensity term-structure is essentially flat. However, their difference from the 5-year estimated intensity varies over time. During times of severe stress in 2009, 2010 and 2011, all three measures are very close. On the other hand, during limes of reduced stress, the intensity implied by the 5-year CDS is higher than those implied by the 6-month and 1-year maturities. This means that during times of stress the intensity term-structure tends to be flat, while during normal times the term-structure increases after the 1-year maturity.

Additionally, we report in Figure 7 the time series for the estimated ETN discounts $\widetilde{D}_{i,t}^{0.5}, \widetilde{D}_{i,t}^1$ and $\widetilde{D}_{i,t}^5$, implied by each default intensity estimate $\widehat{\lambda}_t^{0.5}, \widehat{\lambda}_t^1$ and $\widehat{\lambda}_t^5$, respectively. The results are qualitatively identical to those attained by the default intensity and follow the same pattern. During the three peaks of credit stress in 2009, 2010, and 2011, for each ETN issuer, all three measures for ETN discounts $\widetilde{D}_{i,t}^{0.5}, \widetilde{D}_{i,t}^1$, and $\widetilde{D}_{i,t}^5$, converge. For most issuers, discount levels reached the levels of 50-100 basis points during these times. Only Morgan Stanley reached higher levels of above 200 basis points, and briefly peaking at about 1,000 basis points. During times of least credit stress, the discounts implied by the 6-month and 1-year tenors are about half of those implied by the 5-year tenor and reached levels of 20 basis points across all issuers. In all other times the discounts implied by the 6-month and 1-year tenors were between these two extreme levels, but lower than the 5-year maturity.

These results have several implications with regard to our estimates for the default intensity rates and their implied ETN discounts. First, during times of credit stress, the choice of point on the CDS term-structure is irrelevant for the estimation process, as the term-structure for the intensity rate tends to be flat. Second, even during normal times the short end of the term-structure still remains flat, and thus imposes a lower bound on the magnitude of the intensity rate. Third, even though during normal times the short-end of the intensity term-structure is significantly lower than that of the 5-year point, implied credit risk discounts by the short-end remain sizeable, in the range of 20 to 30 basis points.

11 Summary

In this paper we addressed the issue of counterparty credit risk for ETNs. These notes are essentially equivalent to very short-term unsecured debt securities with time to maturity of

approximately a week. We applied several strategies in order to estimate the discount that ought to be priced into such notes from a theoretical point of view and in combination with real market measures for credit risk. All our predicted discounts show that a substantial price discount should be priced into ETNs, despite their very short-term maturity. These price discounts generally range from 50 to 100 basis points, with some variation depending on the issuing entity and the particular date. However, in sharp contrast, we found no evidence for pricing credit risk for ETNs in real market premiums and discounts. Specifically, ETNs were found mostly to be overpriced and not to experience consistent discounts. Additionally, we found no correlation between ETN premiums and discounts and our market-based measures of credit risk and implied discounts.

These findings suggest that investors in ETNs do not fully understand the product structure and ignore major risks associated with it, a fact which has important implications for regulatory policy. It stresses the need for greater transparency in complex financial products and the disclosure of unambiguous measures to gauge embedded risks. Such transparency could better equip investors to understand the complexity of such products and consequently to make better decisions regarding their risks.

References

Arora, N., P. Gandhi and F. Longstaff, 2012, "Counterparty credit risk and the credit default swap market", *Journal of Financial Economics*, 103, 280–293.

Canabarro E. and D. Duffie, 2003, "Measuring and Marking Counterparty Risk", In *Asset/Liability Management of Financial Institutions*, Tilman, L.M. , London, UK: Euromoney Books.

Collin-Dufresne, P., R.S. Goldstein, and J.S. Martin, 2001, "The Determinants of Credit Spread Changes", *Journal of Finance*, 56, 2177–2207.

Cooper, I.A. and A.S. Mello, 1991, "The Default Risk of Swaps", *Journal of Finance*, 1991, 46, 597-620.

Dempster, A. P., N. M. Laird, and D. B. Rubin, 1977, Maximum Likelihood from Incomplete Data via the EM Algorithm, *Journal of the Royal Statistical Society*, Series B, Vol. 39, No. 1, pp. 1-38.

Duffie, D., 1999, "Credit Swap Valuation", *Financial Analysts Journal*, 55, 73–87.

Duffie, D. and M. Huang, 1996, "Swap Rates and Credit Quality", *The Journal of Finance*, 51, 921-49.

Duffie, D. and D. Lando, 2001, "Term Structures of Credit Spreads with Incomplete Accounting Information", *Econometrica*, 69, 633–664.

Duffie, D., J. Pan, and K.J. Singleton, 2000, "Transform Analysis and Asset Pricing for Affine Jump-Diffusions", *Econometrica*, 68, 1343–1376.

Duffie, D. and K.J. Singleton, 1997, "An Econometric Model of the Term Structure of Interest-Rate Swap Yields", *Journal of Finance,* 52, 1287–1321.

Duffie, D. and K.J. Singleton, 1999, "Modeling the Term Structures of Defaultable Bonds", *Review of Financial Studies*, 12, 687-720.

Duffie, D., and K. J. Singleton, 2003, "Credit Risk", Princeton, NJ: Princeton University Press.

Duffie, D. and H. Zhu, 2011, "Does a Central Clearing Counterparty Reduce Counterparty Risk?", *Review of Asset Pricing Studies*, 2011, Volume 1: 74-95.

Eom, Y.H., J. Helwege, and J. Huang, 2004, "Structural Models of Corporate Bond Pricing: An Empirical Analysis", *Review of Financial Studies*, 17, 499–544.

Elton, E.J., M.K. Gruber, D. Agrawal, and C. Mann, 2001, "Explaining the Rate Spread on Corporate Bonds", *Journal of Finance*, 56, 247–277.

Feller, W., 1951, Two Singular Diffusion Problems, *Annals of Mathematics*, Vol. 54, No. 1, pp. 173-182.

Gregory, J., 2010, *Counterparty Credit Risk: The New Challenge for Global Financial Markets*, John Wiley & Sons, West Sussex, United Kingdom.

Gupta, A. and M.G. Subrahmanyam, 2000, "An Empirical Examination of the Convexity Bias in the Pricing of Interest Rate Swaps", *Journal of Financial Economics*, 55, 239-279.

Huge, B. and D. Lando, 1999, "Swap Pricing with Two-Sided Default Risk in a Rating-Based Model", *European Finance Review*, 3, 239–268.

Hull, J.C., and A. White, ,2001, Valuing credit default swaps II: modeling default correlations, *Journal of Derivatives*, 8,12–21.

Jarrow, R. A. and F. Yu, 2001, "Counterparty Risk and the Pricing of Defaultable Securities", *Journal of Finance*, 56, 1765–1799.

Jones, E.P., S.P. Mason, and E. Rosenfeld, 1984, "Contingent claims analysis of corporate capital structures: An empirical investigation", *Journal of Finance,* 39, 611–625.

Kacperczyk, M. and P. Schnabl, 2010, "When Safe Proved Risky: Commercial Paper during the Financial Crisis of 2007–2009", *Journal of Economic Perspectives*, 24, 29–50.

Lando, D., 1998, "On Cox Processes and Credit Risky Securities", *Review of Derivatives Research*, 2, 99–120.

Levy, A., 2010, "Liquidity and Counterparty Risk Effects in CDS Pricing: an Application to Emerging Markets Sovereign Debt", Working Paper.

Litzenberger, R.H., 1992, "Swaps: Plain and Fanciful", *Journal of Finance*, 47, 831-850.

Liu, J., F.A. Longstaff, and R.E. Mandell, 2006, "The Market Price of Risk in Interest Rate Swaps: The Roles of Default and Liquidity Risk", *Journal of Business*, 79, 2337-2359.

Longstaff, F.A. , S. Mithal and E. Neis, 2005, "Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit Default Swap Market", *Journal of Finance*, 60, 2213-2253.

Longstaff, F. and E. Schwartz, 1995, "A simple approach to valuing risky fixed and floating rate debt", *Journal of Finance,* 50, 789-819.

Minenna, M., 2011, "Enter the quant regulator", *Risk Magazine*, May 2011.

Minton, B., 1997, "An Empirical Examination of Basic Valuation Models for Plain Vanilla US Interest Rate Swaps", *Journal of Financial Economics*, 44, 251–277.

Pan, J., and K. J. Singleton, 2008, "Default and Recovery Implicit in the Term Structure of Sovereign CDS Spreads", *Journal of Finance*, 63, 2345-2384.

Sorensen, E.H. and T.F. Bollier, 1994, "Pricing Swap Default Risk", *Financial Analyst Journal*, 50, 23-33.

Yu, F., 2005, Accounting Transparency and The Term Structure of Credit Spreads, *Journal of Financial Economics*, 75, 53–84.

Table 1

Sample Summary Statistics

Issuer	ETN	Start Date	End Date	No. of Obs.	Underlying Index
Barclays	DJP	08.07.2006	31.12.2011	1393	Dow Jones-UBS Commodity Index
Barclays	GAZ	10.24.2008	31.12.2011	1004	Dow Jones-UBS Natural Gas Subindex
Barclays	INP	12.26.2006	31.12.2011	1263	MSCI India Index
Barclays	JJC	11.02.2007	31.12.2011	916	Dow Jones-UBS Copper Subindex
Barclays	JJG	10.24.2007	31.12.2011	993	Dow Jones-UBS Grains Total Return Subindex
Barclays	OIL	08.16.2006	31.12.2011	1333	S&P GSCI Crude Oil
Barclays	VXX	01.30.2009	31.12.2011	730	S&P 500 VIX Short-Term Futures
Barclays	VXZ	01.30.2009	31.12.2011	704	S&P 500 VIX Mid-Term Futures
DB	DAG	04.16.2008	31.12.2011	924	Agriculture Double Long
DB	DGP	02.28.2008	31.12.2011	953	Gold Double Long
DB	DGZ	03.03.2008	31.12.2011	835	Gold Short
DB	DTO	06.17.2008	31.12.2011	861	Crude Oil Double Short
DB	DZZ	02.29.2008	31.12.2011	960	Gold Double Short
MS	CNY	03.18.2008	31.12.2011	641	Chinese Renminbi
MS	DRR	05.08.2008	31.12.2011	853	Double Short Euro
UBS	MLPI	04.01.2010	31.12.2011	431	Alerian MLP Infrastructure Index
UBS	XVIX	12.01.2010	31.12.2011	179	Daily Long-Short VIX

Table 2

Implied Theoretical Discounts - Benchmark Model

Based on 5-Year CDS Data

Basis Points

Issuer	1-Week Discount				30-Day Discount				90-Day Discount			
	Mean	Std	Min	Max	Mean	Std	Min	Max	Mean	Std	Min	Max
Barclays	2.1	1.9	0.4	8.2	9.0	8.1	1.8	35.3	26.9	24.1	5.5	105.1
DB	1.9	1.4	0.6	9.1	8.0	6.1	2.3	39.1	23.9	18.1	7.0	116.5
MS	4.5	4.7	0.9	45.5	19.1	20.0	3.8	192.4	56.8	58.9	11.4	558.3
UBS	2.0	2.0	0.4	10.6	8.7	8.4	1.7	45.2	26.1	25.0	5.2	134.6

Table 4

Real Market ETN Discounts: Summary Statistics

Basis Points

Issuer	ETN	Real Market Premium				H_0: Discount = 0			
		Mean	Std	Min	Max	Standard Error	t-Stat	95% Confidence Interval	
Barclays	DJP	7.34	16.41	-63.42	105.39	0.44	16.68	6.47	8.20
Barclays	GAZ	221.72	382.82	-205.20	2964.54	12.08	18.35	198.01	245.42
Barclays	INP	159.49	335.22	-613.64	2629.30	9.43	16.91	140.99	178.00
Barclays	JJC	2.10	30.46	-164.73	185.27	1.01	6.53	0.12	4.07
Barclays	JJG	1.59	12.50	-76.23	102.29	0.40	4.00	0.81	2.36
Barclays	OIL	-0.98	10.94	-55.71	49.14	0.30	-3.26	-1.57	-0.39
Barclays	VXX	-2.43	19.14	-66.67	65.37	0.71	-3.43	-3.82	-1.04
Barclays	VXZ	-5.51	17.65	-103.68	68.13	0.67	-8.28	-6.82	-4.21
DB	DAG	47.13	171.73	-382.77	1340.83	5.65	8.34	36.05	58.22
DB	DGP	0.21	42.62	-286.14	269.34	1.38	0.15	-2.50	2.91
DB	DGZ	0.94	22.20	-301.77	106.27	0.77	1.22	-0.57	2.44
DB	DTO	0.64	13.83	-84.58	90.13	0.47	1.36	-0.28	1.57
DB	DZZ	1.93	44.09	-347.27	328.56	1.42	1.35	-0.87	4.72
MS	CNY	-14.42	71.55	-591.36	167.42	2.83	-5.10	-19.97	-8.87
MS	DRR	2.85	35.42	-237.43	220.50	1.21	2.35	0.47	5.23
UBS	MLPI	4.10	13.77	-38.31	82.16	0.66	6.19	2.80	5.41
UBS	XVIX	4.46	21.96	-75.79	71.43	1.64	2.72	1.22	7.70

Table 5

Dicky-Fuller Test Statistic for Unit Root Tests

Test Statistics & P-Values

Issuer	Ticker	Levels		Daily Changes	
		Real Discount	**Est. Discount**	**Real Discount**	**Est. Discount**
Barclays	DJP	-5.94	-2.07	-20.22	-17.41
		0.00	*0.26*	*0.00*	*0.00*
Barclays	GAZ	-5.01	-3.85	-33.90	-24.26
		0.00	*0.02*	*0.00*	*0.00*
Barclays	INP	-7.00	-2.87	-21.10	-26.81
		0.00	*0.05*	*0.00*	*0.00*
Barclays	JJC	-29.41	-3.17	-15.56	-17.47
		0.00	*0.02*	*0.00*	*0.00*
Barclays	JJG	-29.41	-2.98	-16.35	-17.10
		0.00	*0.04*	*0.00*	*0.00*
Barclays	OIL	-15.71	-2.02	-17.70	-11.20
		0.00	*0.28*	*0.00*	*0.00*
Barclays	VXX	-8.42	-2.20	-15.16	-23.28
		0.00	*0.26*	*0.00*	*0.00*
Barclays	VXZ	-6.36	-2.48	-19.77	-19.49
		0.00	*0.12*	*0.00*	*0.00*
DB	DAG	-4.99	-4.45	-15.68	-22.44
		0.00	*0.00*	*0.00*	*0.00*
DB	DGP	-12.60	-4.30	-17.48	-24.60
		0.00	*0.00*	*0.00*	*0.00*
DB	DGZ	-24.92	-4.55	-17.68	-17.47
		0.00	*0.00*	*0.00*	*0.00*
DB	DTO	-27.38	-4.59	-16.75	-22.13
		0.00	*0.00*	*0.00*	*0.00*
DB	DZZ	-28.07	-4.44	-16.99	-23.78
		0.00	*0.00*	*0.00*	*0.00*
MS	CNY	-2.88	-3.41	-15.33	-6.10
		0.05	*0.01*	*0.00*	*0.00*
MS	DRR	-9.37	-3.20	-24.99	-6.03
		0.00	*0.02*	*0.00*	*0.00*
UBS	MLPI	-5.14	-2.17	-17.19	-14.58
		0.00	*0.22*	*0.00*	*0.00*
UBS	XVIX	-5.40	-0.36	-9.86	-14.41
		0.00	*0.91*	*0.00*	*0.00*

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Table 6

Regression Results for Levels:

$$D_t = \alpha + \beta \tilde{D}_t + \epsilon_t$$

Coefficient Estimates and P-Values

Issuer	ETN	Const. α	Slope β	$\overline{R}^2$
Barclays	GAZ	429.34	4.02	0.04
		0.00	*0.00*	
Barclays	INP	199.74	0.89	0.00
		0.00	*0.03*	
Barclays	JJC	-2.09	-0.08	0.00
		0.50	*0.16*	
Barclays	JJG	4.45	0.06	0.01
		0.00	*0.01*	
DB	DAG	-232.27	-6.15	0.26
		0.00	*0.00*	
DB	DGP	8.29	0.18	0.00
		0.08	*0.08*	
DB	DGZ	-3.04	-0.09	0.00
		0.24	*0.11*	
DB	DTO	3.72	0.07	0.00
		0.03	*0.06*	
DB	DZZ	-6.08	-0.18	0.00
		0.22	*0.09*	
MS	CNY	66.94	0.74	0.48
		0.00	*0.00*	
MS	DRR	11.07	0.07	0.02
		0.00	*0.00*	

Table 7

Regression Results for Changes:

$$\Delta D_t = \delta + \gamma \Delta \tilde{D}_t + \mu_t$$

Coefficient Estimates and P-Values

| Issuer	ETN	Const. δ	Slope γ	$\overline{R}^2$
Barclays	DJP	-0.01	0.33	0.00
		0.91	*0.03*	
Barclays	GAZ	0.10	0.82	0.00
		0.98	*0.53*	
Barclays	INP	0.57	11.03	0.02
		0.93	*0.00*	
Barclays	JJC	-0.01	0.39	0.00
		0.99	*0.35*	
Barclays	JJG	0.01	0.16	0.00
		0.98	*0.38*	
Barclays	OIL	0.00	-0.17	0.00
		0.99	*0.25*	
Barclays	VXX	-0.02	0.08	0.00
		0.98	*0.80*	
Barclays	VXZ	0.03	0.29	0.00
		0.97	*0.34*	
DB	DAG	1.09	1.13	0.00
		0.78	*0.47*	
DB	DGP	-0.21	-1.69	0.00
		0.91	*0.03*	
DB	DGZ	0.06	-0.12	0.00
		0.95	*0.75*	
DB	DTO	0.03	0.78	0.01
		0.97	*0.00*	
DB	DZZ	0.04	0.18	0.00
		0.98	*0.82*	
MS	CNY	-0.02	0.44	0.04
		0.99	*0.00*	
MS	DRR	0.04	0.11	0.00
		0.97	*0.12*	
UBS	MLPI	-0.06	-0.19	0.00
		0.94	*0.61*	
UBS	XVIX	-0.23	0.64	0.01
		0.90	*0.32*	

</div>

FIGURE 1: 5-YEAR CDS SPREADS

BASIS POINTS
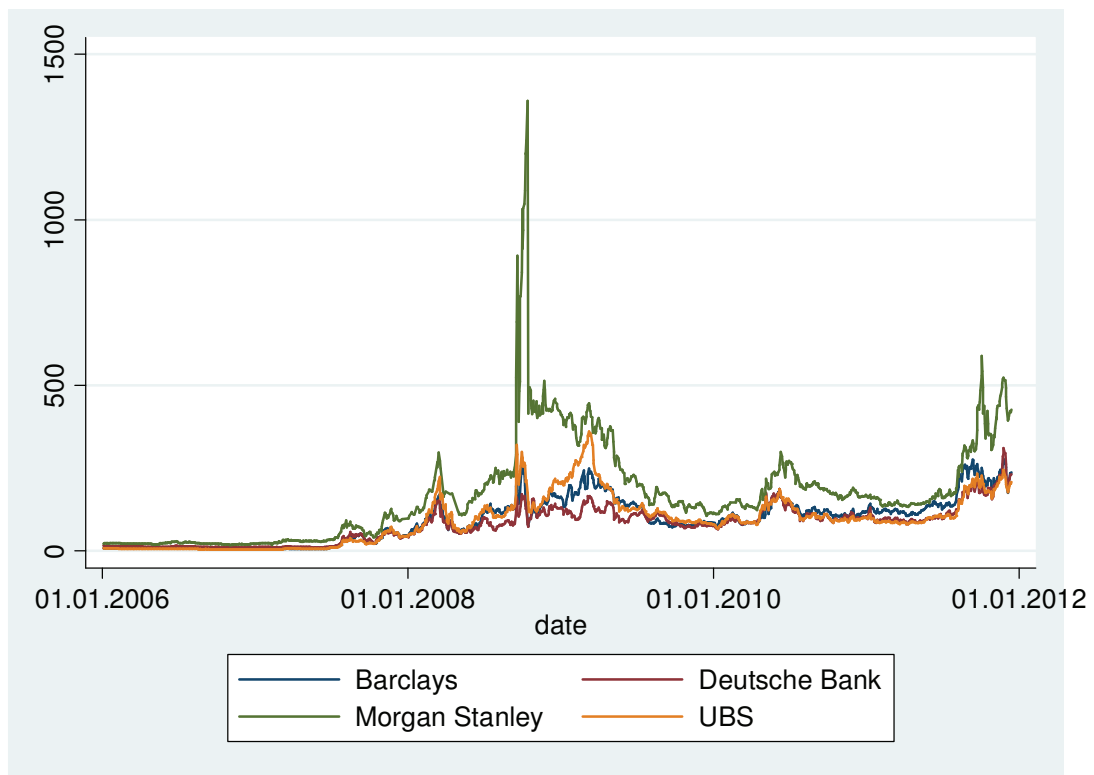
FIGURE 2: TIME-SERIES OF THEORETICAL DISCOUNTS

BENCHMARK MODEL

BASIS POINTS
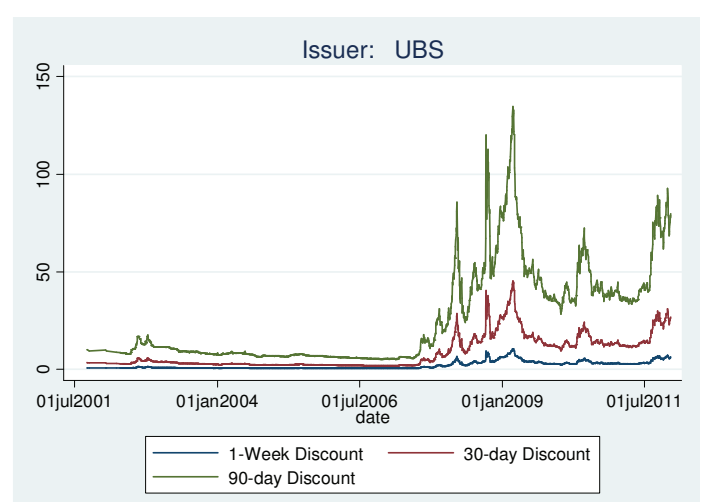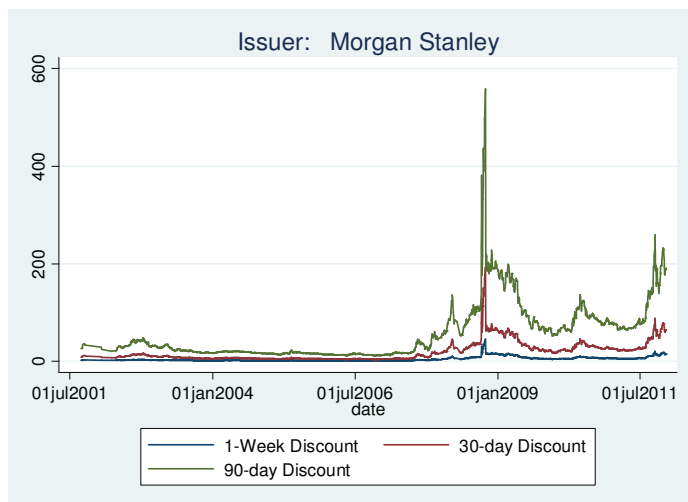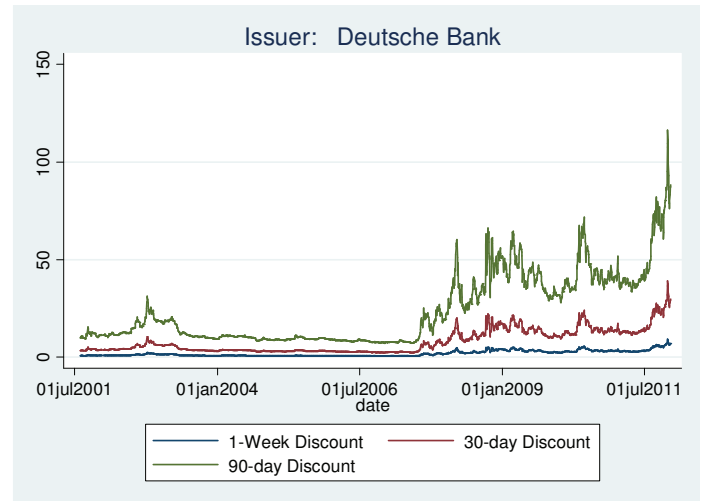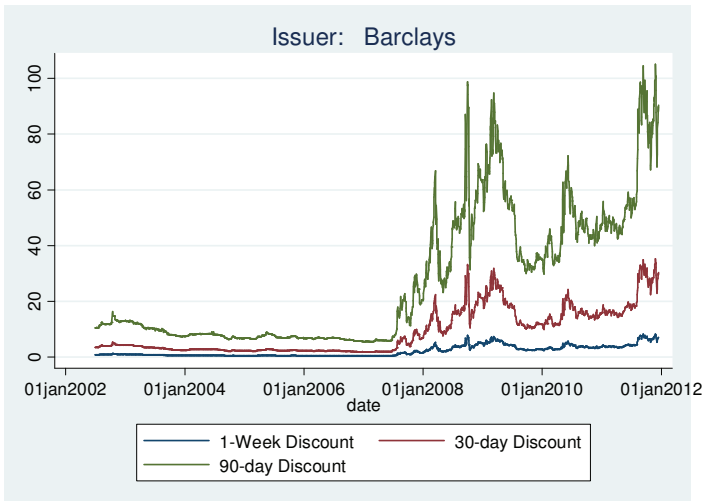
FIGURE 4: COMMERCIAL PAPER ANNUAL CREDIT SPREADS

BLOOMBERG INDEX PER CREDIT RATING

BASIS POINTS

Bloomberg Commercial Paper Index
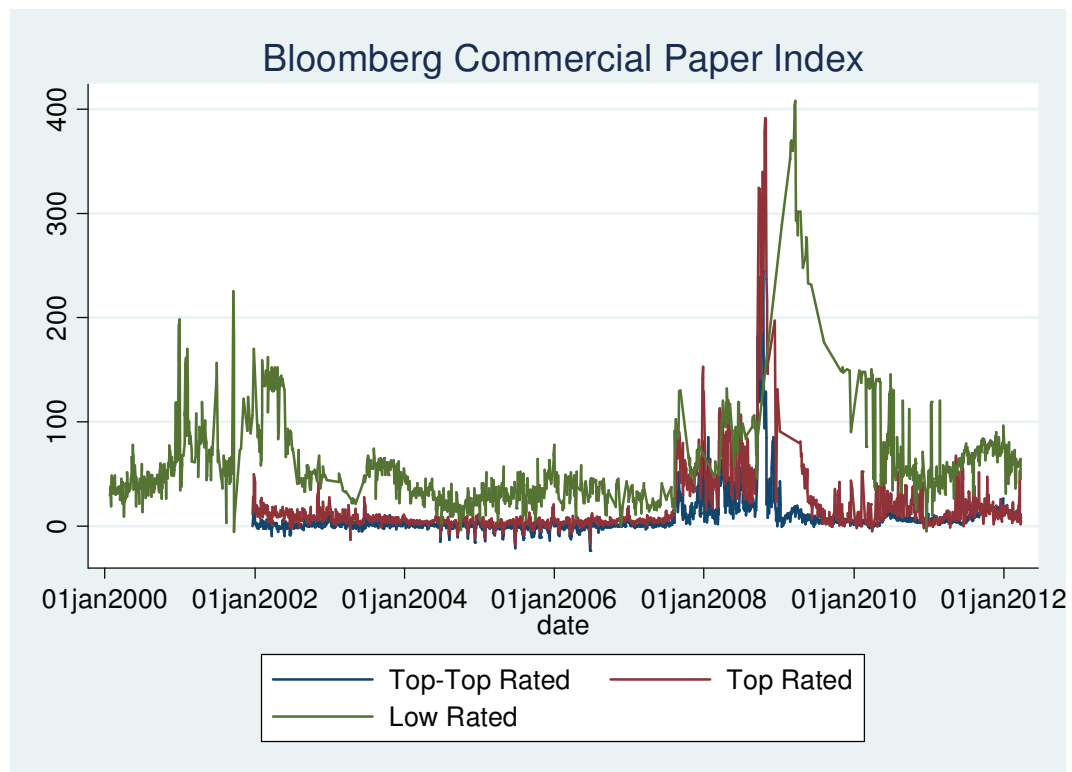
FIGURE 5: LIBOR-OIS 1-WEEK SPREAD

BASIS POINTS

Libor-OIS 1 Week Spread
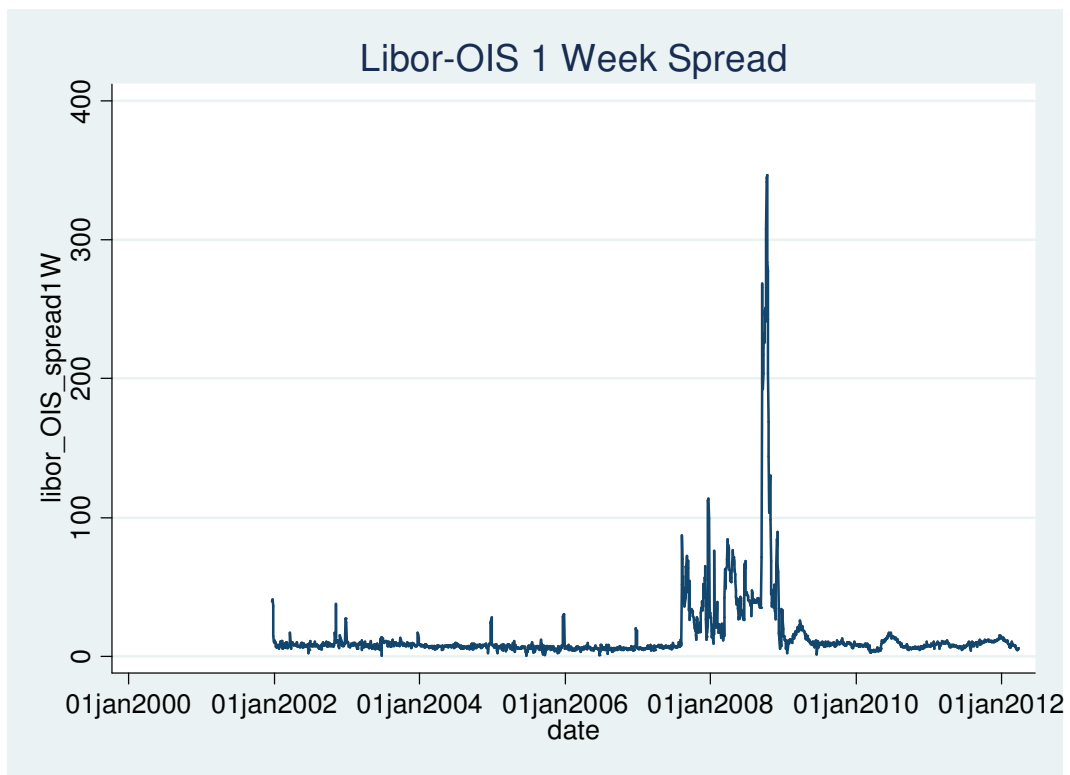
FIGURE 6: TIME-SERIES OF INTENSITY PARAMETER

PER TENOR

BASIS POINTS
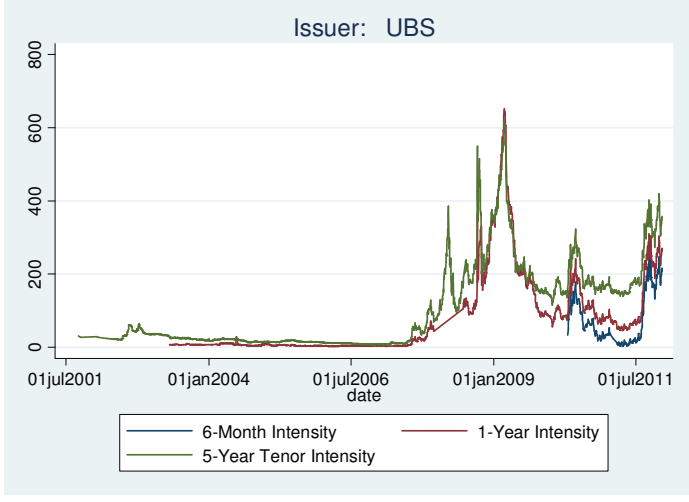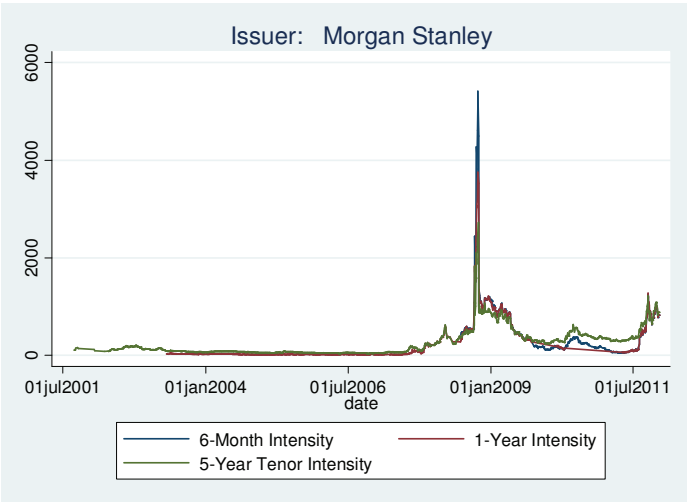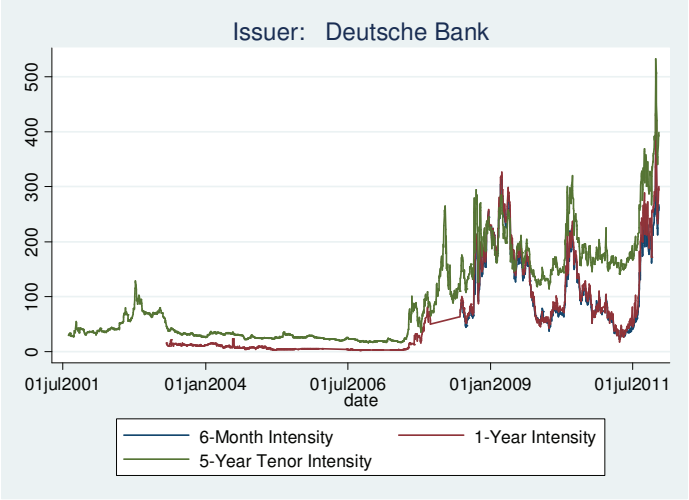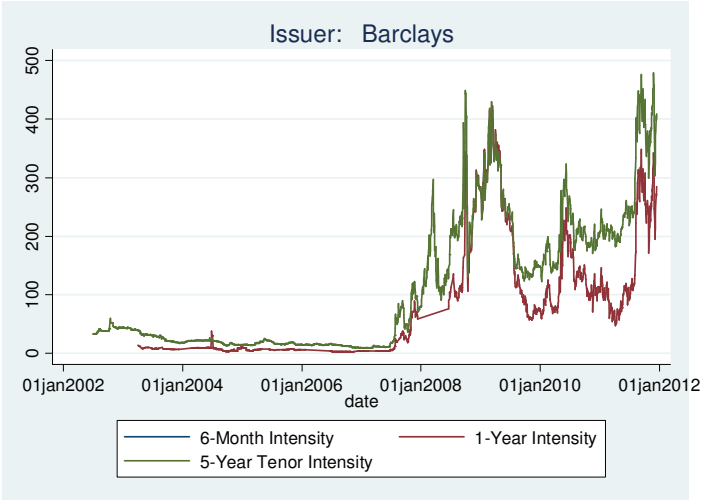
FIGURE 7: TIME-SERIES OF THEORETICAL DISCOUNTS

BENCHMARK MODEL PER TENOR

BASIS POINTS
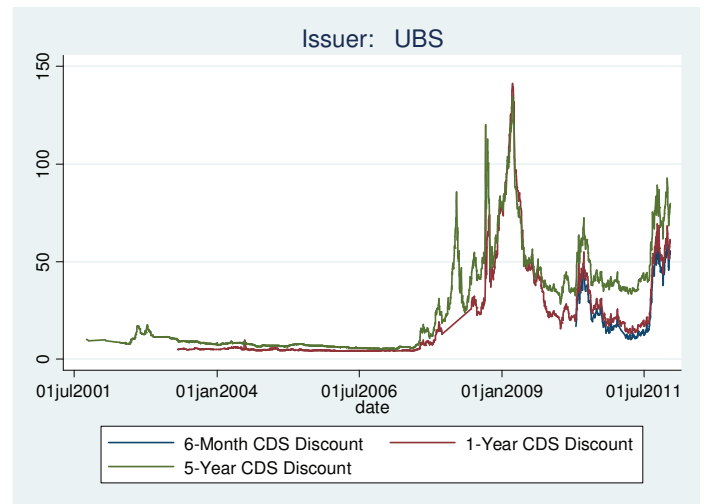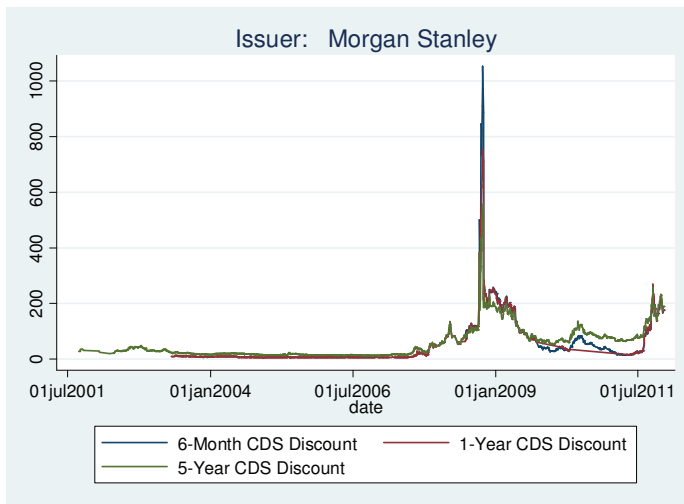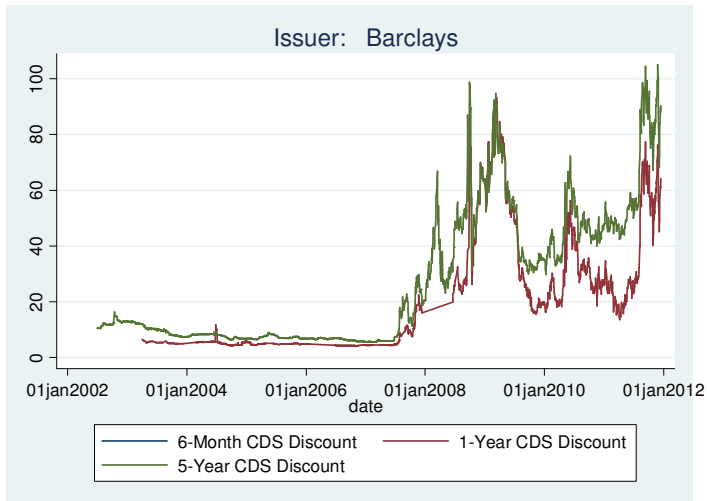
APPENDIX 1: TIME-SERIES OF REAL AND IMPLIED THEORETICAL DISCOUNTS

I. Barclays Bank PLC (*iPath*):

Ticker: DJP   Issuer: Barclays Bank PLC

Ticker: GAZ   Issuer: Barclays Bank PLC

Ticker: INP   Issuer: Barclays Bank PLC

Ticker: JJC   Issuer: Barclays Bank PLC
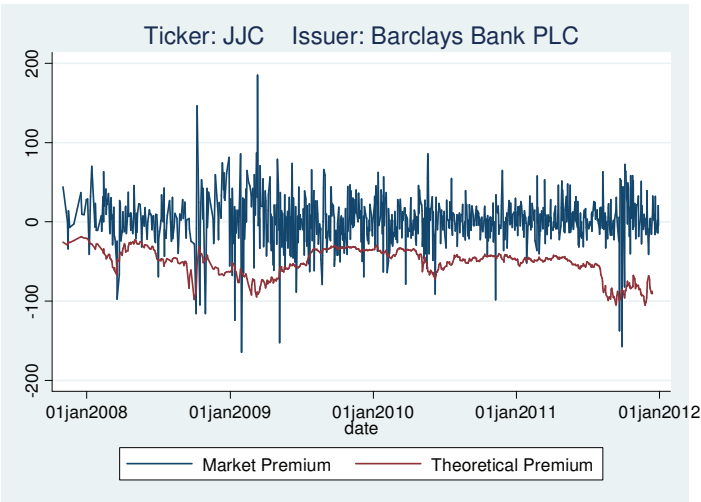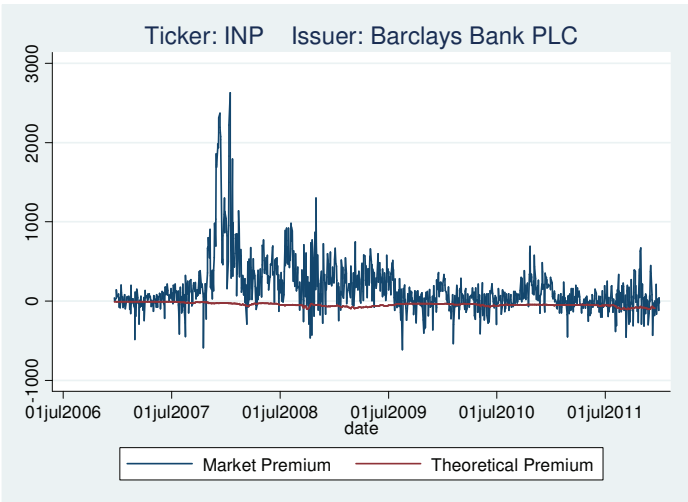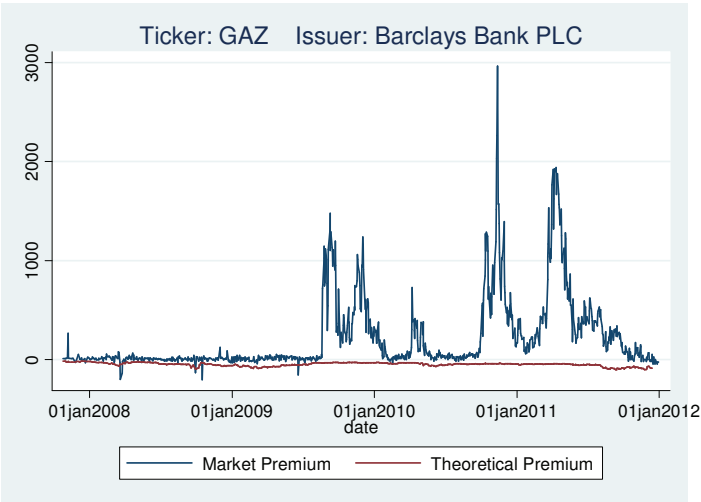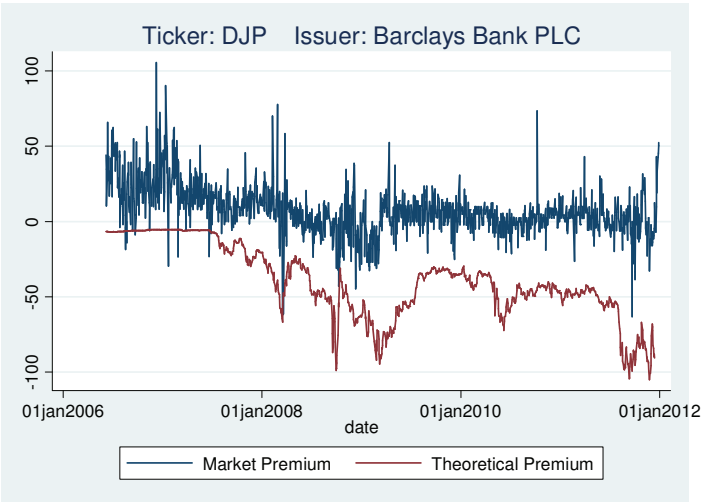
APPENDIX 1: TIME-SERIES OF REAL AND IMPLIED THEORETICAL DISCOUNTS

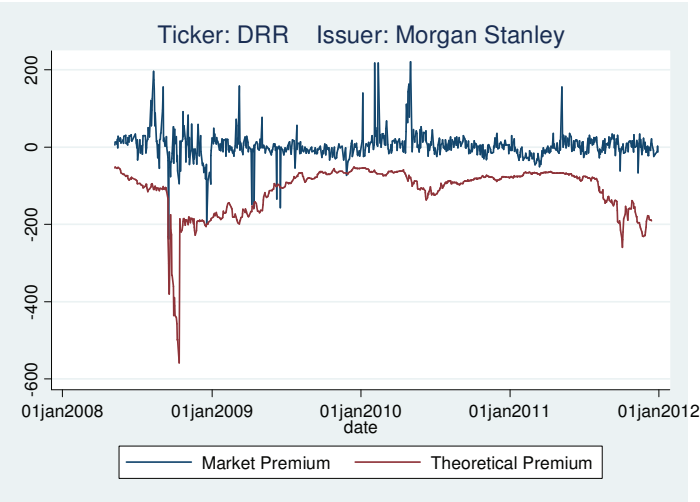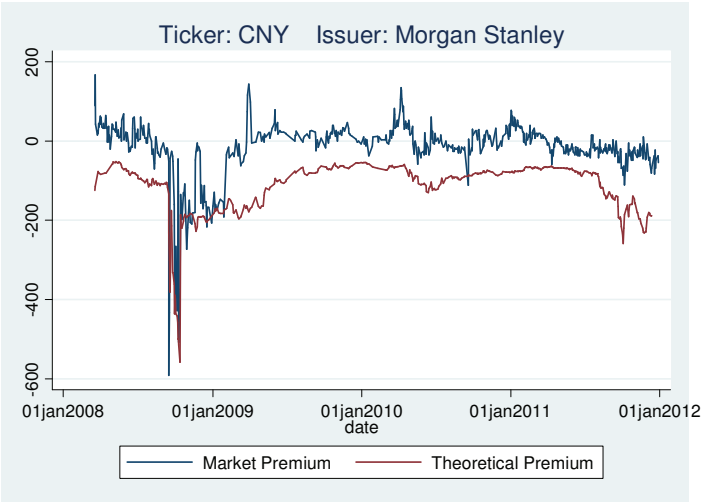I. Barclays Bank PLC (*iPath*) (Cont.):
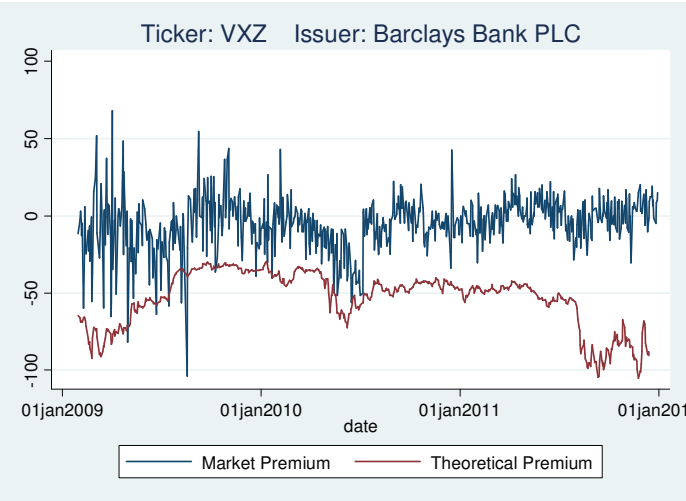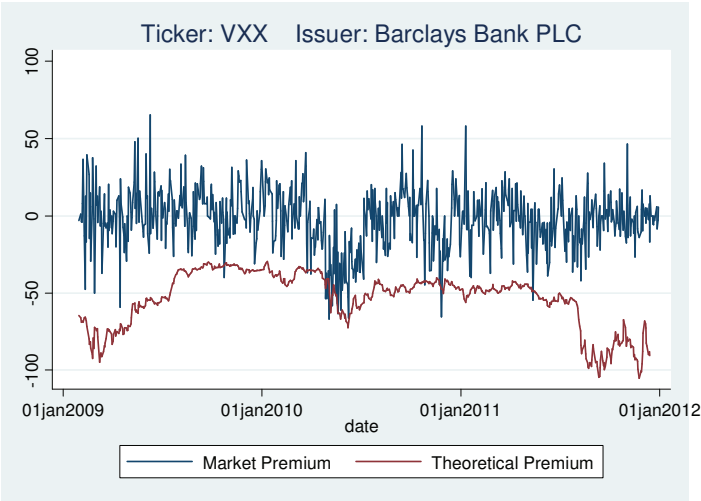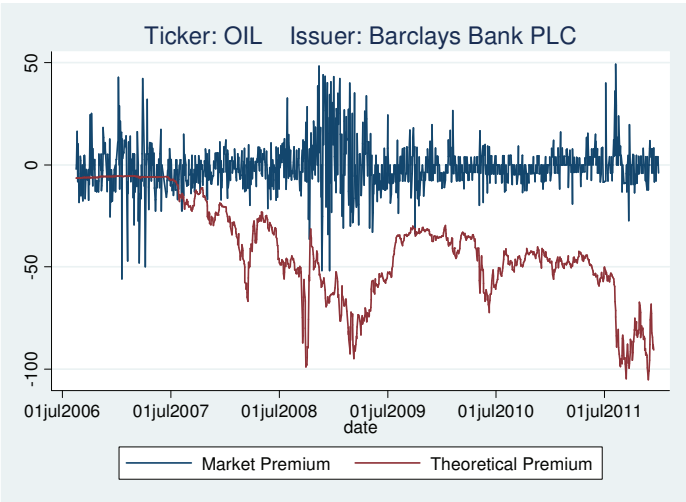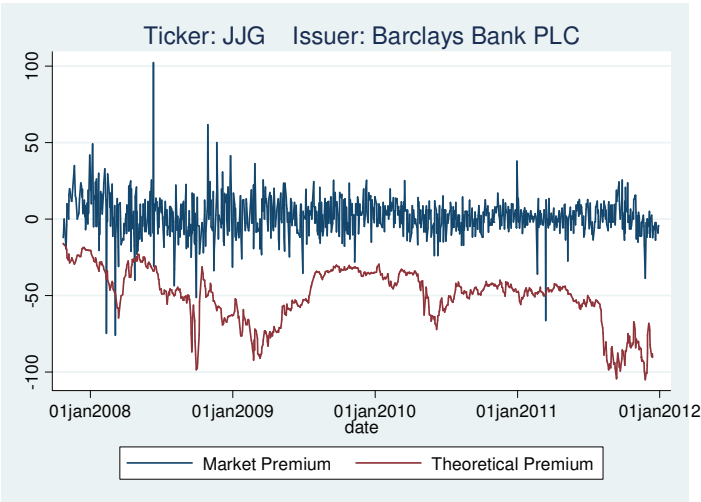
APPENDIX 1: TIME-SERIES OF REAL AND IMPLIED THEORETICAL DISCOUNTS

II. Deutsche Bank AG (*PowerShares*):
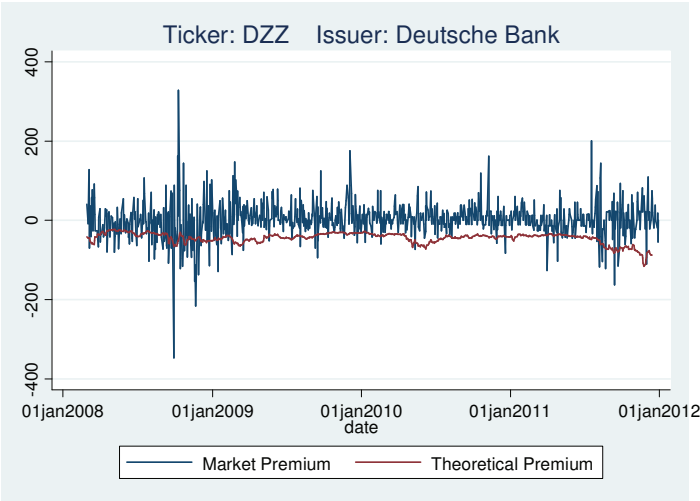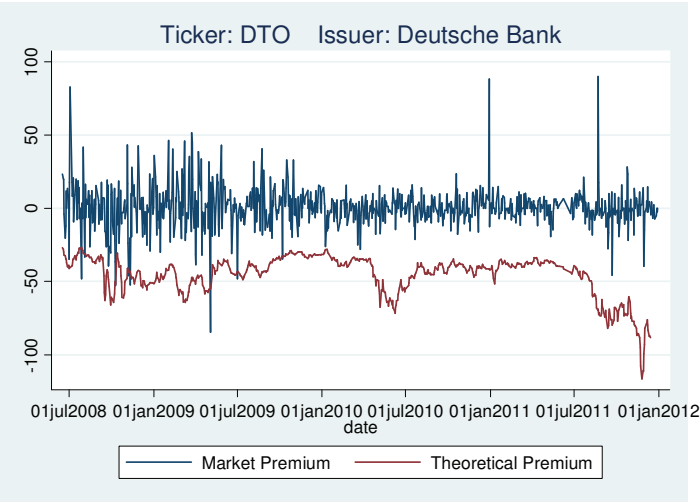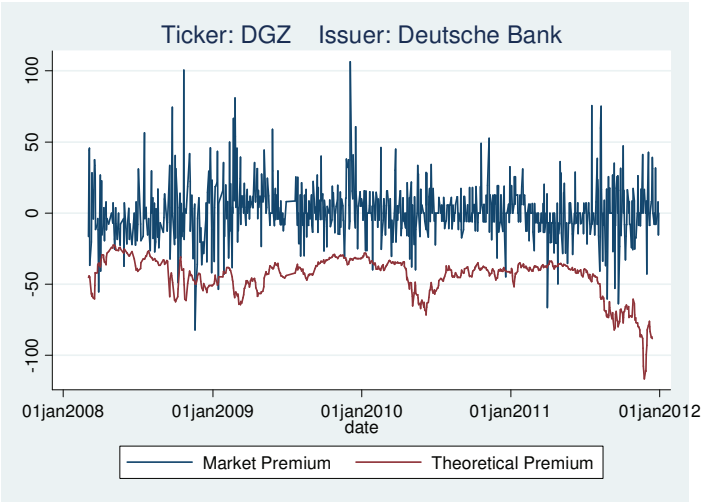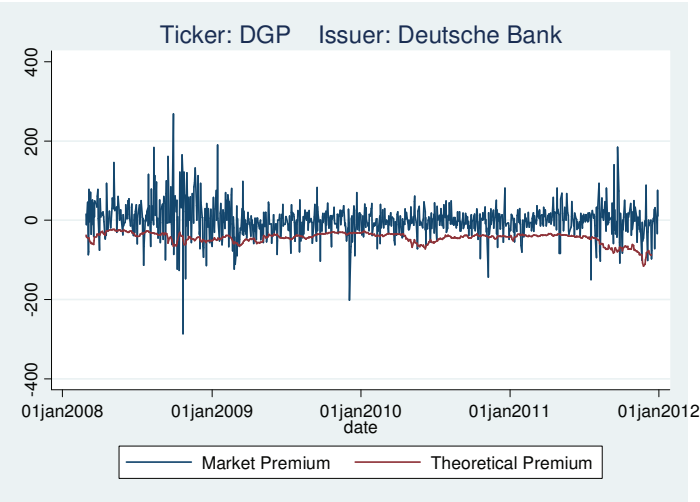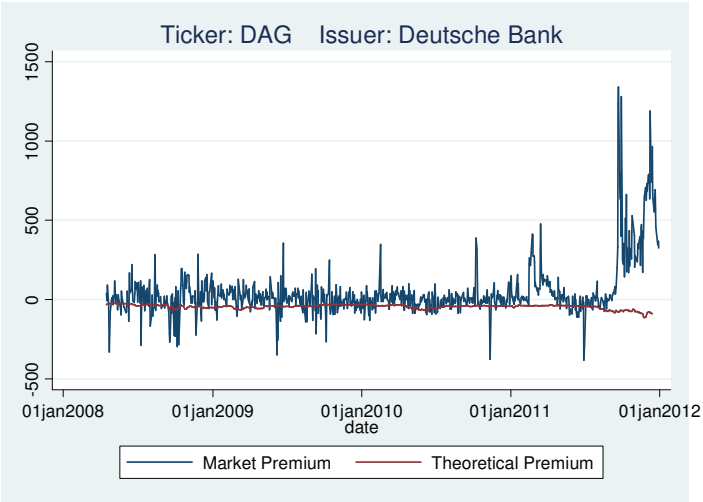
APPENDIX 1: TIME-SERIES OF REAL AND IMPLIED THEORETICAL DISCOUNTS

III. Morgan Stanley (*Market Vectors*):

IV. UBS (*E-TRACS*):