Measuring Risk From IT Initiatives Using Implied Volatility

Dawei (David) Zhang[a]
Barrie R. Nault[b]

a: College of Business and Economics, Lehigh University,
daz215@lehigh.edu
b: Haskayne School of Business, University of Calgary,
nault@ucalgary.ca

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Abstract

We propose an under-recognized measure to capture changes in firm risk from information technology (IT) announcements: implied volatility (IV) from a firm's exchange-traded options. An IV is obtained from a priced stock option and represents the option market's expectation of the firm's average stock return volatility over the remaining duration of the option. Using the change in IV around IT announcements, we can directly assess changes in IT-induced firm risk. IVs are straightforward to obtain, and are forward-looking based on option market investors' estimates of future stock return volatility. They do not rely on historical volatility that is confounded with other events. In addition, options have different expiration dates–each with an IV–allowing us to distinguish between short- and long-term risk. We show how a change in IV can be employed to assess changes in short- and long-term firm risk from IT announcements, and demonstrate this methodological innovation empirically using a set of IT announcements that have been utilized in previous studies.

Keywords: Information technology (IT) announcements; Firm risk; Implied volatility; Options.

1 Introduction

Risky choices are hard to gauge, and few choices affect firms' risk more than new information technology (IT) initiatives. As IT continues to be a major driving force for innovation, productivity, and economic growth, IT projects are becoming increasingly complex and IT capabilities are often unpleasantly hard to build and manage. According to an IBM study, nearly 60% of IT projects do not meet schedule, budget and quality goals (Jorgensen, Owen, & Neus, 2008). A more recent survey shows that more than 50% of the firms had an IT project that failed during the past year (Innotas, 2013).

Adopting the definition for IT risk from Dewan, Shi, and Gurbaxani (2007), "the ex-ante uncertainty associated with IT returns" (p.1829), we propose an important and under-recognized measure of firm risk which allows researchers to explore the relationship between IT investments and both short- and long-term firm risk. Implied volatility (IV) from a firm's exchange-traded options is a unique measure of firm risk that can be used to study changes that come as a result of specific events. An IV is obtained from a priced stock option and represents the option market's expectation of the underlying firm's average stock return volatility over the remaining duration of the option contract (Merton, 1973; Donders & Vorst, 1996). Thus, by construction, IV is the expected uncertainty about underlying firm value by the market (Rogers, Douglas, & Van Buskirk, 2009).

The IS discipline has long been interested in information systems-related risks such as user perceived risk (e.g., Pavlou & Gefen (2004); Nicolaou & McKnight (2006)), investor perceived risk (e.g., Dewan & Ren (2007); Kim, Mithas, & Kimbrough (2017)), security risk (e.g., Loch, Carr, & Warkentin (1992)), IT project risk (e.g., Alter & Ginzberg (1978); Kwon (1987); Benaroch (2002)), software risk (e.g., Charette (1989); Boehm (1991); Fairley (1994); Tian & Xu (2015)), business process risk (e.g., Kettinger, Teng, & Guha (1997); Kliem (2000)), etc. By design, these risk measures are at the user level, project level, business process level, etc.

Assessing changes in firm risk from IT is difficult: prior work is equivocal about whether IT investment announcements (hereafter "IT announcements") or planned IT investments should decrease or increase firm risk, and is silent regarding their short- versus long-term effects on firm risk. On one hand, IT enhances information processing and thus enables firms to better respond to demand and task uncertainties (Galbraith, 1974); on the other hand, IT are inherently risky assets to build and manage (Wang & Alam, 2007).

An example of IT's complex impact on firm-level risk is investments in digitally controlled machines in manufacturing. These machines can easily produce related but different products, whereas non-digital machines are more limited in scope or have large changeover costs. Digitally controlled machines can switch between products at low cost based on demand fluctuations, making the firm more agile and reducing the uncertainty of future cash flows, thus reducing firm risk. On the other hand, to make best use of digitally controlled machines they must be integrated into the existing production environment, may necessitate the redesign of existing business processes, and require training, all increasing firm risk.

Employed as the expected uncertainty about underlying firm value, IV as a measure of IT-induced firm risk has three advantages. First, it is forward-looking and market-driven. As IV is derived from the price of a traded option, it is based on option market investors' estimates of future stock return volatility. In other words, it is risk that is perceived about a firm's future at a particular date by investors. Thus, IV is a market-derived consensus from a set of experts based on their future expectations.

Second, being derived from the option price means that IV does not directly rely on historical stock price volatility – the alternative market-based measure of risk. In practice, this means that measuring changes in IV does not suffer from the need to account for the variety of historical events, and past economic and market trends that are required when measuring effects on historical stock price volatility.

Third, option contracts have different expiration dates, and each option with a specific expiration date has a market price and consequently its own IV. This provides a term structure of IVs. For a given firm, changes in IV for options based on the given firm's stock price with specific expiration dates – ranging from 30, 60, 91, 182, 365, 547 to 730 calendar days – allows IVs to be used assessing changes in firm risk across these different time horizons. Measuring changes in firm risk from IT is a relatively unsolved issue, with only a few studies (e.g., Dewan & Ren (2007, 2011); Kim et al. (2017)) measuring firm risk changes from IT investments.

Indeed, predicting IT returns is notoriously difficult because technologies change quickly, there is tension between IT changing business processes and vice-versa, and effects from IT investments are often intangible (Brynjolfsson & Yang, 1997). Consequently, we argue that IV is an especially good fit for measuring IT-induced firm risk because it is a forward-looking, market-based measure that captures the collective assessment by a large number of investors of uncertainty about future firm performance over different time periods attributable to the IT events. Thus, it avoids the disadvantages of using a particular analytic method to evaluate the risks of such IT investments.

Our goal in highlighting IV as an important and under-recognized measure of firm risk is to propose and explain the advantages of using IV in order to measure firm risk. Through an illustrative study of IT announcements we demonstrate the advantages of using IV in order to assess the effects on firm risk – thus establishing the use of changes in IV as a standard method of studying changes in firm risk from IT initiatives. To begin, we fully define IV, explain the relationship between IV and firm risk, briefly cover relevant research in other disciplines using IV, and then detail the advantages of using IV as a risk measure. Next, we examine prior research in Information Systems that studies firm risk attributable to IT investments, indicating where use of IV may yield critical insights.

We demonstrate how IV and its use may provide a measurement approach that can easily be used by others. Using methods from Accounting and Finance, we show how to formulate an analysis to examine and test for changes in IV, and how to set up a regression on IV that incorporates market effects and adds a variety of controls. Subsequently, we implement these methods using a dataset of IT announcements from Dewan and Ren (Dewan & Ren, 2007). With this previously-published dataset, we describe how IVs are obtained, execute an event study that determines changes in firm risk overall and in various dimensions, and carry out a regression on IV with a variety of controls. Through this process we show how changes in IV can be measured, compare this to alternatives and describe how straightforward it is to obtain, and its usefulness in practice (estimate risk), and for research (see above). This reveals that IV as a measure of firm risk could also be used as an independent variable in other studies.

Using these advantages of IV we also provide novel results. We show that IT announcements significantly increase firm risk between 1% and 3% depending on the expiration length of the option. Firms that only have traded options for expiration lengths of 182 days and less have increased firm risk as a result of IT announcements, and the increase in risk is on the order of 2% to 4%. In contrast, firms with traded options across expiration lengths up to two years do not have increased risk. Firm size is negatively associated with IT announcements' impact on firm risk: IT announcements made by smaller firms significantly increase firm risk, likely because smaller firms are more subject to changes brought about by new IT initiatives. A good news announcement is an event for which the actual stock return is more than the expected stock return upon the information being released, and a bad news announcement is one where the actual stock return for the underlying firm is less than the expected stock return. We find that bad news IT announcements are associated with significantly higher firm risk, whereas good news IT announcements have no effect. This may be because bad news announcements are more surprising to investors given firms have incentives to withhold bad news (Kothari, Shu, & Wysocki, 2009). Finally, IVs show significantly less risk than actual volatility in stock price after the announcement day, indicating the degree to which other events affect stock volatility, and suggest that use of historical stock volatility to predict risk from IT announcements is challenged by the need to control for other effects.

Our results are consistent with those studies that use either the standard deviation of historical earnings or historical stock return volatility as a measure of risk (Carter, Dark, & Singh, 1998; Kothari, Laguerre, & Leone, 2002; Agrawal, Bharath, & Viswanathan, 2003; Fornell, Mithas, Morgeson, & Krishnan, 2006; Dewan et al., 2007; Dewan and Ren, 2011) find IT investments typically increase firm risk. Our contribution is in the key advantages of IVs: IVs are ex-ante, are available daily without the need to account for past events, and assess risk over different terms – and using the latter we find the novel results that increases in risk are shorter-term. To the degree that enterprise resource planning (ERP) systems can reduce risk, and other applications such as automation are relatively less risky, our good/bad news results are consistent with Tian and Xu (2015) and Kim et al. (2017), and maintain the advantages described above over their measures.

2 IV, Firm Risk, and IT Risk

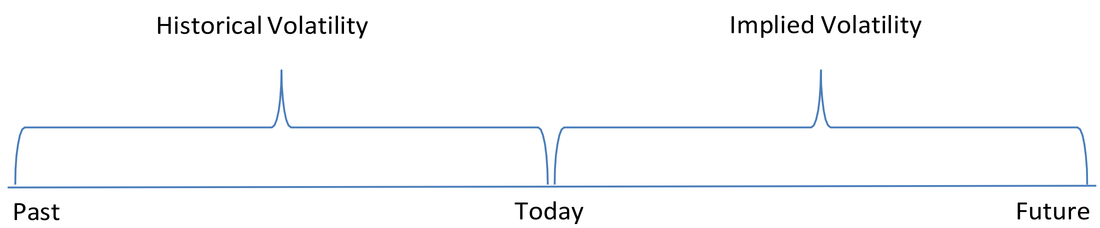
Implied Volatility (IV)

A stock option is a contract between a buyer and a seller. A *call option* gives the buyer the right, but not the obligation, to buy shares of an underlying stock at an agreed-upon price from the seller within a certain period of time. The agreed-upon price is called the *strike price* or the *exercise price*, and the end of the certain period of time is called the *expiration date* or *maturity date*. A *put option* is simply the reverse: the buyer has the right, but not the obligation, to sell shares of an underlying stock at the strike price to the seller by the expiration date. When a buyer exercises its right, then it is said to have exercised *the option*. The difference between an American option and an European option is that the latter can only be exercised on its expiration/maturity date.

Theoretically, IV is derived from an option pricing model such as the Black-Scholes when we know the market price of the option, the time to expiration, the current (spot) price of the underlying stock, the strike price, and the risk-free rate. Thus, the IV is implied by the option pricing model equation together with the other variables that are known. It represents the market’s expectation of the volatility of returns for the underlying stock over the remaining life of the option (Merton, 1973; Donders & Vorst, 1996). For options traders, their estimates of the volatility of returns for the underlying stock until option expiration is effectively their private information about firm risk. When the options are traded on the options exchange the equilibrium price of the option reflects the aggregate market knowledge about firm risk, and this is captured by the IV of the priced option.

IV has been recognized and adopted as a measure of firm risk in many Finance and Accounting studies. Theoretically the IV of an option is the (expected) average volatility over the remaining life of the option (Merton, 1973; Heynen, Kemma, & Vorst, 1994). This is why prices – and consequently IVs – differ for options whose only difference is time to maturity. Comparing IV with historical volatility, Mayhew (1995) asserts in a general conclusion drawn from a large body of literature that IV tends to be more useful than historical data for forecasting volatility. In his Nobel Lecture, Robert C. Merton indicated that the Federal Reserve uses the IV derived from option prices on government bonds as one of its indicators of investor uncertainty about the future course of interest rates (Merton, 1988). Rogers et al. (2009) state that an IV *" . . . is an ex ante measure of volatility that allows us to study how volatility changes over short periods around information releases. Realized volatilities must be estimated using a time series of returns so reflect changes in uncertainty gradually over time.*" (p. 94). Figure 1 shows the forward-looking IV versus historical volatility.

Figure 1 - IV vs Historical Volatility



Advantages of IV as a Measure of Firm Risk from IT Initiatives

IV as a measure of IT-induced firm risk has three advantages over other measures such as the historical volatility of stock returns.

First, risk in the management literature has always had an ex-ante nature. Tracing back to Knight (1921), situations with risk are those where the outcomes were unknown but governed by probability distributions known at the outset. This is distinct from situations where the probability distributions are not known, in which case the issue is how to estimate the probability distribution. This connects with classical decision theory that conceptualizes the risk of a decision alternative in terms of variation in possible outcomes, in their likelihoods as well as their subjective values (Arrow, 1965). Thus, secondary data and/or subjective assessments can be used to estimate probabilities over outcomes. IV can be best understood as a measure of risk where the probabilities over future outcomes are known, and in some cases where the probabilities over future outcomes are not common knowledge (unknown) but can be estimated. What IVs do not measure is unidentified risks, so-called unknown unknowns or unknowable uncertainties, where certain outcomes are not identifiable – missing information is unavailable to all (Chow & Sarin, 2002; Kim, 2012).

Taken at a point in time, risk is the uncertainty about future outcomes. Contrary to the common understanding that risk is only about bad outcomes, it can be the downward or upward variation in expected outcomes. Broadly speaking, risk has been defined along four dimensions: size of loss, probability of loss, variance of returns, and lack of information (Tanriverdi & Ruefli, 2004). In the context of a firm, risk is the volatility of future stock returns that is driven by uncertainty about firm investment decisions and how these will affect firm profitability. IV, by design, is the market's equilibrium expectation about future return volatility of the underlying stock, with the market equilibrium reflecting all available information. Therefore, IV is an ex-ante measure of future return volatility and thus a natural measure for assessing changes in firm risk from decisions that contribute to future stock returns. Ex-ante measures of firm risk are preferable to ex-post measures because firms make decisions based on their expectation of future uncertainties, and ex-post measures expect the future opportunities a firm faces and decisions a firm makes will mirror the past (Silhan & Thomas, 1986; Bromiley, 1991). In the IS literature Dewan and Ren (2011) describe the advantages of ex-ante risk measures: "*Ex ante measure of firm risk reflects the prior assessments of anticipated uncertainty of a firm's earnings stream, which is a better reflection of the actual decisions faced by the firm or its managers, as opposed to the realized variability of returns captured by the ex post measures such as variability of returns*" (p. 377). As described earlier, considerable research in Finance and Accounting uses IV as an ex-ante measure of firm risk.

Second, IV is a measure that is available daily, and can even be computed dynamically during the day as the price of options change. As such, IV is a forward-looking firm risk measure that allows us to estimate changes in firm risk immediately after events such as announcements of future investments, the release of periodic financial information, or other information that affects assessments of firm risk. Thus, IV can change dynamically with the release of new information.

In contrast, historical stock return volatility has to be measured over a period of time that usually ranges from one month to several years. One issue with historical stock return volatility – beyond the fact that it reflects past opportunities and decisions described above – is the challenge of controlling for all the confounding and unobservable factors that affect firm risk during this period. In other words, drawing a causal relationship between the event and subsequent change in risk measured by historical volatilities requires ruling out alternative explanations from historical events. Changes in IV can measure the change in firm risk over relatively short intervals around information releases, which minimize the possibility that the change in firm risk is caused by unobservable or historical factors. Therefore, IV is a natural risk measure for an IT event study.

Third, firms may offer option contracts with different expiration dates ranging from 30 days to 730 days. Each option has its own expiration date and its own market price, and consequently its own IV. Thus, IV by construction has a term structure (i.e., time until expiration). Therefore, it offers unique insights on investors' ex-ante perceptions of changes in firm risk over different time horizons resulting from new information. Although historical stock return volatility could also be measured over different past time horizons, it is an ex- post measure so it does not reveal the "real" changes in investor's perceptions about changes in firm risk after an event.

Recalling that IV is a measure that reflects the average volatility over the life of the option, the term structure constructed by different option contracts with different expiration dates makes it possible to see if information releases such as IT announcements result in increased short-term risk relative to long-term risk – the term structure of changes in risk. In addition to pooled sets of IVs from options of different lengths, it is possible to examine the term structure of changes in risk for specific firms in a matched sample analysis for firms with option contracts of different lengths. This is not possible with historical volatility.

Although not one of the three advantages we focus on, there are arguments that IV is a relatively better measure with less anticipated events. Jin, Livnat, and Zhang (2012) argues that "*relative to equity traders, option traders have superior ability to process less anticipated information*." (p.402). Unlike routine events such as earnings announcements, IT announcements are not usually scheduled events. Moreover, with many firms in a given sample, it is hard to imagine these firms consistently schedule their IT announcements. Therefore, we believe that changes in IV is a better measure of changes in firm risk in the future than any of the equity-market based measures such as historical stock volatility.

Relationship with Prior IS Research

The benefits of our proposed measure are critically important when considering research in the IS literature that studies IT-induced changes in firm risk. Almost all of these studies measure firm risk as variants of historical volatilities. Two different measures for risk are adopted by Carter et al. (1998) and Kothari et al. (2002) respectively: the standard deviation of one-year daily stock returns following the investment, and the standard deviation of realized annual earnings over 5 years following the investment – both ex-post firm risk measures. They show that IT capital investments make a substantially larger contribution to firm risk than non-IT capital investments. Dewan et al. (2007) measure IT risk as the variability of returns on IT investment, which is increased by unexpected positive or negative outcomes. They define systematic risk as the change in total firm risk that can be explained by change in market variance and unsystematic risk as idiosyncratic firm risk. By analyzing abnormal trading activities around IT investment announcements, they find that both total and unsystematic risk show a significant post-event increase in 1998 and 2000, whereas systematic risk adjusts downward in 1996 and 2002. Tian and Xu (2015) use historical earnings volatility as a proxy for firm risk, and find that ERP systems can help reduce firm risk. The risk reduction effect becomes greater when firms are operating in more uncertain environments. Kim et al. (2017) study the impact of IT investments on firm risk measured as initial bond ratings and yield spreads. They find that IT investments are associated with less risk in automate and informate industries than in transform industries.

An unpublished working paper by Agrawal et al. (2003) examines changes in firm risk from e-commerce announcements by traditional “bricks-and-mortar” firms. Using changes in a firm’s historical stock return volatility, they find that both idiosyncratic and total volatility significantly increase after the announcement events. IV is used in one of the robustness tests to reinforce their historical volatility findings. Consequently, the advantages of IVs we detail above were not exploited.

Fornell et al. (2006) find that investment announcements about customer relationship management (CRM) are associated with lower historical stock volatility. Using cross sectional time series regressions, Dewan and Ren (2011) estimate the impact of accumulated IT capital stock on firm returns and firm risk, and adopt two alternative risk measures: historical variability of stock returns and variability of analysts’ annual earnings per share estimates, the latter being an ex-ante (albeit subjective rather than market-driven) measure of firm risk. They discover that IT capital stock is associated with an increase in both risk measures, but the study does not examine changes in firm risk from individual IT-related events.

Relationship with Prior Finance and Accounting Research

Following prior literature in Finance and Accounting, we use an event study approach to study the effects of IT investments on firm risk. Levy and Yoder (1993) examine the behavior of IV around merger and acquisition announcements finding that although the IV of target firms increases significantly three days before the announcement dates, there is no effect on the IV of the bidding firms. Donders and Vorst (1996) study the change in IV around scheduled news announcement days, and find that IV increases as the event day approaches. After the news announcement, however, IV drops back to its long-run level over time. Chen and Clements (2007) explore the link between macroeconomic announcements and the behavior of IV. They find that IV for the S&P 500 falls on average by 2% on the day of Federal Open Market Committee meetings. Using standardized IV, Rogers et al. (2009) examine how management earnings forecast disclosures impact market uncertainty about firm value and find that such forecasts are associated with an increase in short-run market volatility, which is mainly attributable to “bad news” announcements and forecasts that are released more sporadically– thus less anticipated by the investors.

Sources of IT-Related Firm Risk

In enterprise risk management, risk is defined as any possible event or circumstance that can have a negative influence on the enterprise (Enterprise Risk Management Committee, 2003). This stream of research uses expected loss, or conditional value at risk (CVaR) with its focus on losses that have serious economic consequences, as risk measures used to manage firm risks (Bai, Krishnan, Padman, & Wang, 2013). Benaroch (2002) separates IT investment risks for firms into risk arising inside and outside the scope of software development. The former mainly refers to software development cost, and the latter primarily covers competitive risk and market risk. To the extent that the option investors understand these risks, IV captures risk related to the IT project (e.g., system implementation risk, risk with business process redesign) and risk arising outside the scope of the IT project (e.g., change in competitive environment).

Although numerous studies showed that IT investments have significant positive contribution to firm performance and profitability (for a recent review, see Kohli & Grover (2008), and Mithas, Tafti, Bardhan, & Goh (2012)), there is operational evidence supporting IT investments increasing or decreasing firm risk. IT has been shown to have intangible benefits such as improved customer service, higher product and service quality, more efficient business processes and better flexibility in coordination (Mukhopadyay, Rajiv, & Srinivasan, 1997; Brynjolfsson & Hitt, 2000; S. G. Bharadwaj, Bharadwaj, & Bendoly, 2007). Moreover, information sharing among supply chain partners facilitated by Internet-based interorganizational information systems (IOSs) reduces the transaction uncertainty and mitigates demand shocks (Cachon & Fisher, 2000; Lee, So, & Tang, 2000). From the information processing view of the firm (Galbraith, 1974), IT improves coordination, providing information that enables firms to better and more quickly respond to unexpected challenges arising from the business and competitive environment. This leads to less uncertainty about firms’ earnings volatility. Bharadwaj, Bharadwaj, and Konsynski (1999) advocate Tobin's q as a forward- looking measure for firm performance. As a variant of market-to-book, they argue that Tobin's q provides a better reflection of IT's true contribution to firms' long-term performance potential, and find that IT investments are positively associated with Tobin's q value over the 1988-1993 period. They also note that investments in IT also help firms avoid catastrophic losses resulting from liability suits such as fraudulent or careless security handling, and other environmental disasters.

In contrast, IT may increase firm risk, and this increase may be due to sources similar to those proposed by Benaroch (2002). The first is IT project risk, including implementation risk, management risk, business process risk, etc. The fact is that the failure rate of IT projects is high (Iacovou & Dexter, 2005). These include failures to deliver a system, budget overruns, long delays, or organizational rejections. Usually they are outcomes of cognitive limitations, management inattention, or mediocre skills to address observed problems (Lyytinen, Mathiassen, & Ropponen, 1998). Moreover, IT initiatives are difficult projects to manage, sometimes failing spectacularly, often falling short of management expectations, and sometimes succeeding spectacularly (Lyytinen & Hirschheim, 1987; Kobelsky, Hunter, & Richardson, 2008).

The second source of increased firm risk lies outside of the scope of a project, such as competitive risk and user perceived risk. In e-commerce consumers may perceive online shopping for certain products risky and if investors observe this, then that strengthens their perception about IT investments as risky decisions made by firms (Agrawal et al., 2003). Furthermore, if investors believe that a firm's entering the online market increases competition (e.g., trigger a price war), then this may increase risk for the firm. Using Information Week 500 data on IT spending from 1992 to 1997, Kobelsky et al. (2008) find evidence that IT investments increase the volatility of future earnings. Increased stock return volatility has also been found in several other IS studies we cite above.

3 Method

To illustrate one way that IVs can be used in research involving IT and firm risk, and how this compares to other approaches, we study three research questions relating IT announcements to firm risk. First, we examine the impact of IT announcements on firm risk using IVs, and relate our results with other studies that use historical stock return volatility as a measure of firm risk. Second, we examine two dimensions proposed in earlier work to determine the conditions under which IT announcements have a greater or lesser effect on firm risk: firm size and whether the announcement conveys good news or bad news. Third, we use the term structure of IVs to study whether IT announcements differ in the way they affect short- and long-term firm risk. The ability to distinguish between short-term firm risk and long-term firm risk is a unique benefit of using IVs.

Methodologically, we adopt an event study approach and measure the change in firm risk around the IT announcement dates for the full sample as well as for the sub-samples by firm size and by news type. The idea is that, when an IT investment announcement is made, investors evaluate the public information contained in the announcement and then re-adjust their beliefs about the expected value and uncertainty of the announcing firm. According to the semi-strong version of the efficient market hypothesis (Fama, 1970), the investors' belief about the expected value of the firm is immediately reflected in the prices of its traded securities. As a result, we expect to detect a significant change in IV around the events if the investors indeed believe the IT announcements increase or decrease the uncertainty about firms' future returns.

3.1 Data

To demonstrate the use of IV, we adopt a list of 640 electronic commerce announcements from Dewan and Ren (2007). This data was collected from PR Newswire and BusinessWire in Lexis-Nexis, and from four distinct years: 1996, 1998, 2000, and 2002. Events that have confounding factors such as earnings announcements and lawsuits have already been eliminated from the list (see Dewan & Ren (2007), p.378). In this list, each firm can have at most one announcement on any particular day, but can appear multiple times on the list as long as its announcements are on different days.

We use IVs derived from exchange-traded equity options as our measure for firm risk. The IV data are collected from the *OptionMetrics* database, where IV is derived from the hypothetical at-the-money-forward standardized options. Standardized options are built on a daily basis, to be at-the-money and of constant maturity, which reduces measurement error that arises from using options that vary in duration and in the extent to which they are in the money (e.g., Dumas, Fleming, & Whaley (1998); Hentschel (2003); Rogers et al. (2009)). Further information on the calculation of IV by *OptionMetrics* is available in the Technical Appendix. We collect IV data derived from both call and put standardized options for the announcing firm in each event from 10 days before to 10 days after the event, and if the event day is a public holiday we use the next trading day as the event day. To access both short- and long-term firm risk, we collect IV data for options with 7 different expiration lengths: 30, 60, 91, 182, 365, 547 and 730 calendar days. We further drop 3 events because we could not match the underlying firms with the firm identifiers in *OptionMetrics*, which leaves 637 announcements (68 announcements in 1996, 151 in 1998, 215 in 2000, and203 in 2002).

Because of the construction of IV stays the same across time, we can use the same IV measure for an event in 1996, 1998, 2000, 2002 and the construction remains the same to present (2018). In addition, there has been no structural change in how options markets operate. Financial measures including IV from OptionMetrics have been widely adopted by high quality journals in Finance, Accounting, and Business. Some recent publications that have used the same IV measure for periods subsequent to 2002 include Battalio and Schultz (2006); Rogers et al. (2009); Barraclough and Whaley (2012); Hull and White (2017).

In order to test if firm size plays a role in determining the change in firm risk, we collect the "number of employees (EMP)" variable from the *Compustat North American* database and match it with our options datasets. In addition, we calculate the abnormal returns for each event in order to determine if the event is a good or bad news event, by collecting stock prices of the underlying firm from 10 days before to 10 days after each event from the *Center for Research in Security Prices* (known as *CRSP*) database. The price data is also matched with our options datasets.

Continuity Test

We perform a “continuity test” on each of our 7 raw datasets with different expiration lengths (i.e., 30, 60, 91, 182, 365, 547, and 730 calendar days). The continuity test checks if the 11-day interval (i.e., [-5, 5]: from 5 trading days before to 5 trading days after the event date) around each event has sufficient valid IV data. An event is dropped if the announcing firm does not have traded options for the interval at all, or if two consecutive trading days in the 11-day interval are more than 4 calendar days apart, or if the 11-day interval contains missing IV data for more than 4 trading days. Only events that satisfy such continuity tests are selected into our final sample. The purpose of the continuity tests is to further ensure our results are not driven by unobserved factors that may affect market’s response to the IT events. Our final datasets are 7 balanced panel datasets that contain IV for both call and put options, number of employees, and stock prices. Each event has a proper 11-day window around the event date.

The data used in our demonstration – IT announcements, IVs, stock prices and firm size – are public information available to any researcher.

3.2 Research Design

Measuring Changes in IV

A stream of IS literature examines the short-run reactions of the stock market to IT investment announcements by measuring the changes in stock price and trading volume (e.g., Dos Santos, Peffers, & Mauer (1993); Brynjolfsson & Yang (1997); Im, Dow, & Grover (2001); Subramani & Walden (2001); Chatterjee, Pacini, & Sambamurthy (2002); Dewan & Ren (2007)). Among these studies, the most common approach to calculate the abnormal return or abnormal volume is based on the deviation of an actual value from its “predicted” value. This predicted value is usually estimated from historical data. However, we do not use historical data-based method to forecast IV as an IV is derived from current option prices. Thus, we follow the convention from the Accounting literature (e.g., Sheikh (1989); Rogers et al. (2009)) and measure the change in IV around the events as:

$$\Delta IV_{post}^{i} = In\left(\frac{IV_{post}^{i}}{IV_{pre}^{i}}\right) = In\left(IV_{post}^{i}\right) - In\left(IV_{pre}^{i}\right). \quad (1)$$

Thus, the change in IV (ΔIV) is constructed as a log difference between IV from 5 days afterthe event $\left(IV_{post}^{i}\right)$ and IV from 5 days before the event $\left(IV_{pre}^{i}\right)$, where *i* represents a particular event. The log transformation results in the distribution of IV becoming closer to Normal without losing its linear properties. We are able to examine the statistical significance of ΔIV using a one-sample t-statistic:

$$\frac{\overline{\Delta IV}}{sd(\Delta IV)/\sqrt{N}} \sim t_{(N-1),} \quad (2)$$

where $\overline{\Delta IV} = \frac{1}{N}\sum_{i=1}^{N}\Delta IV^{i},\ sd(\Delta IV)$ is the sample standard deviation across events, and N is the number of events. This one-sample t-test is based on the assumption that every observation of $\Delta\ IV^{i}$ is drawn from an independent normal distribution that governs the distribution of risk change for the underlying firm in event *i*. When ΔIV^{i} is positive (negative) and statistically significant, there is evidence for an increase (decrease) in firm risk due to IT announcement *i*. As we examine the changes in IV, our results are not driven by factors that remain constant before and after the events. Indeed, a key advantage of using IV to gauge event-induced firm risk is that IV is available daily.

Multiple Regression on IV

We can use IV directly in a multiple regression framework which allows us to model a further set of relationships and controls. To account for the impact of market volatility we can use the following regression model:

$$\begin{aligned} Ln\left(IV_{t}^{i}\right) &= \beta_0 + \beta_1 Ln\left(IV\_sp500_{t}^{i}\right) + \beta_2 Post\ \_Event_{t}^{i} + \\ &\beta_3 Ln\left(IV\ \_sp500_{t}^{i}\right) * Post\ \_Event_{t}^{i} + \beta_4 NumEmpl_{t}^{i} + \\ &\beta_5 Prem_{t}^{i} + \beta_6 Prem\_sp500_{t}^{i} + \beta_7 Strike_{t}^{i} + \beta_8 Issue_{t}^{i} + \\ &\sum Exch\ \_Dummies + \sum Year\ \_Dummies + \sum Indus\ \_Dummies + \in_{t.}^{i} \end{aligned} \quad (3)$$

IV_{t}^{i} is the IV for the firm making announcement *i* on day *t*. *IV_sp500* is the IV for the *S&P500*

index, which is our measure for market volatility. *Post_Event* is a dummy variable that equals one if the trading day is after the event date, and this is our fixed effect of interest. The interaction term $Ln(IV\_sp500_t^i) * Post\_Event_t^i$ captures the change in the association between firm-level volatility and market volatility after the event – that is, *change in the expected systematic risk* (Aharony et al. 1980). Besides market volatility, we include a number of control variables to make sure our results are not driven by these effects. *NumEmpl* is the number of employees as a measure of firm size. *Prem* is the interpolated premium for the firm-level options. *Prem_sp500* is the premium for the *S&P500* index options. *Strike* is, agreed upon by the seller and buyer of an option, the strike price at which the option can be exercised. *Issue* is an indicator that equals one (zero) if the underlying security is an American depositary receipt (common stock). *Exch_Dummies* are the dummy variables for the security exchanges. *Year_Dummies* are the dummy variables for years when the announcements were made. *Indus_Dummies* are the dummy variables for the industry groups defined by the North American Industry Groups database from *MorningStar*, LLC.

Our set of dummy/control variables in (3) help ensure our measurement of changes in firm risk after the IT announcements accounts for alternative explanations. Similar to the stock market, a main driver of any individual option volatility is market volatility. Therefore, the main purpose of (3) is to control for market volatility by including IV for the *S&P500* index as an independent variable. Moreover, we include control variables such as premium and strike price to make sure that the change in market perception of firm risk is not driven by these effects. We also included dummy variables for security exchanges, years, and industries. This is because changes in IV may be significant only when associated with a particular exchange, year or industry (thus not attributable to the IT announcements), and we need to control for this possibility.

4 Results

4.1 Descriptive Results

A description of our final 7 datasets (i.e., expiration lengths 30, 60, 91, 182, 365, 547, and 730 calendar days respectively) is presented in Table 1. We describe call and put options separately because they have different IV. The number of qualified events for each expiration length is less than 637 because some events do not pass our continuity tests and are dropped. The number of qualified events is 428 for expiration lengths 30, 60, 91, and decreases monotonically as expiration length becomes longer, to 179 events for the length of 730 days. This decrease in the number of events shows that in general, fewer investors trade long-term options because it is harder to gauge long-run firm risk.

The mean value of IV ranges from 0.640 (call) and 0.648 (put) to 0.484 (call) and 0.491 (put), and generally diminishes as expiration length gets longer. In contrast, the average number of employees increases for firms with longer expiration length options. The stock return for each event is calculated as the mean return for the underlying firm over the [-5, 5] day window. We report the average stock return across events for each dataset, which is consistently close to zero. We also calculate the proportion of negative log ratios (i.e., $ln(IV_{post}/IV_{pre})$) across the events for each option type in each dataset. This proportion is consistently around 0.55 for all our datasets, which suggests that about half of the qualified events in our samples are associated with a decrease in IV. Under the assumption that the log ratio for the underlying firm in every event follows an independent normal distribution, we explore if the mean of these distributions is statistically different from zero. We relax this assumption somewhat when we examine the matched sample described later.

Table 1 - Summary Statistics

Expiration Length	# of events	IV		Number of employees		Stock return		Proportion of negative ΔIV
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Call								
30	428	0.640	0.329	41.726	87.089	0.000	0.058	0.533
60	428	0.628	0.319	41.729	87.178	0.000	0.058	0.544
91	428	0.612	0.306	41.986	87.387	0.000	0.056	0.584
182	318	0.556	0.256	53.109	97.877	0.000	0.049	0.541
365	210	0.486	0.184	70.842	112.472	0.001	0.041	0.567
547	209	0.484	0.175	70.348	112.808	0.001	0.041	0.541
730	179	0.488	0.167	69.280	122.118	0.001	0.044	0.564
Put								
30	428	0.648	0.324	41.726	87.089	0.000	0.058	0.526
60	428	0.635	0.315	41.729	87.178	0.000	0.058	0.509
91	428	0.619	0.301	41.986	87.387	0.000	0.056	0.528
182	318	0.566	0.263	53.109	97.877	0.000	0.049	0.535
365	210	0.493	0.192	70.842	112.472	0.001	0.041	0.533
547	209	0.491	0.186	70.348	112.808	0.001	0.041	0.522
730	179	0.493	0.182	69.280	122.118	0.001	0.044	0.564

Notes.
All summary statistics are based on our final datasets that passed the continuity test, so the number of events are always less than 637.
The continuity test is to make sure that each event has a proper estimation window (i.e., 5 days before and 5 days after the event), for details please see Research Design.
IV is the average implied volatility across estimation windows and across events.
Number of employees is the average number of employees (in thousands) across the underlying firms of the events.
Stock return is the average stock return across estimation windows (i.e., [-5,5]) and across events.
ΔIV = ln (IV_post/IV_pre)
IV_pre= Implied Volatility from 5 trading days before the event IV_post=Implied Volatility from 5 trading days after the event

4.2 Empirical Results

The analysis is executed for each of our final 7 datasets. The longer expiration options are necessary because investment in IT may take years to add value to a firm (Bharadwaj et al., 1999). Assuming option market investors understand this, they would make adjustments to their beliefs about long-run firm risk compared to short-run risk. To make sure that our results are robust and are not driven by unique factors about put or call options alone, we calculate the log ratios using

IVs derived from both put and call options.

4.2.1 Changes in IV

We present our baseline evidence on IV changes around IT announcements in Table 2. The log ratios of IV from (1) are presented in Column 3 and Column 4, and the corresponding mean percentage change in Column 5 and Column 6. Overall, there are statistically significant increases in IV around the IT announcements (except for call options with the 547-day expiration length). The put and call options generate similar results. We note that even though a majority of the samples are associated with a decrease in IV from Table 1, the significance of the results in Table 2 also depends on the size and spread of change in IV. The change in IV is greater for shorter-term options, and gradually declines as the term gets longer. For call options IV, the increase is greater than 2.0% for the expirations of 91 days and less; for put options IV, the increase is greater than 2.0% for expirations of 182 days and less. Our results indicate that IT announcements increase ex-ante firm risk, especially in the short-term. This suggests that, despite all the potential benefits from IT, investors view IT capabilities as risky assets to build and manage (Wang & Alam, 2007).

To ensure the significance of our baseline evidence does not depend on the distribution of our IV changes around IT announcements, or on the number of days pre- and post-event, we follow Donders and Vorst (1996) and apply a non-parametric Wilcoxon test to our event sample of 30-day call options. The results are presented in Table 3. In the first row with relative days equal to 10, we compare the average IV over 10 days before the event to the average IV over 10 days after the event (including the event day). N+ (N-) gives the number of events for which the post-event average IV is higher (lower or equal).

Table 2 - Base Results

Expiration length	# of events	ln (IV_post/IV_pre)		Mean percentage change	
		Call	Put	Call	Put
30	428	0.018** (2.20)	0.018** (2.27)	3.05%	3.01%
60	428	0.017** (2.51)	0.019*** (2.97)	2.45%	2.66%
91	428	0.017*** (2.96)	0.019*** (3.48)	2.27%	2.56%
182	318	0.012** (2.33)	0.017*** (3.34)	1.59%	2.01%
365	210	0.009* (2.06)	0.010** (2.42)	1.10%	1.18%
547	209	0.006 (1.47)	0.009** (2.26)	0.78%	1.12%
730	179	0.008* (1.68)	0.009** (2.17)	0.94%	1.16%

Notes.

Each expiration length represents the group of standardized options that would expire in the exact length of calendar days.

Number of events is the total number of events that passed our continuity test. The log ratio and t statistics are calculated at the event level.

IV_pre= Implied Volatility from 5 trading days before the event IV_post=Implied Volatility from 5 trading days after the event Mean percentage change is the mean of (IV_post - IV_pre)/IV_pre t-statistic is presented in the brackets

***, **, and * indicate significance at the 1%, 5%, and 10% level (two-tailed).

Median % change gives the relative change in IV after the events. The Wilcoxon column reports the Wilcoxon single-rank statistics, and we are able to reject the null hypothesis that the IT announcements have no effect on IV comparing up to 10 trading days before and after the events. We fail to reject this null hypothesis when comparing the event day with its previous trading day, which indicates there may be information leakage before announcements, or it could take time for investors to absorb the information conveyed by announcements. We performed the same Wilcoxon test on both put and call options for all expiration lengths. Our results reported above hold except that for the 730-day options the difference between IVs before and after the event is not significant within 3 trading days around the event, suggesting that it may take investors more time to absorb the information conveyed in the event for these longer-term options. Overall, we confirm that there are significant increases in IV immediately after IT announcements.

Table 3 - Wilcoxon Tests

Relative Days	Events	N+	N-	Median % Change	Wilcoxon (p-value)
10	428	235	193	1.40%	-3.45*** (0.001)
9	428	236	192	1.20%	-3.30*** (0.001)
8	428	234	194	1.80%	-3.315*** (0.001)
7	428	230	198	1.93%	-3.09*** (0.002)
6	428	232	196	1.70%	-2.92*** (0.004)
5	428	235	193	2.40%	-2.78*** (0.006)
4	428	241	187	3.17%	-3.01*** (0.003)
3	428	234	194	2.40%	-3.01*** (0.003)
2	428	238	190	1.08%	-3.32*** (0.001)
1	428	225	203	1.33%	-1.42 (0.156)

Note: Results based on 30-day call options
N+: average post-event IV > average pre-event IV (post event period includes the event day) Median%Change: (post - pre)/pre
Wilcoxon: Wilcoxon single-rank statistic, p-values reported in the parentheses. H0: The IT announcements have no effect on IV
***, **, and * denote significance at 1%, 5%, and 10%, respectively, for two-tailed tests.

4.2.2 Regression Using IV

To account for the impact of market volatility on firm-level volatility, we construct a panel dataset covering 120 trading days before and after each of the 428 events that passed our continuity test for 30-day call options. We then estimate our extended market model in (3) using a set of hierarchical regressions including OLS (Ordinary Least Squares) and FGLS (Feasible Generalized Least Squares). Using the log of firm-level IV as the dependent variable, our independent variables include (the log of) IV derived from SP500 index (i.e., market volatility), a post-event dummy variable that equals one if on or after the event date, otherwise zero, and the interaction of these two main effects. The other control variables are detailed in (3) and we adjust for heteroscedasticity and panel-specific auto-correlation in our FGLS regressions.

Table 4 presents the regression results. We consistently find significant increases in firm- level IV after the announcements, controlling for market-level IV. Specifically, our results from the OLS regression with robust standard errors (column 3 in Table 4) show that post-event IV is on average 9.4% higher than pre-event IV (over a 120-day window). In addition, the interaction term is significant, indicating the systematic risk also goes up for the firms after they make the e-commerce announcements.

Table 4 - - Regression controlling for market volatility

Variables	OLS	OLS (Robust SE)	FGLS (He + PSAR1)	
IV_sp500	0.445*** (0.007)	0.276*** (0.008)	0.106*** (0.006)	0.202*** (0.006)
Post_Event	0.133*** (0.018)	0.094*** (0.008)	0.015*** (0.005)	0.024*** (0.005)
IV_sp500*Post_Event	0.069*** (0.012)	0.055*** (0.005)	0.005* (0.003)	0.009*** (0.003)
# of Employees		-0.0002*** (0.000)	-0.001*** (0.000)	-0.0001*** (0.000)
Premium		0.118*** (0.001)	0.195*** (0.001)	0.181*** (0.000)
Premium_sp500		0.003*** (0.000)	-0.002*** (0.000)	-0.005*** (0.000)
Strike_Price		-0.011*** (0.000)	-0.017*** (0.000)	-0.016*** (0.000)
Issue		0.138*** (0.004)	0.022* (0.011)	0.033*** (0.012)
Exch_Dummies		Yes		Yes
Year_Dummies		Yes		Yes
Indus_Dummies		Yes		Yes
N	103140		97299	92256

Note.
FGLS (Feasible Generalized Least Squares) regressions are adjusted for heteroscedasticity and panel-specific auto-correlation
Coefficients on the dummies variables are suppressed for brevity Standard errors are provided in the brackets
Significance Level: *** 0.01 ** 0.05 * 0.10

We note that our continuity test only applies to the 11-day interval, for all expiration lengths. The purpose again is to make sure there were no unobserved confounding factors during the event windows. We did not do the same continuity test for the 241-day period which extends to 120 trading days before and after the event. The reason is that if we apply the same continuity test, then we would often have zero acceptance: none of the 241-day periods would survive the test due to the fact that firm-level options may not be actively traded on every trading day (especially for longer-term options). However, for the dataset used in our regression we apply a relaxed version of the continuity test on the 241-day periods such that every 241-day period belong to the same announcing firm and should have less than 15% missing values for IV.

4.2.3 Short- vs. Long-Term Firm Risk

A critical advantage of IV as a measure of firm risk is the term structure of IVs, as IVs are available for options with different expiration lengths. From Table 2 it is straightforward to observe that as the expiration length grows, the magnitude and significance of the increase in firm risk from IT announcements diminishes. Thus, one could conclude that firms with traded options that have longer expiration lengths have lesser increases in risk from IT announcements. However, in our dataset events are pooled by option expiration length, and by examining the number of events in Table 2, the number of events fall substantially for options with greater than 91 days to expiration.

To study the effects of term structure in more depth, we reduced the sample of events to those for firms that had traded options for each expiration length, effectively matching the firms/events in the sample across the option expiration lengths. This resulted in 179 events – thus, 179 of the original 428 events were for firms that had traded options for every expiration length we study. For the original 428 events, all firms had traded options for the 30-60-91 expirations lengths, and most had traded options for 182 days. We then ran the analysis using the change in IV on the reduced sample of 179 events and on the full sample with the 179 events excluded, and the results are presented in Table 5. For firms that have traded options in all expiration lengths – up to 2 years – there is no increase in risk from IT announcements. In contrast, for firms with traded options of 182 days or less, there is a substantial and significant increase in firm risk from IT announcements.

We conclude that IT announcements do not increase firm risk for firms that have traded options with longer expiration lengths, and conjecture that these firms may be larger and thus have more stable returns over time. However, for firms with only traded options of shorter expiration lengths the increase in firm risk from IT announcements is high. We note that this analysis and result from IT announcements could not be obtained with other measures of firm risk, and is a clear advantage of IV.

4.2.4 Effect of Firm Size (Number of Employees)

As IVs are firm- and option length-specific, we show how it is possible to subset firms by different dimensions such as size, and continue to use IV as a measure of firm risk. Compared to larger firms, smaller firms are less experienced with handling IT investment projects, and a greater proportion of the activities of a smaller firm are usually affected by IT projects. Thus, smaller firms are exposed to more fundamental challenges from IT projects. Moreover, spending on IT projects usually accounts for a larger proportion of the overall budget for smaller firms, exposing smaller firms to greater risks from project failures. In addition, IT announcements made by smaller firms may contain more new information about firm earnings than for larger firms - making them more likely to surprise investors (Bamber, 1986; Wang, 1994; Im et al., 2001).

We divide our full sample of 637 events at the 60th percentile value of the number of employees. We choose the 60th percentile value (i.e., 15500 employees) as the threshold because the continuity test drops more events that belong to smaller firms. By including slightly more firms in the "small" group we ensure that we have a better-balanced sample size between the "small" and "large" sub-samples after the continuity test. Notice that our division of "small" and "large" sub-samples is only relative, many "small" firms really are not that small based on number of employees. The results are presented in Table 6. The log ratios are reported in Column 4 and Column 5, and their t-statistics in Column 6 and Column 7. We find statistically significant changes in IV around the event days for the "small" firm sub-samples, except for call options that have a longer time to expiration: 365 or 547 days. However, the "large" firm sub-samples do not have any significant changes in IV around the event days. This finding supports that IT announcement events more substantially affect uncertainty about underlying firm value for smaller firms. In addition, the log ratios for the smaller firm sub-sample is much greater than those in our baseline results table (Table 2), indicating the overall results are in part driven by the smaller firms. This corresponds with our analysis of the term structure: larger firms are likely to be those with traded options across expirations lengths, and IT announcements do not increase firm risk for those firms. In order to test if our results are robust to different thresholds of firm size, we divide our full sample into "small" and "large" sub-samples at 6580 which is the 50th percentile value of number of employees. Our qualitative findings do not change.

Table 5 - Short vs. Long Term

Expiration length	# of events	ln (IV_post/IV_pre)		Mean Percentage Change	
		Call	Put	Call	Put
Short Term					
30	249	0.032*** (3.70)	0.028*** (3.15)	4.36%	3.93%
60	249	0.024*** (3.32)	0.023*** (3.07)	3.07%	3.15%
91	249	0.023*** (3.58)	0.026*** (3.78)	2.94%	3.34%
182	139	0.018** (2.53)	.023*** (3.23)	2.15%	2.65%
Long Term					
30	179	-0.005 (-0.34)	0.001		
60	179	0.005 (0.42)	0.011		
91	179	0.006 (0.64)	0.008		
182	179	0.008 (1.03)	0.012		
365	179	0.007 (1.47)	0.009		
547	179	0.005 (1.05)	0.008*		
730	179	0.008* (1.68)	0.010**		

Notes.
Events under "Short Term" are those pass our continuity test, excluding the 179 events that have 730-day options traded before and after the events.
The 179 events under "Long Term" are those pass our continuity test, and have 730-day options traded before and after the events.
Mean percentage change is the mean of (IV_post - IV_pre)/IV_pre t-statistic is presented in the brackets.
***, **, and * indicate significance at the 1%, 5%, and 10% level (two-tailed).

We also examine if our results are robust to different measures of firm size such as total assets and total market capitalization, using a similar approach to dividing our sample into small and large firms. Results from using these different measures of firm size are qualitatively consistent with those presented in Table 6.

Table 6 - Results by Firm Size

Expiration length	Firm size	# of events	ln (IV_post/IV_pre)		t-statistic	
			Call	Put	Call	Put
30	Small	220	0.026***	0.032***	2.85	3.50
	Large	208	-0.003	-0.003	-0.22	-0.28
60	Small	220	0.018**	0.023***	2.38	3.02
	Large	208	0.004	0.006	0.37	0.70
91	Small	220	0.021***	0.024***	3.02	3.59
	Large	208	0.003	0.007	0.32	0.82
182	Small	127	0.016**	0.023***	2.45	3.82
	Large	191	0.003	.007	0.39	1.06
365	Small	44	0.011	0.013**	1.32	2.16
	Large	166	0.003	0.004	0.55	0.86
547	Small	45	0.007	0.015**	0.94	2.34
	Large	164	0.002	0.003	0.46	0.73
730	Small	54	0.015*	0.023***	1.70	2.80
	Large	125	0.002	0.001	0.32	0.23

Notes.
small: Number of Employees < 15.5 (in thousands), 60th percentile across all firms. large: Number of Employees > 15.5 (in thousands), 60th percentile across all firms.
***, **, and * indicate significance at the 1%, 5%, and 10% level (two-tailed).

4.2.5 Effect of News Type

In examining the effect of news type, good news or bad news as defined earlier, we show how IV can be used with other firm-specific market data. Controlling for such news type, even though it is determined ex-post, allows us to control the role of returns on firm risk.

We examine the two types of news separately because prior literature suggests that changes in volatilities around information releases may be asymmetric (Black, 1976; Campbell & Hentschel, 1992; Skinner, 1994; Kothari et al., 2009; Rogers et al., 2009). First, good news IT announcements mean that investors believe the information conveyed in the announcement is "better" than they expect, and thus gives them more confidence about the firm's future returns. Bad news IT announcements, however, surprise investors in a negative way and thus create more doubts about future firm returns. Second, Skinner (1994) suggests that, in order to preempt the big surprises, managers voluntarily disclose bad news early when they know that current period earnings news is adverse. Similarly, when managers have insider information about their IT projects that may be considered adverse news by investors, they may choose to announce it early to preempt the surprises later. Assuming that investors understand this, they may expect future bad news events related to the same project and adjust their beliefs about future volatility of the firm accordingly. Thus, we expect IT announcements that convey bad news increase firm risk and those that convey good news decrease firm risk. Moreover, Skinner (1994) suggests that investors react more strongly to early bad news disclosures than good news disclosures, and this would be partially reflected in greater variation in investors' expectations for future stock prices.

We follow a modified method from Campbell, Lo, and MacKinlay (1996) to divide the full sample of events into "good news" and "bad news" sub-samples. Specifically, we categorize each announcement using the deviation of the actual stock return from the expected stock return on the announcement day. The calculation largely follows a standard abnormal returns model (Dos Santos et al., 1993; Dewan & Ren, 2007), and we use a standard market model to predict the expected return. If the actual exceeds expected returns (i.e., the abnormal return is positive), then the announcement is designated as good news, otherwise the announcement is designated as a bad news. Among our 637 announcements, 312 are good news, and the remaining 325 are bad news.

Table 7 reports the results for the two sub-samples. The log ratios are reported in Column 4 and Column 5, and their t-statistics in Column 6 and Column 7. There is consistent evidence that bad news IT announcements significantly increase firm risk both in the short- and long-term, and good news has no effect on firm risk. It again shows that investors view new IT capabilities as risky assets for the firms: their expectations of the volatility of returns for the underlying stock substantially increases after the bad news announcements. Moreover, investors respond with caution to good news IT announcements: there is no significant change in IV around these events, which is likely because good news is less surprising than bad news given managers' incentive to report good news and hide bad news. We also find that the magnitude of volatility change tends to be greater for shorter expiration lengths (i.e., the average log ratios for expiration lengths 30, 60 and 91 for the bad news are 2.8% (call) and 2.9% (put); the average log ratios for expiration lengths 365, 547, and 730 for the bad news are 1.5% (call) and 1.9% (put)).

If the abnormal return of an IT announcement is close to zero, it may be "neglected" by investors and thus have no effect on firm risk. To examine this, we further categorize an announcement as good news only if the actual return exceeds the expected return by more than 5.0%, and as a bad news if the actual return is more than 5.0% less than the expected return. The remaining announcements are designated as no news. Of our 637 announcements, 73 are good news, 75 are bad news, and the remaining 485 are no news. We find that the results are highly significant across all expirations for the bad news events, not significant for the good news events, and rarely significant for the events with no news.

Given the Skinner analysis (Skinner, 1994) that managers may decide to make announcements early if current period earnings are averse, then announcement events related to earnings in the case of bad news may be endogenously determined as suggested by Viswanathan and Wei (2008). However, as we examine IVs pre- and post-event rather than earnings or returns, our analysis is not directly affected by this endogeneity so long as earnings or returns are not directly related to IVs.

Table 7 - Results by News Type

Expiration length	News type	# of events	ln (IV_post/IV_pre)		t-statistic	
			Call	Put	Call	Put
30	Good News	218	0.005	0.006	0.45	0.62
	Bad News	210	0.031***	0.029**	2.76	2.53
60	Good News	218	0.007	0.010	0.75	1.20
	Bad News	210	0.026***	0.028***	2.85	2.94
91	Good News	218	0.006	0.009	0.80	1.22
	Bad News	210	0.027***	0.030***	3.50	3.63
182	Good News	167	0.004	0.006	0.59	0.95
	Bad News	151	0.021***	0.028***	2.79	3.87
365	Good News	117	0.005	0.004	0.88	0.74
	Bad News	93	0.015**	0.018***	2.06	3.01
547	Good News	117	0.001	0.002	0.20	0.38
	Bad News	92	0.013*	0.019***	1.98	3.34
730	Good News	101	0.001	0.002	0.12	0.29
	Bad News	78	0.016**	0.019***	2.43	3.59

Notes.
Good News = SAR (stock abnormal return) > 0
Bad News = SAR (stock abnormal return) < 0
***, **, and * indicate significance at the 1%, 5%, and 10% level (two-tailed).

4.3 Robustness of IV vs Historical Volatility

IVs may be sensitive to the time it takes for new information to be incorporated in option prices. To examine whether our analyses are sensitive to the length of interval that centers on the event dates, we re-ran all of our analyses using IV from 3 trading days before and after the event dates, and all the qualitative findings in our results remain unchanged. We do not suggest using 1 trading day before and after because new information may be leaked to public just before the event date, and it may take some investors longer than a day to absorb the information conveyed by the IT announcements.

One advantage of IV over historical stock return volatility is that IV can be measured on a daily basis, and thus can capture the changes in firm risk over a short time interval around the IT events. Our dataset allows us to explore the difference between IV and actual volatility for options with an expiration length up to 91 days. Table 8 presents the mean difference between IV for the 5th day after the events and historical volatility over a period starting on the 5th post-event day. Our results show that actual volatility is significantly greater in magnitude than IV for all durations. This is because actual volatility over, say 30 days, could be influenced by all events happening in the same 30 days, whereas IV represents investors' expectation of volatility, given their knowledge today, over the next 30 days. We can safely assume that changes in IV right before and after the events are driven by the events. However, changes in historical volatility over, say 30 days before and after the events, could be affected by confounding factors in the two 30-day windows.

Table 8 - Comparison between IV and Actual Volatility

Expiration length	Call		Put	
	Mean Δ	t statistic	Mean Δ	t statistic
30	-3.50***	-8.39	-3.49***	-8.35
60	-4.99***	-9.97	-4.98***	-9.96
91	-5.58***	-11.93	-5.53***	-11.88

Note. Mean Δ = Mean of (IV - Actual) across the events
IV = implied volatility on the 5th trading day after the event
Actual = realized price volatility over 30/60/91 days after the 5th post-event trading day
***, **, and * indicate significance at the 1%, 5%, and 10% level (two-tailed).

5 Conclusion and Discussion

This research introduces an important and under-recognized measure of firm risk that can be used to assess the impact of firm-level IT investments. The measure, implied volatility (IV) is obtained from the price of a stock option traded on the option exchange. Advantages of IV as a measure of firm risk from IT initiatives include that it is based on traders' expectations of future stock return volatility that represents volatility of future earnings, it is forward-looking in contrast to historical stock volatility, and firms have options with different expiration dates providing a term structure of IVs to measure firm risk.

After reviewing the literature on the effects of IT on firm risk, we show how changes in IV can be set up for testing and how regressions on IV can be formulated using methods from Accounting and Finance. We follow this by demonstrating how these methods are implemented in practice using a dataset from previously published research.

In the process we also provide a set of findings – some of them novel due to our ability to exploit IVs. First, IT announcements significantly increase firm risk between 1% and 3% depending on the expiration length of the option. Second, the term structure of traded options separated which firms have increased risk as a result of IT announcements: firms with traded options only for expiration of 182 days and less have increased firm risk as a result of IT announcements, and the increase in risk is on the order of 2% to 4%. In contrast, firms with traded options across expiration lengths up to two years do not have changes in firm risk as a result of IT announcements.

Third, firm size is negatively associated with IT announcements' impact on firm risk. In particular, IT announcements made by smaller firms significantly increase firm risk, likely because smaller firms are more subject to changes brought about by the new IT initiatives. Fourth, we find that bad-news IT announcements are associated with significantly higher firm risk, whereas good-news IT announcements have no effect. This may be because bad- news announcements are more surprising to investors, as well as their impression about the riskiness of new IT capabilities. Finally, we find that IVs show significantly less risk than actual volatility in stock price after the event day, indicating the degree to which other events affect stock volatility, and suggest that use of historical stock volatility to predict risk from IT announcements is compromised by other events that may be challenging to account for.

To demonstrate the economic significance of our findings, we take call options with 30 days to expiration as our example. We find that IV increases by about 3% on average after the events (see Table 2). This means that, on average, the IV jumped from 0.64 (mean IV for 30-day call options in our sample) to about 0.66. We then calculate how much the price of a call option changes if the underlying stock volatility increases by 3%. Specifically, we assume a typical at-the-money call option with a $30 stock price, 5% risk free rate, and a volatility increase from 0.64 to 0.66. Using the Black-Scholes model, we find that the value of the call option increases from 2.25 to 2.32 – roughly a 3.1% increase. A 3% change in firm risk as well as in option price is rather significant for a large firm as a result of a single IT initiative. The magnitude of our results is consistent with prior research findings in top journals. For example, Rogers et al (2009) report a 1% to 4% increase in IV around management earnings forecasts. Patell and Wolfson (1981) report that IV increases by about 4% for 30-day options. We also calculate the average percentage change in VIX (IV for the S&P 500 Index) over an 11-day window from 2004 to 2018, which is around 1.7%.

The managerial implications of having a measure like IV available are that within a few days of the announcement of an IT initiative, it is possible for management to observe the market's assessment of how the initiative may impact firm risk. Together with cumulative managerial experience, such information can be useful for managerial oversight: if management perceives the risk of an IT initiative differently from what the market yields changes in IV, then this difference can be identified, explained, and possibly controlled. For example, management could review and revise their internal risk assessments, provide more detailed explanation to the market in a follow-up announcement, devote more resources to an IT project as a way of neutralizing the potential increase in risk, and change the schedule of development and implementation so as to lessen the risk over time. In this way, a change in IV complements other risk assessments.

Prior research find that IT investment announcements tend to be associated with positive abnormal returns (Dos Santos et al 1993, Dewan and Ren 2007). Our findings show that, even though firms may expect positive abnormal returns, managers need to balance the gain in the short-run firm value versus the higher volatility of future returns to make a strategic decision about making an e-commerce announcement. One future research direction is to explore the risk effects of the IT investments in more state-of-the-art technologies such as artificial intelligence. The findings of such research could help managers develop strategies to, for example, reduce firm risk by strategically using IT announcements.

One limitation of our study is the age of our IT events. Our events were e-commerce announcements collected from the 1996-2002 period which is about 20 years ago, and our specific results for e-commerce announcements may differ for announcements about current IT initiatives such as data analytics and cloud computing. However, the advantages we present about IV as a measure that can be used to determine how firm risk is impacted by IT-related investments do not fade over time. That is, our methods whereby we show that IV is a robust and informative measure of IT-induced risk should persist. We suggest that future studies examining the relationship between firm risk and IT investments should be held to this metric. We recognize that our method is restricted to publicly available firms. IT announcements might be available for privately held firms, but if they are not publicly traded the IV and other data is not available. A limitation to our market-based (returns) classification of events into good and bad news is that the classification is ex-post. Future work could compare a content analysis classification with the market-based one, which could be a contribution to the literature on its own.

A theoretical implication of our approach is that IVs represent a market version of crowd-sourcing such that they represent risk based on accumulated information about the firm and the IT initiative. IVs connect firm risk to IT risk in a forward-looking manner rather than retrospectively, and have the further advantage of a term structure. If conducting an event study, then the method requires a set of events such as IT announcements and IVs for a certain number of days around the IT announcements. For instance, we measure the impact of firm risk by the log ratio of IV from 5 trading days after to IV from 5 trading days before the event date. Other useful publicly-available data that can be used to perform robustness tests include the S&P500 index, number of employees for each firm, and stock prices around the event date to determine if the announcement is bad, good or no news. In this way, IVs can be used as a measure of firm risk across a variety of different studies examining IT initiatives.

6 Technical Appendix for Implied Volatility

Implied Volatility (IV) can be determined using an option pricing model such as the Black- Scholes Model and the Binomial Model. The IV measure used by OptionMetrics is obtained by using the Cox-Ross-Rubinstein (CRR) binomial tree model, which has become an industry standard for American options because it allows the valuation of options before their expirations. Below we provide a concise technical note on the calculation of standardized IV that we use as our measure of firm risk.

The CRR model assumes there are N subperiods between now the option expiration date, and the security price can either move "up" or "down" during each subperiod. Therefore, we can build a tree starting from now (time 0) with security price *S*. Since *S* can only move up or down during the first subperiod, there will be two possible prices for this security by the end of the first subperiod: *Su* (price up) and *Sd* (price down). If we keep expanding the tree until option expiration, we can build a binomial tree where the option price at expiration (end of the tree) is calculated by setting the option expiration value equal to the exercise value. We can then work backwards to calculate the price of the option at time 0. Specifically, the price of a call option at the beginning of the a subperiod is given by

$$C_i = max\left\{\frac{\left[pC_{i+1}^{up} + (1-p)C_{i+1}^{down}\right]}{R, S_i - K}\right\}, \tag{4}$$

where C_i is the price of a call option at the beginning of subperiod *i*, C_{i+1}^{up} and C_{i+1}^{down} are two possible option prices at the end of the subperiod, *p* is the risk-neutral probability, *r* is the interest rate, *h* is the size of the subperiod, *q* is the continuous dividend yield, *K* is the strike price of the option, and *S* is the current price for the underlying security, which is a function of σ - implied volatility as well as S_{i-1} and *h*. The calculation of the price of a put option is likewise.

To get the value for IV (σ), the model is run iteratively with different values of σ until the calculated price of the option at time 0 converges to its market price. Next, the standardized IV are calculated using a kernel smoothing technique. Specifically, a kernel smoother is used to generate a “volatility surface” where a smoothed volatility, $\hat{\sigma}$, is calculated for each grid point on the surface. *OptionMetrics* uses the following formula to calculate $\hat{\sigma}$:

$$\hat{\sigma}_j = \frac{\sum_i V_i \sigma_i \Phi_{ij}(.)}{\sum_i V_i \Phi_{ij}(.)} \tag{5}$$

where $\hat{\sigma}_i$ is the smoothed volatility for grid point *j* on the volatility surface, *i* is indexed over all the options for that day, V_i is the vega of the option, σ is the implied volatility, and Φ(.) is the kernel function. The firm risk measure that we use in this paper, the standardized, at-the-money-forward IV, is then calculated by interpolating the volatility surface points to the forward price and the target expiration.

References

Aharony, J., C. P. Jones, I. Swary. (1980). An analysis of risk and return characteristics of corporate bankruptcy using capital market data. J. Finance 35(4) 1001–1016.

Agrawal, D., Bharath, S. T., & Viswanathan, S. (2003). Technological Change and Stock Return Volatility: Evidence from eCommerce Adoptions. (Working Paper)

Alter, S., & Ginzberg, M. (1978). Managing uncertainty in mis implementation. *Sloan Management Review*, *20* (1), 23-31.

Arrow, K. (1965). *Aspects of the theory of risk bearing*. Helsinki, Finland: Yrj Jahnssonin Sti.

Bai, X., Krishnan, R., Padman, R., & Wang, H. J. (2013). On risk management with information flows in business processes. *Information Systems Research*, *24* (3), 731-749.

Bamber, L. S. (1986). The information content of annual earnings releases: A trading approach. *Journal of Accounting Research*, *24* (1), 40-56.

Barraclough, K., & Whaley, R. (2012). Early exercise of put options on stocks. *Journal of Finance*, *67* (4), 1423-1456.

Battalio, R., & Schultz, P. (2006). Options and the bubble. *Journal of Finance*, *61* (5), 2071-2102.

Benaroch, M. (2002). Managing Information Technology Investment Risk: A Real Options

Perspective. *Journal of Management Information Systems*, *19* (July), 43–84.

Bharadwaj, A. S., Bharadwaj, S. G., & Konsynski, B. R. (1999). Information Technology Effects on Firm Performance as Measured by Tobin's q. *Management Science*, *45* (6), 1008–1024.

Bharadwaj, S. G., Bharadwaj, A. S., & Bendoly, E. (2007). The performance effects of complementarities between information systems, marketing, manufacturing, and supply chain processes. *Information Systems Research*, *18* (4), 437-453.

Black, F. (1976). Studies of stock price volatility changes. In *Proceedings of the 1976 meetings of the business and economic statistics section.* Washington, D.C.: American Statistical Association.

Boehm, B. (1991). Software risk management: Principles and practice. *IEEE Software*, *January*, 32-41.

Bromiley, P. (1991). Testing a Causal Model of Corporate. *Academy of Management Journal*, *34* (1), 37–59.

Brynjolfsson, E., & Hitt, L. M. (2000). Beyond computation: It, organization transformation, and business performance. *Journal of Economic Perspectives*, *14* (4), 23-48.

Brynjolfsson, E., & Yang, S. (1997). The intangible benefits and costs of computer investments: Evidence from the financial markets. In *Proceedings of the 18th international conference on information systems.* Atlanta, GA.

Cachon, G. P., & Fisher, M. (2000). Supply chain inventory management and the value of shared information. *Management Science*, *46* (8), 1032-1048.

Campbell, J. Y., & Hentschel, L. (1992). No news is good news:an asymmetric model of changing volatility in stock returns. *Journal of Financial Economics*, *31* (3), 281-318.

Campbell, J. Y., Lo, A. W., & MacKinlay, A. C. (1996). *The econometrics of financial markets*. Princeton, NJ: Princeton University Press.

Carter, R., Dark, F., & Singh, A. (1998). Underwriter reputation, initial returns, and the long-run performance of ipo stocks. *Journal of Finance*, *53* (1), 285-311.

Charette, R. N. (1989). *Software engineering risk analysis and management*. New York: McGraw-Hill.

Chatterjee, D., Pacini, C., & Sambamurthy, V. (2002). The shareholder wealth and trading-volume effects of information-technology infrastructure investments. *Journal of Management Information Systems*, *19* (2), 7-42.

Chen, E. T. J., & Clements, A. (2007). S&P 500 implied volatility and monetary policy announcements. *Finance Research Letters*, *4* (4), 227–232. doi: 10.1016/j.frl.2007.07.002

Chow, C. C., & Sarin, R. K. (2002). Known, Unknown, And Unknowable Uncertainties. *Theory and Decision*, *52* (4), 227–232.

Dewan, S., & Ren, F. (2007). Risk and return of information technology initiatives: Evidence from electronic commerce announcements. *Information Systems Research*, *18* (4), 370–394.

Dewan, S., & Ren, F. (2011). Information technology and firm boundaries: Impact on firm risk and return performance. *Information Systems Research*, *22* (2), 369–388.

Dewan, S., Shi, C., & Gurbaxani, V. (2007). Investigating the Risk Return Relationship of Information Technology Investment: Firm-Level Empirical Analysis. *Management Science*, *53* (12), 1829–1842.

Donders, M. W. M., & Vorst, T. C. F. (1996). The impact of firm specific news on implied volatilities. *Journal of Banking and Finance*, *20* (9), 1447–1461.

Dos Santos, B. L., Peffers, K., & Mauer, D. C. (1993). The impact of information technology investment announcements on the market value of the firm. *Information Systems Research*, *4* (1), 1-23.

Dumas, B., Fleming, J., & Whaley, R. E. (1998). Implied volatility functions: Empirical tests. *Journal of Finance*, *53* (6), 2059-2106.

Enterprise Risk Management Committee. (2003). Overview of enterprise risk management. http://www.casact.org/area/erm/overview.pdf. (Casualty Actuarial Society)

Fairley, R. (1994). Risk management for software projects. *IEEE Software*, *11* (3), 57-67.

Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. *Journal of Finance, 25* (2), 383-417.

Fornell, C., Mithas, S., Morgeson, F. V., & Krishnan, M. S. (2006). Customer satisfaction and stock prices: High returns, low risk. *Journal of Marketing, 70* (1), 3-14.

Galbraith, J. R. (1974). Organizational design: An information processing view. *Interfaces*, *4* (3), 28-36.

Hentschel, L. (2003). Errors in implied volatility estimation. *Journal of Financial and Quantitative Analysis*, *38* (4), 779-810.

Heynen, R., Kemma, A., & Vorst, T. (1994). Analysis of the term structure of implied volatilities. *Journal of Financial and Quantitative Analysis*, *29* (1), 31-56.

Hull, J., & White, A. (2017). Optimal delta hedging for options. *Journal of Banking and Finance*, *82*, 180-190.

Iacovou, C. L., & Dexter, A. S. (2005). Surviving it project cancellations. *Communications of the ACM*, *48 (4)*, 83-86.

Im, K. S., Dow, K. E., & Grover, V. (2001). Research Report: A Reexamination of IT Investment and the Market Value of the Firm: An Event Study Methodology. *Information Systems Research*, *12* (1), 103–117.

Innotas. (2013). The Project and Portfolio Management Landscape Report.

Jin, W., Livnat, J., & Zhang, Y. (2012). Option Prices Leading Equity Prices: Do Option Traders Have an Information Advantage? *Journal of Accounting Research*, *50* (2), 401–432.

Jorgensen, H. H., Owen, L., & Neus, A. (2008). Making change work. *IBM Global Services*.

Kettinger, W. J., Teng, J. T., & Guha, S. (1997). Business process change: A study of methodologies, techniques, and tools. *MIS Quarterly*, *21* (1), 55-80.

Kim, K., Mithas, S., & Kimbrough, M. (2017). Information technology investments and firm risk across industries: Evidence from the bond market. *MIS Quarterly*, *41* (4), 1347-1367.

Kim, S. D. (2012). Characterizing unknown unknowns. *Paper presented at PMI Global Congress 2012 North America, Vancouver, British Columbia, Canada. Newtown Square, PA: Project Management Institute*.

Kliem, R. L. (2000). Risk management for business process reengineering projects. *Information Systems Management*, *17* (4), 1-3.

Knight, F. H. (1921). *Risk, Uncertainty and Profit*. Boston and New York: Houghton Mifflin.

Kobelsky, K., Hunter, S., & Richardson, V. J. (2008). Information technology, contextual factors and the volatility of firm performance. *International Journal of Accounting Information Systems*, *9* (3), 154–174.

Kohli, R., & Grover, V. (2008). Business value of it: An essay on expanding research directions to keep up with the times. *Journal of the Association for Information Systems*, *9* (11), 23-39.

Kothari, S., Shu, S., & Wysocki, P. D. (2009). Do managers withhold bad news? *Journal of Accounting Research*, *47* (1), 241-276.

Kothari, S. P., Laguerre, T. E., & Leone, A. J. (2002). Capitalization versus expensing: Evidence on the uncertainty of future earnings from current investments in pp&e versus r&d. *Review of Accounting Studies*, *7* (4), 355-382.

Kwon, R. Z., T. H. (1987). *Unifying the fragmented models of information systems implementation*. Chichester: Wiley.

Lee, H. L., So, K. C., & Tang, C. S. (2000). The value of information sharing in a two-level supply chain. *Management Science*, *46* (5), 626-643.

Levy, H., & Yoder, J. A. (1993). The Behavior of Option Implied Standard Deviations Around Merger and Acquisition Announcements. *The Financial Review*, *28* (2), 261 - 272. doi: 10.1111/j.1540-6288.1993.tb01347.x

Loch, K. D., Carr, H. H., & Warkentin, M. (1992). Threats to Information Systems: Today' s Reality, Yesterday' s Understanding. *MIS Quarterly*, *16* (2), 173–186.

Lyytinen, K., & Hirschheim, R. (1987). *Information systems failures a survey and classification* *of the empirical literature*. England: Oxford University Press.

Lyytinen, K., Mathiassen, L., & Ropponen, J. (1998). Attention Shaping and Software Risk: A Categorical Analysis of Four Classical Risk Management Approaches. *Information Systems Research*, *9* (3), 233–255.

Mayhew, S. (1995). Implied volatility. *Financial Analysts Journal*, *51* (4), 8-20.

Merton, R. (1973). The theory of rational options pricing. *Bell Journal of Economics and Management Science*, *4* (1), 141-183.

Merton, R. (1988). Applications of option-pricing theory: twenty-five years later. *American Economic Review*, *88* (3), 323-349.

Mithas, S., Tafti, A., Bardhan, I., & Goh, J. M. (2012). Information Technology and Firm Profitability: Mechanisms and Empirical Evidence. *MIS Quarterly*, *36* (1), 205–224.

Mukhopadyay, T., Rajiv, S., & Srinivasan, K. (1997). Information technology impact on process output and quality. *Management Science*, *43* (12), 1645-1659.

Nicolaou, A. I., & McKnight, H. D. (2006). Perceived Information Quality in Data Ex- changes: Effects on Risk, Trust, and Intention to Use. *Information Systems Research*, *17* (4), 332–351.

Patell, J. M., and Wolfson, M. A. (1981). The Ex ante and Ex post price effects of quarterly earnings announcements reflected in option and stock prices. *Journal of Accounting Research*, 19 (2), 434-458.

Pavlou, P., & Gefen, D. (2004). Building effective online marketplaces with institution-based trust. *Information Systems Research*, *15* (1), 37-59.

Rogers, J. L., Douglas, J. S., & Van Buskirk, A. (2009). Earnings guidance and market uncertainty. *Journal of Accounting and Economics*, *48* (1), 90–109.

Sheikh, A. M. (1989). Stock splits, volatility increases, and implied volatilities. *Journal of Finance*, *44* (5), 1361-1372.

Silhan, P. A., & Thomas, H. (1986). Using Simulated Mergers to Evaluate Corporate Diversification Strategies. *Strategic Management Journal*, *7* (6), 523–534.

Skinner, D. (1994). Why firms voluntarily disclose bad news. *Journal of Accounting Research*, *32* (1), 38-60.

Subramani, M., & Walden, E. (2001). The Impact of E-Commerce Announcements on the Market Value of Firms. *Information Systems Research*, *12* (2), 135–154.

Tanriverdi, H., & Ruefli, T. W. (2004). The Role of Information Technology in Risk /Return Relations. *Journal of the Association for Information Systems*, *5* (11), 421–447.

Tian, F., & Xu, S. X. (2015). How Do Enterprise Resource Planning Systems Affect Firm Risk? Post-Implementation Impact., *MIS Quarterly*, *39* (1), 39–60.

Wang, J. (1994). A model of competitive stock trading volume. *Journal of Political Economy*, *102* (1), 127-168.

Wang, L., & Alam, P. (2007). Information Technology Capability: Firm Valuation, Earnings Uncertainty, and Forecast Accuracy. *Journal of Information Systems*, *21* (2), 27–48.