December 2006

IT Investment and Firm Risk: The Risk Paradox?

Matt Wimble
Michigan State University

IT Investment and Firm Risk: The Risk Paradox?

Matt Wimble
Michigan State University
wimblema@msu.edu

ABSTRACT

Measuring the impact of information technology (IT) investment on firm performance is a long standing issue among both information systems (IS) and researchers in other disciplines. Most research to date on the impact of IT spending on firm performance has focused on the returns that IT investments can provide to firms. Initial studies showed no impact of IT investment and more recent studies have shown an abnormally positive influence. Given the mixed results to date an open question is what is the impact of IT investment on firm performance? Economics has shown a tradeoff between returns and risk, yet most studies to date have not measured risk. Using firm-level IT spending data this research-in-process paper shows that higher levels of IT spending increase the volatility of firm cash flows and earnings, as financial theory suggests, but also reduces the impact of this volatility on in the financial markets.

Keywords

IT Investment, Risk, Productivity, Risk-Return

INTRODUCTION

The impact of Information Technology (IT) investment on firm performance is a central theme of information systems (IS) research for many years and remains an active topic of interest for IS researchers. The majority IS literature to date on IT investment has focused on returns from IT investment. Only recently has research (Wimble, 2006; Dewan, et.al., 2005; Dewan and Ren 2005; Tanriverdi H. and Ruefli, 2004) begun to address the risk-return tradeoff. This paper will address IT impact on risk in terms of cash-flow and market-based volatility. Initial findings to date have only looked at impact of IT capital on firm risk and only risk in the context of accounting returns. This paper will show that overall IT spending does impact the risk of a firm in terms of actual cash-flow and earnings the firm produces.

CONCEPT DEVELOPMENT

There has been a long history of researchers looking at the value of IT investment. Debate about the business value of IT investment can be traced to economist Robert Solow (1987) who noted the difficulties in determining the productivity gains from IT investment, coining the term “productivity paradox”. As late as the early 1990s researchers (Brynjolfsson 1993) had difficulty finding returns from IT investment. More recently IS researchers have found positive returns from IT investment in terms of productivity (Brynjolfsson and Hitt 1996), profitability, consumer surplus (Hitt and Brynjolfsson 1996) , and product quality (Mukopadhyay et. al. 1997). More recently the increasing number of finding of abnormal returns has lead to discussions of the “new productivity paradox” due (Anderson et. al. 2003) to the excessively high returns IT assets seem to provide.

Financial theory informs this work by looking at risk from the variability standpoint. A tradeoff in inherent between risk and return, as shown in figure 1. Finance theory builds from theory by looking at securities markets, but lessons learned from theory can apply to interfirm projects when the firm is viewed as a collection of assets. Markowitz (1952) first looked at risk of an asset as the volatility of that asset, with emphasis placed upon the timing of the returns and the impact on overall portfolio risk and how that risk can be reduced through diversification or counter correlated timing of returns. The role of risk also (Modigliani and Miller, 1958) extends into determining the appropriate return rate for a firm is a weighted result of equity and debt used to capitalize the firm. Risk was formalized for equity in the Capital Asset Pricing Model (CAPM) by Sharpe in 1964. Options pricing theory (Black and Scholes, 1973) extended the role of risk into the pricing of options and looked at how the value of an option is impacted by the volatility of the underlying asset. The important point is that the volatility of an asset is a function of both the a) variability of the cash flows the asset produces and b) the timing of those cash flows. It is worth noting the how important and well investigated the risk/return phenomena is outside the IS community because underinvestigation of risk represents a significant gap in IS literature.

Historically IS literature has looked primarily at the impact of IT investment on firm performance and ignored the impact on firm risk. IS literature has taken up looking volatility via the impact on the real option component (Kumar, 1996; Benaroch and Kaufman, 1999; Sambamurthy et. al. 2003; Fichman 2004) of IT investments. Recent IS literature has begun to look at the impact of IT investments on firm risk. Early work (Hunter et. al. 2005; Dewan and Ren 2005; Dewan et. al. 2005) has shown that IT announcements have a positive relation to firm risk. The aforementioned studies introduce control factor for firm risk that include firm leverage, industry concentration, industry, and diversification. The first published study (Tanriverdi and Ruefli, 2004) that explicitly laid out a relationship between IT spending and firm risk included a moderating effect of the strategic IT vision. Economic theory suggests that there is an inherent tradeoff between risk and return, thus abnormal returns observed recently should result in cost in terms of increased risk.

Risk can be characterized in terms of informational uncertainty and volatility. Informational risk can arise out of bounded rationality issues, where the bound (Spear, 1989) is a function of computability constraints. Rationality bounds can result in having insufficient information and can result in variation. Informational uncertainty can arise when informational search space is so large (Simon, 1955) that it is infeasible to perform an exhaustive search of possible outcomes, giving rise to situations whereby outcomes can vary significantly (Conlisk 1996; Kahneman 2003) from those predicted by rational equilibria. Although originally theorized at the individual level, bounded rationality has been applied in an organizational context and provides is a central concept (Williamson, 1975) in transaction cost economics. An example (Papadimitriou, 1994) is the well known “Traveling Salesman Problem” (TSP) which firms face in a logistics context where getting close to the optimal route is literally a function of the computational power allocated to the problem due to the combinatorial nature of the problem. As a result IT should decrease volatility of performance outcomes attributed to limited cognition by lowering search costs.

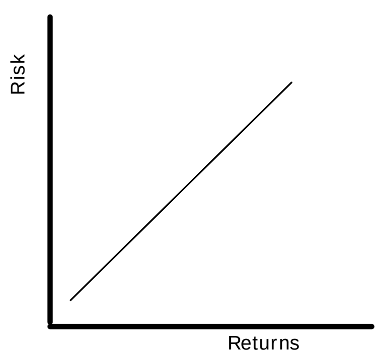

Figure 1. Risk/Return Tradeoff

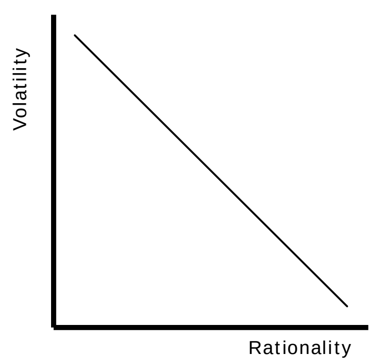

Figure 2. Volatility and rationality

The key conceptual arguments presented are that: 1) bounded rationality theory suggests that increasing the limit on information processing capability should reduce variation, and 2) there is a robust evidence to suggest a tradeoff between risk and return, 3) IT investment can reduce on firm risk, and 4) IS literature has limited explanations as to why returns to IT investments were at first undetectable for decades and are now considered abnormally large.

THEORETIC DEVELOPMENT

Given that the data that is available for this study is a cross-section of 1995, the first year in which positive returns from IT spending (Brynjolfsson and Hitt, 2003) have been observed, existing financial theory suggests that IT spending should increase volatility over this time period. This leads to the following hypotheses:

Hypothesis 1a: Higher IT spending increases the volatility of a firm’s overall cash-flow.

Hypothesis 1b: Higher IT spending increases the volatility of a firm’s earnings.

Hypothesis 1c: Higher IT spending increases the observed volatility in financial markets.

As noted in the conceptual framework, increasing the rationality bound has been shown (Conlisk 1996; Kahneman 2003) to reduce variability of observed outcomes. Current theory makes it difficult to rectify the Solowian “productivity paradox” with the “new productivity paradox” without assuming very large time span for improvement. Volatility inherently necessitates passage of a significant amount of time before results can be observed. Reduction in volatility is suggested by bounded rationality and represents a plausible explanation for why investment kept occurring in the past despite no observable returns to IT in terms of profitability. This leads to the following hypothesis:

.

Hypothesis 2: IT spending moderates the impact of increased cash-flow volatility on volatility in the financial markets.

METHODOLOGY

Firm-level spending information was obtained from the Infoweek500 IT spending survey. 1995 was chosen for three reasons 1) it is often cited (Brynjolfsson and Hitt, 2003) as the first year in which returns from IT spending are empirically observable, 2) it has more firm level spending listed for individual firms, and 3) the data is in a form that make automated entry possible. The remaining firm-level data from COMPUSTAT, which resulted in a final sample size of 158 firms. Volatility in accounting-based returns has shown high correlation (Bowman 1979) with volatility of market returns. Regressions were performed using both net cash flows and earnings as accounting-based measures. Control factors for firm risk include firm leverage and firm size. Firm leverage is calculated as average leverage in 1995. Revenue is used as a measure of firm size. Firm leverage (Bowman 1979) has been shown to positively correlate with firm risk. Level of concentration within an industry has also been used to control risk factors (Kwok and Reeb, 2000; Hunter et. al. 2003; Dewan et. al. 2005), which is measured using the Herfindahl-Hirschman Index (HHI) commonly used in industrial economics. Also controls for industry have been included to control for specific industry-level effects, the controls were at the 2-digit SIC level. Volatility would be primarily in terms of standard deviations for the accounting based returns and in terms of CAPM Beta for the financial-market-based measure of volatility. Initial regression model used to test hypothesis 1 would be:

$$V = \beta_0 + \beta_1 IT + \beta_2 S + \beta_3 L + \beta_4 HHI + \beta_5 PV + \beta_6 I_{Dummy} + \varepsilon$$

Where IT = IT spending, S = firm size in terms of sales, L = financial leverage of the firm, HHI= Herfindahl-Hirschman Index for the firm’s primary industry, PV=past volatility and IDummy is a dummy variable for the 2-digit SIC industry code. The models were tested over five-year periods. Past volatilities were measured using volatilities of the trailing years of corresponding length. Volatility measures were not calculated using 1995 data for either the dependant variable or past volatility measured variables in order to avoid endogenous issues. In order to test hypothesis 2 the following regression model was used:

$$Beta = \beta_0 + \beta_1 IT + \beta_2 S + \beta_3 L + \beta_4 D + \beta_5 HHI + \beta_6 PBeta + \beta_7 CFV + \beta_8 CFV * IT + \varepsilon$$

Where Beta = Volatility in the financial markets, IT = IT spending, S = firm size in terms of sales, L = financial leverage of the firm, HHI= Herfindahl-Hirschman Index for the firm’s primary industry, PBeta= past volatility in the financial markets, CFV = Variance of cash-flows over this time period, and IT*CFV = the moderation effect of IT spending on the impact of cash-flow variance.

RESULTS

Given the potential for heteroskedasticity in cross-sectional data the White test for Heteroskedasticity were performed on all regressions, unless otherwise noted. When tests indicated the presence of heteroskedasticity it was corrected using White Heteroskedasticity-Consistent Standard Errors (WHCSE). The results of the first regression are shown in Table 1, which shows IT to have the predicted impact on cash-flow volatility. Control facts were directionally consistent with existing literature, but not statistically significant. A possible reason for non-significance in the control factors is that empirical research that found the relationships in the past typically dealt with significantly larger sample sizes, such as 10,000 observations.

Table 1. Corrected cash-flow estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	323.6971	177.5496	1.823136	0.0703
SALES	0.006083	0.006388	0.952273	0.3425
LEV	15.67827	20.70355	0.757275	0.4501
IT	3.08E-06	5.20E-07	5.914626	0.0000
HHI	-0.181822	0.179395	-1.013533	0.3125
SIC10	-47.24751	226.2238	-0.208853	0.8349
SIC15	-47.59641	170.7791	-0.278702	0.7809
SIC40	-306.6599	364.0740	-0.842301	0.4010
SIC50	-305.6132	363.0625	-0.841765	0.4013
SIC60	137.1261	366.8617	0.373781	0.7091
SIC70	-436.7251	308.1149	-1.417410	0.1585
SIC80	-513.0692	167.8217	-3.057228	0.0027
CFT5	0.011423	0.153359	0.074488	0.9407

R-squared	0.515038	Mean dependent var	965.3838
Adjusted R-squared	0.474903	S.D. dependent var	2016.788
S.E. of regression	1461.436	Akaike info criterion	17.49092
Sum squared resid	3.10E+08	Schwarz criterion	17.74291
Log likelihood	-1368.783	F-statistic	12.83271
Durbin-Watson stat	2.095535	Prob(F-statistic)	0.000000

Because the nature of the heteroskedasticity was not of major concern to this study, weighted least-squares estimation was not performed. After the correction IT spending was still positively-significantly related to 5-year cash-flow volatility, therefore we find support for hypothesis 1a at the 1% level. Next regression estimations were performed on the 5-year earnings in order to investigate hypothesis 1b.. Again the model was estimated using WHCSE and the results are shown in table 2.

Table 2 . Corrected 5-year earnings volatility

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	94.29728	17.44158	5.406464	0.0000
SALES	0.000194	0.000777	0.250172	0.8028
LEV	-1.100411	0.628801	-1.750013	0.0822
IT	2.84E-07	3.76E-08	7.565589	0.0000
HHI	0.001418	0.019204	0.073834	0.9412
SIC10	-93.72895	59.92194	-1.564184	0.1200
SIC15	-85.55712	20.58037	-4.157220	0.0001
SIC40	3.707461	43.75414	0.084734	0.9326
SIC50	-46.56471	44.57268	-1.044692	0.2979
SIC60	-6.538258	30.68469	-0.213079	0.8316
SIC70	-29.91171	32.66493	-0.915713	0.3613
SIC80	-24.84167	19.36431	-1.282858	0.2016
ET5	0.026773	0.060092	0.445524	0.6566

R-squared	0.402720	Mean dependent var	148.7774
Adjusted R-squared	0.353290	S.D. dependent var	211.7591
S.E. of regression	170.2931	Akaike info criterion	13.19161
Sum squared resid	4204962.	Schwarz criterion	13.44360
Log likelihood	-1029.138	F-statistic	8.147255
Durbin-Watson stat	1.886618	Prob(F-statistic)	0.000000

After the correction IT spending was still positively-significantly related to 5-year earnings volatility, therefore we find support for hypothesis 1b at the 1% level. Next we examined the impact of IT spending on the volatility observed in the financial markets. The model was estimated using WHCSE and the results are shown in table 3.

Table 3. Corrected 5-year Beta estimations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.434759	0.067908	6.402157	0.0000
SALES	7.10E-07	1.29E-06	0.551380	0.5822
LEV	0.000846	0.003038	0.278546	0.7810
IT	1.14E-10	4.12E-11	2.762922	0.0065
HHI	-6.14E-06	4.97E-05	-0.123526	0.9019
SIC10	-0.100011	0.104278	-0.959081	0.3391
SIC15	-0.298627	0.050666	-5.894052	0.0000
SIC40	-0.162448	0.058766	-2.764317	0.0064
SIC50	-0.069988	0.070426	-0.993787	0.3220
SIC60	-0.077181	0.070512	-1.094574	0.2755
SIC70	-0.148408	0.070535	-2.104027	0.0371
SIC80	-0.224459	0.045602	-4.922086	0.0000
BETA5T	0.313012	0.054139	5.781616	0.0000

R-squared	0.328822	Mean dependent var	0.751208
Adjusted R-squared	0.273277	S.D. dependent var	0.302782
S.E. of regression	0.258116	Akaike info criterion	0.207877
Sum squared resid	9.660428	Schwarz criterion	0.459863
Log likelihood	-3.422279	F-statistic	5.919851
Durbin-Watson stat	2.409566	Prob(F-statistic)	0.000000

After the correction IT spending was still positively-significantly related to 5-year earnings volatility, therefore we find support for hypothesis 1c at the 5% level. Finally we estimated a model of 5-year Betas using cash-flow variance that is known to be correlated (Bowman, 1979) along with other known volatility causes in order to investigate hypothesis 2. Since we were going to add an interaction term to test it significance we did not test nor correct for heteroskedasticity, since the corrections done to the standard errors would violate the assumptions of the F-test needed to compare the impact of the interaction effect variable. Next OLS estimation was performed with an interaction effect to determine if IT spending moderates the impact of cash-flow volatility on volatility observed in the financial markets.

Table 5. IT-cash-flow interaction estimation.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.341097	0.052727	6.469118	0.0000
SALES	9.90E-07	1.15E-06	0.861764	0.3902
LEV	0.000248	0.001965	0.126425	0.8996
IT	1.43E-10	8.58E-11	1.664725	0.0981
HHI	3.06E-05	3.26E-05	0.937629	0.3499
CFF5	6.14E-05	1.57E-05	3.898895	0.0001
BETA5T	0.302545	0.044234	6.839606	0.0000
CFF5*IT	-2.42E-14	8.84E-15	-2.739947	0.0069

R-squared	0.362270	Mean dependent var	0.751208
Adjusted R-squared	0.332509	S.D. dependent var	0.302782
S.E. of regression	0.247373	Akaike info criterion	0.093467
Sum squared resid	9.179009	Schwarz criterion	0.248535
Log likelihood	0.616100	F-statistic	12.17275
Durbin-Watson stat	2.425705	Prob(F-statistic)	0.000000

Finally to construct a test of the impact of the interaction term on the new model we use the F-test found in Gujarati (2003) of:

$$F = \frac{\left(r_{new}^2 - r_{old}^2\right)/df}{\left(1 - r_{new}^2\right)/df}$$

Where df numerator is the number of new IVs and df-denominator is n-number of IVs in the new model. These results in $\hat{F} = \frac{(0.3623 - 0.3304)/1}{(1 - 0.3623)/(158 - 8)}$ or $\hat{F} = 7.504$ where C.V. 1/150 for F-distribution = 6.85 @ 1% we find the interaction term to be significant and support hypothesis 2. A summary of the findings is shown in table 9.

Table 1. Summary of findings

Hypothesis	Description	Findings
1a	Higher IT spending increases the volatility of a firm cash-flow	Significant at 1%
1b	Higher IT spending increases the volatility of a firm earnings	Significant at 1%
1c	Higher IT spending increases firm volatility in the financial markets	Significant at 5%
2	IT spending moderates the impact of increased cash-flow volatility on volatility in the financial markets	Significant at 1%

DICCUSSION AND CONCLUSIONS

The primary finding for the research to date is that IT spending has a significant impact upon the future volatility of a firm's cash flows. The work is primarily limited in sample size and time span. This research-in-process will be expanded to include both a larger cross-section of firms and longer time horizon. It was shown that IT spending that is known to have a positive impact upon earnings does, as financial theory suggest, increase both accounting-based and financial market risk. The interesting finding to emerge from this study is that IT spending appears to reduce the impact of cash-flow volatility on volatility in the financial market. The implications for managers are that in order to get the productivity benefits from IT it might be necessary to accept some additional accounting-based risk, but financial markets appear to discount the risk attributable to IT making the impact on cost-of-capital less than for other investments. For researchers this work-in-process represents a significant step toward investigating the impact of IT spending on what has been an extremely important area in other disciplines and raises significant issues as to the true impact of IT on firm risk. Possible future areas of research include examination of risk impacts from IT over longer time horizons, investigation of possible moderators, and frontier-based performance measures such as DEA or SFA.

REFERENCES

1. Anderson M.C., Banker R.D., and Ravindran S., 2003, "The new productivity paradox", Communications of the ACM, 46(3), 91-94
2. Benaroch M. and Kaufmann R., 1999, "A Case for Using real Options pricing Analysis to Evaluate Information Technology Development Projects Investments", Information Systems Research, 10(1), 70-86
3. Bharadwaj A., Bharadwaj S., and Konsynski B., 1999, "Information technology effects on firm performance as measured by Tobin's q", Management Science, 45(6), 1008-1024.
4. Black F. and Scholes M., 1973, "The Pricing of Options and Corporate Liabilities", Journal of Political Economy, 81(3), 637-654
5. Bowman R., 1979, "The Theoretical relationship Between Systematic Risk and Financial (Accounting) Variables", Journal of Finance, 34(3), 617-630
6. Bresnahan, T., and Trajtenberg, M., 1995, "General Purpose Technologies: 'Engines of Growth'?", Journal of Econometrics, 65, 83-108
7. Brynjolfsson E., 1993, "The Productivity Paradox of Information Technology", Communications of the ACM, 35(Dec.), 66-67
8. Brynjolfsson, E. and Hitt, L., 1996, "Paradox lost? Firm-level Evidence on the Returns to Information Systems Spending", Management Science, 42(4), 541-558
9. Brynjolfsson, E. and Hitt,L., 2003 , "Computing Productivity: Firm-Level Evidence", Review of Economics and Statistics, 85(4), 793-808

10. Dehning B., Richardson V.J., and Zmud R.W., 2003, "The Value Relevance of Announcements of Transformational Information Technology Investments", MIS Quarterly, 27(4), 637-656
11. Dewan S. and Min C., 1997, "The substitution of information technology for other factors of production: A firm level analysis", Management Science, 43(12), 1660-1675
12. Dewan S., Shi C. and Gurbaxani V., "Investigating the Risk-Return Relationship of Information Technology Investment: Firm-Level Empirical Analysis," working paper, September 2005.
13. Dewan S. and Ren F., 2005, "Risk Vs. Return of IT Initiatives: An Event Study Analysis", WISE 2005
14. Fama E. and MacBeth J., 1973, "Risk, Return, and Equilibrium: Empirical Tests", The Journal of Political Economy, 81(3), 607-636.
15. Fichman, R., 2004, "Real Options and IT Platform Adoption: Implications for Theory and Practice", Information Systems Research, 15(2), 132-154
16. Guay W., 1999, "The Impact of derivatives on firm risk: An empirical examination of new derivative users", Journal of Accounting and Economics, 26, 319-351
17. Gujarati, D., 2003, *Basic Econometrics 4th Edition, McGraw-Hill*, New York, NY.
18. Hitt and Brynjolfsson, 1996, "Productivity, Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value", MIS Quarterly, 20(2), 121-142
19. Hunter S., Kobelsky K., and Richardson V., 2003, "Information Technology and the Volatility of Firm Performance", Working Paper #4449-03, MIT Sloan School of Management
20. Kwok C. and Reeb D., 2000, "Internationalization and Firm Risk: An Upstream-Downstream Hypothesis", Journal of International Business Studies, 31(4), 611-629
21. Kumar, R., 1996,"A Note on Project risk and Option Values of Investments in Information Technologies", Journal of Management Information Systems, 13(1), 187-193
22. Lockwood, L., and Kadiyala, K., 1988, "Risk Measurement for Event-Dependant Security Returns", Journal of Business and Statistics, 6(1), 43-49
23. Markowitz H. M., 1952, "Portfolio Selection", Journal of Finance, 7(2), 77-91.
24. McGrath, R. G., 1997, "A real options logic for initiating technology positioning investments", Academy of Management Review, 22(4), 974–996
25. Minton, B. and Schrand, C., 1999, "The Impact of Cash-Flow Volatility on Discretionary Investment and the Costs of Debt and Equity Financing", Journal of Financial Economics, 54, 423-460
26. Modigliani F. and Miller M., 1958, "The Cost of Capital, Corporation Finance and the Theory of Investment", The American Economic Review, 48(3), 261-297
27. Mukhopadhyay T., Rajiv S., and Srinivasan K., 1997, "Information Technology Impact on Process Output and Quality", Management Science, 43(12), 1645-1659
28. Sambamurthy, V., A. Bharadwaj, and V. Grover., 2003, "Shaping agility through digital options: Reconceptualizing the role of information technology in contemporary firms", MIS Quarterly, 27(2), 237–263.
29. Sharpe W., 1964, "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk", Journal of Finance, 19(4), 425-442.
30. Solow, Robert M. 1987. "We'd better watch out." New York Times Book Review (July 12): 36.
31. Subramani M. and Walden E., 2001, "The Impact of E-commerce Announcements on the Market Value of Firms", Information Systems Research, 12(2), 135-154
32. Tanriverdi H. and Ruefli T., 2004, "The Role of Information technology in Risk/Return Relations of Firms", Journal of the Association for Information Systems, 5(11-12), 421-447
33. Wimble,M., 2006, submitted to MWAIS, "IT Investment, Risk, and Firm Performance"