

# Financial Performance of Internet and Brick-and-Mortar Companies: A Comparative Analysis

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## ABSTRACT

*This paper aims to explore potential differences in financial performance of Internet companies and the traditional brick-and-mortar companies. A compressive financial ratio analysis is used to investigate these differences for the period from 1998 to 2003. Contrary to our expectations, the average performance of the Internet companies was significantly worse than that of traditional brick-and-mortar companies.*

## INTRODUCTION

Since the late 1990s, buying and selling goods over the Internet has become a common business practice. Forrester research reported that E-commerce sales in 2005 increased 22% to \$172 billion from \$141 billion in 2004. This trend is expected to continue and according to Forrester, e-commerce sales will reach \$228 billion in 2007 (Khan 2006). Even U.S. e-commerce sales in 2004 alone were estimated at \$69.2 billion, which represent 23.5 percent increase from 2003 (U.S. Census Bureau 2005).

In spite of its importance and contribution to the whole economy, e-commerce is associated with the stock market bubble and the following crash. During this so-called dotcom crash, in 2000 and 2001, many, often very promising Internet companies, went out of business (Javalgi et al. 2004).

Practitioners and academic researchers provided a number of explanations for the dotcom crash (Shama 2001; Thornton and Marche 2003). The possible explanations included inexperienced management, absence of sound business model, and lack of attention to financial reality.

Prior to the dotcom crash, many business managers and investors followed the assumption that the traditional financial analysis tools are restricted to old economy. For example, a systematic ratio analysis has been rarely conducted for Internet companies. This is very surprising due to the fact that ratio analysis is one of the most common tools used for measuring financial performance (Bharadwaj 2000; Hunton et al. 2003; Kudyba and Vitaliano 2003; Santhanam and Hartono 2003; Motiwalla et al. 2005; Bose and Pal 2006).

According to a rich body of research, ratio analysis is a powerful tool in assessing the financial health of companies and predicting business failures (Beaver 1966; Altman 1968). However, regarding the Internet companies, it is not clear whether this method needs to be adjusted and what the reasonable ratios are.

This scarcity of financial ratio research in Internet companies provides motivation for our study. Although Motiwalla et al. (2005) examined the impact of e-business on financial performance, the study focused on an intra- and inter-industry level of three industries. Besides, the examined firms were not pure "click" companies but "brick and click" companies, which decided to embrace the Internet in order to support their traditional operations and to improve the bottom-line performance. In contrast, our study focuses on the financial performance of pure "click" companies and compares it with that of the traditional brick-and-mortar companies.

The structure of our paper is as follows: the next section, based on literature review, introduces a set of hypotheses; research methodology section describes the methodology, the results section presents the empirical results, and the discussion section includes a brief discussion of the results. The final section provides conclusions of the paper and offers some ideas for future research.

## BACKGROUND AND RESEARCH HYPOTHESES

The Internet has changed the way the organizations conduct their business today. The number of firms that take advantage of Internet technology has grown rapidly in the late 1990s. Firms that heavily use the Internet for their business activities are commonly defined as the dotcoms, Internet firms or pure "click" companies. Consequently, many of these companies conduct their business almost exclusively over the Internet. Dotcoms can be classified into two categories: the digital and physical dotcoms depends on the products and services that they sell (Barua et al. 2004a). Yahoo and eBay are examples of digital dotcoms that deliver services directly over the Internet. Amazon.com is an example of physical dotcoms, which are often referred to as e-retailers that sells physical products on the Internet.

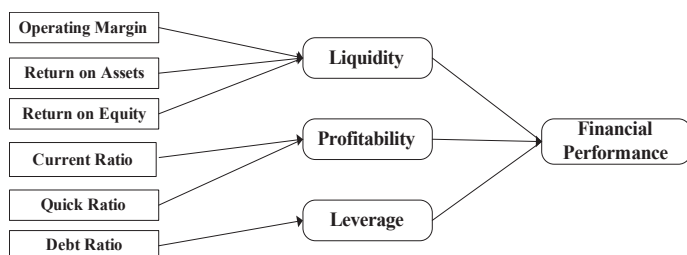
As described previously, Internet companies are often associated with dotcom crash. During this period, many firms run out of cash, closed their doors for business or become easy acquisition targets. Liquidity, or ability to meet financial obligations in short term, is important factor in avoiding financial difficulties. Thus, Internet companies may be expected to have liquidity problems. However, we argue that most of the Internet companies which managed to survive the dotcom crash and are in operations for several years must have a better position in liquidity. In other words, their liquidity is not worse than the established brick-and-mortar companies. The most well known measure of liquidity of the firms are current and quick ratios (Yang et al. 2001; Pasiouras et al. 2006). Therefore, the following hypothesis is proposed.

H1: Internet companies' liquidity, measured in terms of *current ratio* and *quick ratio*, is comparable to the traditional companies' liquidity.

Internet related technologies enable firms to reduce inventory, decrease stock-out situations, and improve response time (Barua et al. 2004b), and organization's operational efficiency and effectiveness (Chang et al. 2003). For example, these dotcoms can enjoy the benefits of reduced transactions cost, smaller or no inventory, 24/7 access with minimal cost (Motiwalla et al. 2005). Thus, we assume that Internet companies have greater operational efficiency as compared with traditional brick-and-mortar companies. There are several common measures of profitability. *Operating margin* (OM) is considered as one of important profitability measures since it measure a firm's core operations by excluding interest expenses, other financing costs, and other non-operating income (Kudyba and Vitaliano 2003). *Return on assets* (ROA) has been the most commonly used measure of firm performance (Hitt and Brynjolfsson 1996; Bharadwaj 2000) and a useful performance measure since it incorporates organizational profitability and efficiency (Hunton et al. 2003). *Return on equity* (ROE) is also another performance indicator that was often used in previous research (Hitt and Brynjolfsson 1996; Wheale and Amin 2003; Shin 2006). Regarding the Internet companies, the obvious ability of reaching a large customer base combined with the indisputable advantages of reduced costs should translate into higher profitability. Thus, the following hypothesis is proposed.

H2: Internet companies' profitability, measured in terms of *operating margin* (OM), *return on assets* (ROA), and *return on equity* (ROE), is greater than traditional companies' profitability.

Figure 1. Financial performance measure



Most of Internet companies finance their operations mainly with help of the venture capital and the stock market (Wheale and Amin 2003). More traditional sources of financing, such as bank loans, prevalent in the brick-and-mortar firms, are rather uncommon for Internet companies. Leverage, defined as ability to meet financial obligations in long-term, is also another important factor identifying financial difficulty. *Debt ratio* is a commonly used measure of leverage (Yang et al. 2001). Therefore, the following hypothesis is proposed.

H3: Internet companies' financial leverage, measured in terms of *debt ratio*, is lower than traditional companies' financial leverage.

The hypotheses can be summarized into the research model shown in Figure 1.

## RESEARCH METHODOLOGY

The "matched sample comparison group" methodology is used to explore the potential differences in financial performance between Internet based and traditional brick-and-mortar companies. This method has also been used in previous studies (Bharadwaj 2000; Hunton et al. 2003). Our sample includes two groups; the treatment and control groups. The treatment group represents a sample of Internet companies and the control group represents companies that were selected to match the treatment group by size and industry.

### Sample Selection

To select Internet firms, we started out with the list from USA Today Internet 100 Index (as of August, 9, 1999). This index consisted of 100 most relevant Internet companies at this time. To be included, the companies needed to have market capitalization of \$200 millions and their share price needed to be at least \$12 (Smith 1999). The selection from USA Today Internet 100 Index, assured that our treatment group included only firms which can be considered as Internet companies with relatively established business. Furthermore, this selection procedure increased comparability of the firms and minimized selection bias. From this initial list of 100 Internet companies, firms that are not included in Compustat were removed. Furthermore, firms that have merged with another firm or had missing data during the period from 1998 to 2003 were removed. As a result, the treatment group includes 16 firms.

To control for confounding changes in industry and the firm size, we followed some steps to select a matching control firm that is comparable to the treatment firm. Initially, firms from the same primary four-digit code as the treatment firm were selected from Compustat as potential control firms. Then, we used total assets and annual sales as the size measure, which are commonly used as proxies for the firm size and chose the firm that has the closest to the corresponding treatment firm's values in 1998. When no comparable control firms were available, we allowed the size measures to be between 70% and 130% of the treatment firm's values. Next, we allowed using three-digit SIC codes, and then if no potential firms are found, two-digit SIC codes are finally used to select the control firm. This method was also used in previous studies for selecting matching control group from the same industry and similar in size as the treatment group (Barber and Lyon 1996; Hunton et al. 2003). Once the potential control firm is selected, the firm is evaluated carefully to make sure that it is a traditional brick-and-mortar company. Companies with substantial portion of sales on Internet were not considered for

Table 1. List of financial ratios studied

Ratio	Category	Description
Current Ratio	Liquidity	Current assets / Current liabilities
Quick Ratio	Liquidity	(Current assets – inventories) / Current liabilities
OM (Operating Margin)	Profitability	Operating income / Net sales
ROA (Return on Assets)	Profitability	Net income / Total assets
ROE (Return on Equity)	Profitability	Net income / Stockholders' equity
Debt Ratio	Leverage	Total debt / Total assets

the control group since they are considered "brick and click" companies. See the Appendix for the list of treatment and control groups.

For all treatment and control firms, we selected six years' (1998 – 2003) financial data. As a result, 192 data points were included in our analysis.

### Measuring Performance

To evaluate financial performance, we used ratio analysis, which is the most commonly used approach to measure a firm's performance (Beaver 1966; Altman 1968; Barney 1997; Bharadwaj 2000; Hunton et al. 2003). We used two liquidity based ratios (*current* and *quick* ratios), three profit based ratios (OM, ROA, and ROE) and one leverage ratio (*debt ratio*) for investigating the performance of 16 Internet companies and 16 traditional brick-and-mortar companies. Financial data from Compustat are pulled for these companies for the years from 1998 to 2003.

Liquidity ratios are used to examine the firm's ability to meet its current debts. Profitability ratios are used to determine firm's profitability or efficiency. Leverage ratios are used to predict the long-term solvency of the firm. The list of the financial ratios included in this study is shown in Table 1.

## RESULTS

### Descriptive Statistics

To assure the comparability between the treatment and control groups, a t-test and non-parametric (Mann-Whitney) tests were carried out. As depicted in Table 2, on average, treatment group's total assets were slightly larger and control group's sales were slightly larger. However, these differences were statistically insignificant. Therefore, it could be assumed that the characteristic of companies included in the control group is comparable to these selected for the treatment group.

### Results of the Differences Between Two Groups

Table 3 summarizes the results of the differences of financial performance, as captured by studied ratios, between the treatment and control groups. The t-statistics from the t-test and the Z-statistics from the Mann-Whitney (non-parametric) test

Table 2. Descriptive statistics for Internet (Treatment) and traditional (Control) firms

Variables	Treatment group		Control group		T-test (p value)	Mann-Whitney Test (p value)
	Mean	Std. dev.	Mean	Std. dev.		
Total assets (in million)	266.3	338.6	225.1	226.5	-0.405 (0.323)	0.226 (0.821)
Sales (in million)	109.0	154.9	147.2	148.9	0.712 (0.765)	-1.131 (0.258)

Table 3. Performance differences between treatment and control firms

Performance measures	1998		1999		2000	
	T	Z	T	Z	T	Z
Current Ratio	1.513	1.697 <sup>c</sup>	2.375 <sup>b</sup>	2.392 <sup>b</sup>	-0.249	-0.900
Quick Ratio	2.376 <sup>b</sup>	2.232 <sup>b</sup>	2.997 <sup>a</sup>	2.717 <sup>a</sup>	0.107	1.068
OM	-3.237 <sup>a</sup>	-2.374 <sup>b</sup>	-3.006 <sup>a</sup>	-2.299 <sup>b</sup>	-2.587 <sup>b</sup>	-2.337 <sup>b</sup>
ROA	-2.605 <sup>b</sup>	-3.110 <sup>a</sup>	-1.950 <sup>c</sup>	-3.034 <sup>a</sup>	-2.709 <sup>b</sup>	-3.467 <sup>a</sup>
ROE	-0.671	-2.412 <sup>b</sup>	-2.142 <sup>b</sup>	-2.808 <sup>a</sup>	-0.485	-2.714 <sup>a</sup>
Debt Ratio	-2.396 <sup>b</sup>	-2.105 <sup>b</sup>	-1.464	-1.818 <sup>c</sup>	-1.162	-1.780 <sup>c</sup>
Performance measures	2001		2002		2003	
	T	Z	T	Z	T	Z
Current Ratio	-0.621	-0.669	-0.552	-0.051	0.870	0.956
Quick Ratio	-0.531	-0.679	-0.012	-0.707	1.474	1.508
OM	-2.842 <sup>a</sup>	-2.940 <sup>a</sup>	-1.669	-1.508	-0.774	-0.720
ROA	-3.768 <sup>a</sup>	-3.241 <sup>a</sup>	-2.660 <sup>b</sup>	-2.770 <sup>a</sup>	-1.634	-1.222
ROE	-2.435 <sup>b</sup>	-2.789 <sup>a</sup>	-2.200 <sup>b</sup>	-2.789 <sup>a</sup>	-1.772 <sup>c</sup>	-1.397
Debt Ratio	-0.956	-1.677 <sup>c</sup>	-1.335	-1.780 <sup>c</sup>	-1.390	-1.538

<sup>a</sup> 1 % level<sup>b</sup> 5 % level<sup>c</sup> 10 % level

are reported. A negative sign before the test statistic indicates that the performance of the treatment group (Internet firms) is lower than the control group (brick-and-mortar companies) and a positive sign indicates otherwise.

Results from the analysis were as follows: First, the Internet firms' *current* and *quick* ratios were higher than the traditional firms in 1998, 1999, and 2003 although they were not significant in 2003. The positive signs of these ratios indicate the Internet firms' ability to meet short-term obligations is high. However, these ratios have changed to negative and low during 2000 to 2002 although they were not significant. The unusually high ratios in 1998 and 1999 could be easily explained with high cash reserves initially raised from investors. In contrast, beginning in 2000 the *current* and *quick* ratios of the Internet and traditional companies are not significantly different. Based on these results our hypothesis 1 seems to be supported.

All differences in profit ratios in each of the six years were negative. Thus, the average performance of the treatment group was significantly lower than that of the control group.

For example, OM was significant and negative for all years except for 2003. This shows that, on average, Internet companies were not able deliver their products or services at high price while keeping their costs low. ROA was significant and negative for all years except for 2003. Also, ROE was significant and negative in 2001 to 2003. These profitability ratios indicate that Internet firms were not as profitable as the traditional firms. Therefore, our hypothesis 2 is not supported.

The negative *debt ratio* in each of the six years indicates that the treatment group's leverage ratios were lower than that of the control firms. Thus, it indicates that Internet firms are considered to be less leveraged than traditional firms. Companies that are highly leveraged are believed to be at greater risk of bankruptcy if they cannot make payments on their debt. In other words, when financing their business operations, Internet companies seem to rely more on equity investors than on banks and other creditors. Our hypothesis 3 seems to be supported.

## DISCUSSION OF RESULTS

The results of our analysis show substantial similarities and differences in accounting measures of Internet as compared to the traditional brick-and-mortar companies. In the line with our expectations, the liquidity (as measured by *current* and *quick* ratios) of Internet companies is comparable to the liquidity of brick-and-mortar companies. In addition, as we expected, the Internet companies

still rely on investors and equity as main source of financing their business and their average *debt ratio* is low.

Contrary to our expectations, the average performance of the Internet companies was significantly worse than that of traditional brick-and-mortar companies. Our results are also contrary to the common theory that companies constantly learn to be more efficient as they stay in business (Jovanovic 1982). Accordingly to this theory, companies which are not able to learn and improve their efficiency to match their competitors are not likely to survive over long term.

Surprisingly, the differences in performance did not prevent the studied Internet companies to successfully survive the dotcom crash. Moreover, these differences did not diminish over the time and even the most current financial records of Internet companies are still dissimilar from the brick-and-mortar companies. One possible explanation could be that the negative differences in the business performance (as measured by OM, ROA, and ROE) reflect the relatively early stage in the development of these companies and very vibrant but growing market. Contrary to the brick-and-mortar companies, Internet companies must invest heavily to protect and build their market shares. They are less likely to have the luxury to rely on established brands, protected or highly regulated markets, or loyal customer base. This claim could be supported by the observation that in Internet companies financial accounting losses are accepted by the investors as necessary strategic investments and often rewarded with increasing stock prices (Wheale and Amin 2003).

Results of our study are summarized in Table 4.

Table 4. Summary of results

Hypothesis	Supported?	Results
H1	Yes	Liquidity of Internet companies is comparable with traditional brick-and-mortar companies
H2	No	Profitability of Internet is lower than the profitability of traditional brick-and-mortar companies
H3	Yes	Financial leverage of Internet companies is lower as compared with traditional brick-and-mortar companies

## CONCLUSIONS AND FUTURE RESEARCH PLANS

Contrary to our expectations, the average financial performance of the Internet companies was significantly worse than that of traditional brick-and-mortar companies. Although we expected that the Internet companies should be more efficient since these companies made great deal of investment in technology to support e-commerce business operations, our results indicated otherwise.

There are several limitations of our study. First, Internet companies in our sample are those who survived after the dotcom crash and did not go bankrupt or merged. All Internet companies studied were still in operations as of year 2003. Second limitation of our study is that accounting measures might not be the best measures although they are the most commonly used financial performance measure in the previous studies. Third our results are limited to only six ratios. A greater number of ratios may yield different results. In addition, our results are based on relatively short series of data. As mentioned earlier in our analysis, we only used available financial information from the years 1998-2003. It is possible that a longer time period might produce different results. Finally, another limitation is our relatively small sample size of companies studied, which might limit the generalizability of the findings although it does not affect our ability to draw the conclusion.

In spite of these limitations, we believe our study made an important contribution to the research by exploring financial performance of Internet companies using ratio analysis. Research comparing the Internet companies with traditional companies can provide valuable information to IT managers searching for higher productivity or profitability. For companies engaged in e-commerce, this kind of research could help to determine their optimal level of IT investments. Furthermore, it points out the potential gaps in performance which can then be addressed by business managers.

There are plenty of research opportunities related to our study. One future research could simply validate our results with the expanded sample size of companies and an expanded set of financial ratios. Further research opportunity is also to find out the portion of technology investment of Internet companies and determine the productivity or profitability impact from IT. Although Internet companies were not as profitable or efficient as the traditional companies in our study, the years that we have studies might have caused the different outcome since many of Internet companies went out of business during this period. It might be worth investigating using financial data beyond year 2003 to determine if these companies' performance is improving.

## REFERENCES

- Altman, E.I. "Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy," *The Journal of Finance* (23:4) 1968, pp 589-609.
- Barber, B.M., and Lyon, J.D. "Detecting Abnormal Operating Performance: The Empirical Power and Specification of Test Statistics," *Journal of Financial Economics* (41:3) 1996, pp 359-399.
- Barney, J.B. "What is performance?," in: *Gaining and Sustaining Competitive Advantage*, Addison-Wesley, Boston, MA, 1997, pp. 30-64.
- Barua, A., Brockett, P.L., Cooper, W.W., Deng, H., Parker, B.R., Ruefli, T.W., and Whinston, A. "DEA evaluations of long- and short-run efficiencies of digital vs. physical product 'dot com' companies," *Socio-Economic Planning Sciences* (38:4) 2004a, pp 233-253.
- Barua, A., Konana, P., and Whinston, A. "An Empirical Investigation of Net-Enabled Business Value," *MIS Quarterly* (28:4) 2004b, pp 585-620.
- Beaver, W.H. "Financial Ratios as Predictors of Failure," *Journal of Accounting Research* (4:Empirical Research in Accounting: Selected Studies 1966) 1966, pp 71-111.
- Bharadwaj, A.S. "A resource-based perspective on information technology capability and firm performance: An empirical investigation," *MIS Quarterly* (24:1) 2000, pp 169-196.
- Bose, I., and Pal, R. "Predicting the survival or failure of click-and-mortar corporations: A knowledge discovery approach," *European Journal of Operational Research* (174:2) 2006, pp 959-982.
- Chang, K.-C., Jackson, J., and Grover, V. "E-commerce and corporate strategy: an executive perspective," *Information & Management* (40:7) 2003, pp 663-675.
- Hitt, L., and Brynjolfsson, E. "Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value," *MIS Quarterly* (20:2) 1996, pp 121-142.
- Hunton, J., Lippincott, B., and Reck, J.L. "Enterprise resource planning systems: comparing firm performance of adopters and nonadopters," *International Journal of Accounting Information Systems* (4:3) 2003, pp 165-184.
- Javalgi, R., Cultler, B., and Tood, P. "An Application of an Ecological Model to Explain the Growth of Strategies of Internet Firms: The Case of eBay and Amazon," *European Management Journal* (22:4) 2004, pp 464-470.
- Jovanovic, B. "Selection and the Evolution of Industry," *Econometrica* (50:3) 1982, pp 649-670.
- Khan, M.R. "Forrester: E-Commerce Sales in Multi-channel World Surged 22% to \$172B in 2005," in: *DM News*, January 17, 2006.
- Kudyba, S., and Vitaliano, D. "Information Technology and Corporate Profitability: A Focus on Operating Efficiency," *Information Resources Management Journal* (16:1) 2003, pp 1-13.
- Motiwalla, L., Khan, M.R., and Xu, S. "An intra- and inter-industry analysis of e-business effectiveness," *Information & Management* (42:5) 2005, pp 651-667.
- Pasiouras, F., Gaganis, C., and Zopounidis, C. "Multicriteria decision support methodologies for auditing decisions: The case of qualified audit reports in the UK," *European Journal of Operational Research* (upcoming) 2006.
- Santhanam, R., and Hartono, E. "Issues in Linking Information Technology Capability to Firm Performance," *MIS Quarterly* (27:1) 2003, pp 125-153.
- Shama, A. "Dot-coms' coma," *The Journal of Systems and Software* (56:1) 2001, pp 101-104.
- Shin, N. "The impact of information technology on the financial performance of diversified firms," *Decision Support Systems* (41:4) 2006, pp 698-707.
- Smith, E.B. "New index measures wide range of Net stocks," in: *USA Today*, August 9, 1999.
- Thornton, J., and Marche, S. "Sorting though the dot bomb rubble: how did the high-profile e-tailers fail?," *International Journal of Information Management* (23:2) 2003, pp 121-138.
- U.S. Census Bureau "Quarterly Retail E-Commerce Sales 4th Quarter 2004," in: *United States Department of Commerce News*, February 24, 2005.
- Wheale, P.R., and Amin, L.H. "Bursting the dot-com 'Bubble': A Case Study in Investor Behaviour," *Technology Analysis & Strategic Management* (15:1) 2003, pp 117-136.
- Yang, B., Li, L.X., Ji, H., and Xu, J. "An early warning system for loan risk assessment using artificial neural networks," *Knowledge-Based Systems* (14:5-6) 2001, pp 303-306.

## APPENDIX 1: TREATMENT AND CONTROL COMPANIES

Treatment Group	Control Group
Amazon.com	Bay St Bancorp Inc
Ameritrade	Blair Corp
Autobyte	Calif First National Bancorp
Barnesandnoble.com	Elbit Vision Systems Ltd
Broadcom	Electro Scientific Inds Inc
Checkfree Holdings	Electro Rent Corp
DoubleClick	First Albany Companies Inc
eBay	Hummingbird Ltd
iVillage	Integral Systems Inc
MarketWatch	Mercury Interactive Corp
Multex.com	Medquist Inc
Net.Bank	Obie Media Corp
Priceline.com	Pervasive Software Inc
Sportline USA	Pinnacle Data Systems Inc
TheStreet.com	Softech Inc
Yahoo	Star Gas Partners -LP



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