Valuation of innovation: The case of iPhone

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Abstract

We estimate the private value of Apple's iPhone by observing abnormal stock market reactions to news announcements and patent publications related to the innovation. Our estimate of the lower bound on the market valuation of iPhone is fairly high, at minimum 30 billion U.S. (event day) dollars. We find that patentable technology explains about 25% of that total value. We also find a weak negative reaction among Apple's rivals to the news about iPhone but no significant reaction to the publication of patent documents concerning iPhone can be observed. The evidence suggests that the value of iPhone primarily stems from Apple's management and marketing abilities and efforts rather than from underlying "hard" technologies and intellectual property.

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1. Introduction

Valuation of innovations and the determinants of that valuation are crucial but challenging questions for corporate managers and technology policy makers. One popular valuation method uses the stock market returns as their measuring tool. This valuation effort is often hampered by noise that is present in stock returns. In this study, we tackle the challenges in measurement of the value of innovations by conducting a careful in-depth case study of a single technology product.

The high-profile entry by Apple into the cellular phone market via the launch of iPhone in 2007 presents a fruitful case to study valuation of new product innovations. The cellular phone industry is very patent intensive, and characterized by cumulative innovation, strong network effects and a high degree of standardization. Such features tend to create high implicit barriers to entry, thus leading to a high level of market concentration. Apple's positions in the product and stock markets provide a number of features that support the use of stock market reactions to news announcements in valuation of iPhone. First, the size and the status of Apple allow us to study the value of a market entry from a viewpoint that differs markedly from that of a typical technology entrant with a small size and a low trading volume. Specifically, Apple's stock has high trading volume, which should reduce concerns of thin trading that tends to plague innovation valuation studies. Second, stock market reactions are likely to be more informative with innovations that are highly visible, as identification of an innovation is easier than in the case of incremental innovations (Sorescu and Spanjol 2008). Undoubtedly, iPhone falls into this category. Furthermore, the high level of concentration in the cellular phone market should amplify the effect of product innovation, as suggested by findings by Doukas and Switzer (1992). Finally, the high level of concentration in the cellular market allows us to also study the effects of the introduction

of iPhone on Apple's main horizontal rivals in the industry, which are relatively easy to identify in the market dominated by a limited number of large companies.

Innovative activity can be tracked through (1) news announcements and rumors, and (2) publications of patent documents, but the two methods are seldom studied together.[1] In this paper, we measure Apple's stock reactions to publications of both news and patent documents related to iPhone. Using the two sources should not only give a more accurate estimate of the value of iPhone but also shed light on the determinants of that value: The value of an innovation can be viewed as stemming from both investments in developing "hard" technologies embodied in the firm's intellectual property, and from the firm's managerial ability to take advantage of its own and its rivals' R&D efforts ("soft technologies") (Bloom and Van Reenen 2010). The soft technologies would thus capture the firm's knowhow in operations, management, marketing, assimilating external information, etc. We view value reactions to patent applications as more pure measures of the value of hard technology, whereas the reactions to news would capture overall value effects.[2]

The launch of Apple's iPhone provides a particularly interesting background for our objective of distinguishing the value of hard technologies and intellectual property from other components of innovation value. The high-patent intensity of the cellular phone industry makes extensive patenting a pre-requisite for entering the industry. Hence, Apple has faced a need to patent their iPhone-related innovations actively.[3] Given the high visibility and the user appeal of iPhone, one could expect that a significant

[1] A prominent exception is Lerner (2006) who uses both news and patent document announcements to identify financial innovations and their determinants.
[2] Naturally, the two sources of value are not completely mutually exclusive. One can posit that firms with high managerial abilities would have more value in their patents as well. Similarly, news announcements of the new upcoming products might at least partially reflect value of the technology too.
[3] In the launch event of iPhone, January 9, 2007, Steve Jobs, the CEO of Apple, emphasizes several times that the technology is patented, e.g., "We have filed for over 200 patents for all the inventions in iPhone and we intend to protect them".

fraction of iPhone's value comes from new hard technologies. However, the intellectual property environment in the cellular phone industry is also characterized by less precise property rights than, say in the pharmaceutical industry (see, e.g., Bessen and Maurer 2008). This easily results in "a patent thicket" and hence almost unavoidable patent infringement, which should reduce the value of patents.[4] New cellular phone products also constitute prime examples of cumulative innovation where new innovations are built on previous ones. In such an environment the value of new product may reflect the value of intellectual property over previous innovations rather than the intellectual property of the new product (Green and Scotchmer 1995). Moreover, Apple is known for its brand management and marketing, and the introduction of iPhone created a possibility for leveraging economies of scale between it and Apple's existing products (e.g., Mac and iPod) which competent corporate management would be able to realize. The case of iPhone also offers an opportunity to explore the effect of product pre-announcement to Apple and its competitors. Product pre-announcements constitute an important strategic communication tool for a firm, especially in network industries where consumers' decisions to wait for an upcoming product introduction play a major strategic role (Dranove and Gandal 2003 and Sorescu, Shankar and Kushwaha 2007). Finally, competent corporate management should know not only how to exploit the firm's own innovative efforts but also how to absorb and assimilate the efforts by others (Cohen and Levinthal 1990 and Zahra and George 2002). Hence it is conceivable that much of iPhone's value comes from marketing and management rather than from novel technologies.[5]

[4] Shapiro (2001) defines a patent thicket as "a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology". According to *Economists* (21 October, 2010), Apple's iPhone is indeed at the centre of one the greatest patent controversies in the history.

[5] We define management ability broadly, including absorptive capacity and ability to realize potential organizational synergies from various product lines.

Our methodology builds on a long line of literature of using the event study methodology in valuation of innovations (see, e.g., Chaney, Devinney, and Winer 1991 for an early example, and Girotra, Terwiesch, and Ulrich 2007, and Sood and Tellis 2009 for recent ones). As mentioned above, valuation based on stock market reactions is known to be sensitive to a number of issues. Those issues include identification of an innovation and dates relevant to it, estimation period, trading volume and market structure (see, e.g., Doukas and Switzer 1992, MacKinlay 1997, Tkac 1999). Following Girotra, et al. (2007) who study the value of R&D portfolios in the pharmaceutical industry, we use the methodology suggested by Tkac (1999) to distinguish significant events among a large number of news announcements, using the daily trading value as an indicator of significance. Similar to Chen, et al. (2005), we also extend our analysis to Apple's rivals in the cellular phone industry. One of our contributions is to combine the value of news and patent application announcements. Building on Austin's (1993) seminal paper, we use the event-study approach in patent valuation, estimating both the value of patent (applications) to the firm applying for those patents, and their effects on rival firms using daily stock returns. Besides estimating returns on granted patents, which has been the focus in the previous literature, we use the publication of a patent application as an event date, as most of the new information embodied in patent documents becomes public at that point.[6] This method allows us to study the market value of individual patents, and it should be seen as complementary to the popular method of estimating the market value of patents on a more aggregate level (see, e.g., Bloom and van Reenen 2002, Hall, Jaffe, and Trajtenber 2004). Here, our paper comes close to the literature that studies the stock market reactions to patent litigation decisions and settlements, stemming from Cutler and Summers (1988).

[6] Pending patent applications filed prior to November 29, 2000 were not published in the U.S and thus the distinction between applications and grants is not an issue, e.g., in Austin (1993).

Studying a unique case allows us to mitigate many concerns associated with valuation based on stock market reactions. Moreover, previous valuation studies fail to consider the hard and soft technology components of value separately. We argue that stock market reactions to news announcements might better reflect firm's marketing and management abilities and efforts related to the innovation, whereas the reactions to patent application publications could reflect the value of underlying "hard" technologies and intellectual property. We thus contribute to the innovation valuation literature by studying stock market reactions to both types of information events. In this respect our paper has a link to an extensive literature on the determinants of firm productivity which has documented substantial and persistent productivity differences across firms, even after controlling for measurable inputs such as capital intensity, R&D expenditures and patent portfolios. Reminiscent of our findings, Bloom and Van Reenen (2010) argue that variation in management practices largely accounts for the persistent productivity differences.

We find the value of iPhone to be fairly high, at minimum 30 billion U.S. dollars.[7] The patentable technologies explain about 25% of the total value. More specifically, our estimates of the value of iPhone based on the news announcements vary from $19.7 billion to $24.2 billion, depending on the estimation method. Accounting for abnormal reactions to patent application publications contributes another $6.9 billion (publication date) dollars to the value of the product. Given the Apple market capitalization of $190.6 billion at the end of 2009, the news announcement-based value of iPhone would be between 10% and 13% of the total market capitalization, with the patent application publications contributing another 4% of the market capitalization. We

[7] At the end of section 4 we discuss the reasons for why we think that $30 billion establishes a lower bound on the estimate of the value of iPhone to Apple. For example, we use a tight filter in selecting the news events to consider, which is likely to leave some value effects unobserved. Also, all our valuation figures are measured in event day dollars. Compounding of those values to the present day would increase the value.

also find that the shares of some of Apple's rivals in the cellular phone industry react negatively to the news about iPhone but similar effects are not present in connection to the publications of patent documents concerning iPhone. This further suggests that marketing and management abilities and efforts play a key role in explaining the value of iPhone.

In the next section we describe our data and the industry environment. In section 3 we explain our valuation method. The results of the valuation are presented in section 4 and section 5 presents the conclusions.

2. Data

We study the valuation effects of news related to iPhone from the first hints of the product until December 31, 2009. We employ various data sources in this study. Our main source for news announcements is Lexis-Nexis, with Bloomberg and Google being used as secondary sources. There, we search for news announcements that are related to iPhone. In total, we find 74 days on which news announcements related to iPhone occur. The earliest of these announcement dates back to December 15, 1999, when Apple registered iPhone.org website. The first significant group of news came in 2004, as Apple's partnership with Motorola on a product called ROKR became public. The official announcement of iPhone was made by Steve Jobs on January 9, 2007. Out of the 74 announcement dates, 31 take place prior to that date. Table 1 indicates the breakdown of our events. A full list of all news items analyzed is provided in Appendix 1.

Another potential source for information on the upcoming product is patent documents and trademark filings. Indeed, a key rationale for patent system is to enhance information disclosure (see, e.g., Kultti, Toikka, and Takalo 2006), and disclosure requirements related to patent documents are inherently rooted in patent laws (see, e.g.,

35 United States Constitution (U.S.C.) §112 and §122). Furthermore, patents can only be granted to new and non-obvious inventions (e.g., 35 U.S.C. §102 and §103), and thus the information disclosed in a patent application should be new to the market almost by definition.[8] In the United States, like in other countries, the average lag from the filing of a patent application to a patent grant is several years but pending applications are often made public 18 months after the earliest filing date.[9] We hence seek both the dates when patent applications are published and the dates when patents are issued.

We use the United States Patent and Trademark Office (USPTO) patent database to identify those patent filings made by Apple that are related to a cellular phone product. Generally, it is not easy to identify patents associated with a certain type of innovation without Type I or II errors (see, e.g., Bessen and Hunt 2007 and Hall, Thoma and Torrisi 2009 for discussion on how to identify software and financial patents, respectively). In our case, the challenge is to distinguish Apple's patent applications concerning iPhone from Apple's applications that are related to their other product lines. Following, e.g., Bessen and Hunt 2007, we use a search algorithm based on keywords rather than, e.g., the USPTO patent classification system to identify the patent documents related to iPhone.[10] Whenever it is unclear from the patent application description whether the patent is related to cellular phones, we download the full patent application that includes information such as pictures of the invention to be patented, to study the application area further.

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[888] In theory, the situation is somewhat more complicated, especially in the United States, which uses the first-to-invent rule in determining the novelty criterion. Hence only an information leakage prior to (12 months of) filing the patent application constitutes a novelty bar. However, as firms usually strive to keep their R&D information secret, especially when they aim at filing patents, information disclosed in patent applications should generally be new to the market.

[9] More specifically, the 18 months publication rule applies to all U.S. patent applications filed on or after 29 November, 2000, subject to some exceptions such design patents the cases in which an applicant waives her right to seek patent protection outside the United States..

[10] We first studied several applications clearly related to iPhone in detail to identify appropriate keywords. This suggested the following keyword search algorithm: (((((portable OR (mobile AND device)) OR cellular) OR telecom) OR (wireless AND device)) OR ringtone).

We find patent documents for a total of 213 iPhone related inventions.[11] The sample includes 47 applications published prior to the product pre-announcement on January 9, 2007. The earliest publication date is February 7, 2002. There are 44 (utility and design) patents without prior publication, and they therefore are included in our analysis of granted patents but not in the analysis of patent applications. Since many of the patent applications share common publication dates, we end up with a total of 97 unique patent application publication dates. Following similar procedure, we identify 72 unique patent issue dates.

We also identify dates related to trademark filings on iPhone in various countries. The trademark filings occur relatively early, with the first filing in Singapore taking place on October 18, 2002, and filings in the UK and Australia following within the same year. In total, we find six trademark filings, all of them occurring prior to the product pre-announcement on January 9, 2007. The trademark filing in Canada on October 14, 2004 coincides with an extremely favorable quarterly earnings announcement, and is therefore dropped from further analysis due to event contamination.

For stock return and trading volume data, we use the Center for Research in Security Prices (CRSP) database. As part of our analysis deals with Apple's competitors, we retain stock returns also for Ericsson, Motorola, Nokia and Research in Motion (RIM) from CRSP. Some of the largest companies in the cellular phone industry are not traded in the U.S. exchanges. Therefore, we use Datastream as an alternative data source for stock returns on Samsung Electronics, LG Electronics, and HTC Corp.

[11] The unity of invention requirement maintains that one patent application can only refer to one invention (see, e.g., 35 U.S.C. §121). Our figure is a sum of all iPhone related granted (utility and design) patents and published (utility) patent applications that were still pending as of 31 December, 2009. In other words, those patents from which we have both an issued patent and a published patent application are counted just once. Albeit being in line with Apple's own estimate (cf. footnote 2), our figure is likely to slightly underestimate the number of iPhone related patent applications.

3. Event Study

In order to establish the dollar value of iPhone to Apple, we complete a number of event studies that explore the abnormal stock return that various information releases cause on Apple's stock. As mentioned above, we identify 74 different days on which news releases or speculation regarding iPhone occur. We use the event study methodology (see MacKinlay, 1997 for a survey) to study the valuation effect of these announcements. Our primary event study method is based on the market model, as shown in equation (1):

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \qquad (1)$$

where R_{it} and R_{mt} are the period-t stock returns for firm i and the market, respectively, and α_i and β_i are parameters estimated within the estimation period. Finally, ε_{it} is the zero mean disturbance term. As the market model generates expected returns for the stock, we then measure abnormal returns within the event window following equation (2):

$$AR_{it} = R_{it} - \alpha_i - \beta_i R_{mt}. \qquad (2)$$

Since the market model parameter estimates are sensitive to our choice of estimation period, we vary the estimation period to test the robustness of our findings. Our first choice of estimation period is to use a period outside the main time period of iPhone events for Apple, as significant events may cause bias in market model parameter estimation. One could also posit that an earlier estimation period allows us to estimate the relation between Apple's stock and the market portfolio without iPhone. We therefore use the daily returns from 2003 and 2004 to estimate the alpha and the beta in equation

(1). The CRSP value-weighted market index serves as a proxy for R_m in all our tests requiring a market portfolio.

The beta for Apple with the two year estimation period is 1.3104, and the alpha is 0.0022. However, the parameters for Apple have somewhat varied during our sample period, as witnessed by Figure 1, where we use a rolling 250-day window to calculate the market model beta for Apple. To ensure that our choice of estimation window does not significantly affect our findings, we use the more standard estimation window of (-250,-10) as an alternative setting.

A constant-mean-return model is an alternative way to observe the effect of an event on asset returns (MacKinlay 1997). In the constant-mean-return model, the expected returns are assumed to equal the observed mean return during the estimation period. We use this method both with the fixed estimation period of years 2003-2004, and with (-250,-10) estimation period as additional alternative metrics on the value of each event.

In order to minimize potential biases caused by contaminating events, we use the tightest possible event window by observing abnormal returns only on the day of the news announcement (t = 0). In this effort, we make three assumptions. First, we assume that the news items bring genuinely new information to the market, so that we do not need to account for possible information leakage prior to the event. Second, we assume that the market on Apple's stock is deep and efficient enough that new information will be embedded in the stock price within a single trading day[12]. Third, we assume that there is no systematic pattern of contaminating events occurring on the event dates that we consider.[13] An exception to the rule of using the publication date as the event day is made for those news announcements that became public after 4:00 p.m. Eastern time.

[12] We later provide data on the days surrounding the event, to reduce concerns regarding both of these assumptions.
[13] We also study each event date carefully in order to exclude days with obvious contaminating events.

NASDAQ reports closing prices for the day to the CRSP database based on the Market Hours, which end at 4:00 p.m. Therefore, any market reaction to announcements that occur after that time should be reflected in the following day's CRSP stock return. For that reason, we use $t = +1$ as the event day for those events. Out of the total of 74 news events, five fall into this category.

On the first row of Table 2, we report the abnormal mean return for Apple on all 74 news events. The average one-day abnormal return for Apple is 0.47%, which is statistically significant at the 10% level. We compare the Apple returns to those of their main competitors. Out of them, CRSP returns are available for Nokia, Motorola, Ericsson, and RIM. On the event days, Nokia also posts a moderate average abnormal gain of 0.29%, whereas Motorola (-0.07%), RIM (-0.19%), and Ericsson (-0.37%) lose value on average on the event days related to iPhone. None of the competitors' reactions is statistically significant at the conventional levels.

In an effort to focus on the set of events that bring significant new information to the market, Tkac (1999) suggests using trading volume as an indicator. Her model indicates that extraordinary events induce an increase in the volume of the firm's stock trading (measured as daily market volume/market capitalization), relative to the trading volume for the entire market (measured as daily market volume for the market/total market capitalization). Thus, she motivates the use of a model similar to the market model for returns, presented in our equation (1), to identify significant events for a firm. Girotra, et al. (2007) use the same method in their study of R&D value in the pharmaceutical industry. We follow the work of Tkac (1999), and identify event days with abnormal trading volume for Apple, by estimating the following equation:

$$V_{it} = \gamma_i + \delta_i V_{mt} + \lambda_i D_t + \varepsilon_{it}, \qquad (3)$$

where V_{it} is the natural log of the ratio of trading volume over market capitalization for Apple on day t, V_{mt} is a similar measure for the market on day t, and D_t is a dummy variable that takes the value of one for the event day.[14] We run a separate regression for each event. As trading volume of Apple has undergone significant and persistent shifts during our study period (see Figure 2), we use an estimation period that is near the event, and thus include the days (-250,+1) in each regression.[15] An event is determined to have significant abnormal volume if λ_i is statistically significant at the 5% level or higher. In order to account for heteroskedasticy present in daily trading volume data, we use robust standard errors.

Our tests indicate that 22 of our 74 total news events are associated with abnormal trading volume. We next take these events under a closer examination. The second row of Table 2 indicates the average abnormal returns separately for these events. The effect measured in Apple's stock reaction is markedly more significant, with the mean abnormal return of 1.93% on day $t = 0$, which is statistically significant at the 1% level. Except for Nokia's slightly positive average reaction at 0.20%, all other competitors exhibit negative abnormal mean returns in this sample of events, varying from -0.20% for Motorola to -0.39% for RIM. However, none of the competitor average returns on day t=0 differs from zero at the conventional levels of statistical significance.

As a robustness check, we use internet activity related to iPhone to gauge the informative value of our events. We first extract data from Google trends with a search word "iPhone". Then, following Da, et al. (2010) who use Google trends to measure

[14] Relative daily market volume for both Apple and the total market exhibit skewness, which is why we use the natural log of the relative trading volume in this specification.
[15] In Figure 2, we report abnormal trading volume in number of shares, rather than in natural logs, while in our tests, we use the logs.

investor attention to stocks, we construct an index to capture abnormal internet activity as follows:

$$ASVI_t = \log(SVI_t) - \log[\text{Mean}(SVI_{t-1}, ..., SVI_{t-60})].. \quad (4)$$

In (4), $ASVI_t$ is the Abnormal Search Volume Index for day t. In contrast to Da, et al. (2010), who utilize weekly data, we use daily data. Also, they specify normal internet activity as the median SVI for weeks -1 to -8, whereas we use the mean for days -1 to -60. Our use of mean instead of median is dictated by the value of zero for numerous days particularly in the early part of our study period, resulting in the median value of zero for several events. When we compare the events that are indicated by the trading volume measure in equation (3) as bringing new information to the market, the ASVI measure for that group is higher than that for the group that does not exhibit abnormal relative trading volume. The difference is statistically significant at the 10% level.

In Figure 3, we observe average abnormal returns for days surrounding each event. Compared to the relatively large abnormal return on day $t = 0$ for Apple, all other days within the (-2,+2) window exhibit only modest average effects. This finding increases our confidence on our event day identification strategy. We further repeat the same analysis to include Apple's competitors in Figure 4. Besides Nokia, Samsung and HTC, all of the competitors exhibit slightly negative abnormal returns on day $t = 0$.[16]

Next, we compare our findings across different estimation periods and methods. The results are reported in Table 3. The table indicates that variation across models and estimation periods is negligible. The average abnormal return related to the event days varies from the minimum of 1.81% using the constant-mean-return model with an

[16] In this graph, we utilize Datastream returns for firms, denoted by an asterisk (*), that are not traded in the United States. Since all three of them trade on exchanges that close prior to the U.S. trading hours, we use the one-day lag returns for them in all of our analysis.

estimation period that immediately precedes the event, to the maximum of 1.93%, which result is obtained from the market model with a fixed estimation period. Adding the Fama-French factors to our market model reduces the average event day abnormal return by one basis point.

We complete a similar analysis for days on which patent applications related to iPhone have been made public. As mentioned above, we identify a total of 97 such days. In Table 4, we report average abnormal returns for both Apple, and those of its competitors that are traded in the U.S. stock market. The results are based on the market model, with years 2003 and 2004 serving as the estimation period. Panel A of Table 4 shows the average abnormal returns across all 97 days. The abnormal return is slightly positive for Apple, but falls far short of statistical significance. Similarly, the competitors do not appear to exhibit any signs of systematic abnormal performance around patent application publication dates for Apple. In Panel B of Table 4, we focus on the patent application publications that are connected with abnormal trading volume. 31 of the 97 dates fall into that category. Furthermore, we check the dates of abnormal volume for potential event contamination due to corporate information releases on those days. This check is performed using both Lexis-Nexis, and Bloomberg. Coincidentally, it appears quite common for patent application publications to coincide with corporate information releases. On nine of the 31 days, we detect either quarterly earnings announcements, high-level managerial changes, or on one occasion an adoption of a stock option expensing rule in accounting. Thus, we are left with 22 days on which patent applications are published, and which are free of contamination. On those days, the Apple average abnormal return is 1.13%. The effect is statistically significant, with the *p*-value of 5.5%.

Next, we repeat the abnormal return analysis for the 72 days when patents are granted. This includes patents both with and without prior publications of corresponding

patent applications. Since patents without prior publications are generally less valuable[17], and since information about the (more valuable) patents with prior publications becomes public when the corresponding applications are published, it is unlikely that the grant of the patent would bring significant new information to the market. This prediction is confirmed by our data, as the average reaction to the patent grants is very small relative to the findings reported above. For all 71 patent grants, the daily average abnormal stock reaction is -0.11%. Out of those 71 days, 13 exhibit abnormal trading volume, and on those days, the abnormal return is 0.35%. We have not performed a contamination check on those days, which means that the abnormal trading volume could well be caused by other corporate events for Apple, taking place on those days. Based on the evidence that patent grants do not appear to bring new information to the market, we exclude them from further analysis.

Finally, we analyze the set of six days on which Apple filed a trademark for iPhone. The first two (in Singapore and UK) occur on subsequent trading days, on October 18 and October 21, 2002. The filing in Singapore exhibits abnormal trading volume, while the filing to the UK fails to do so. Filing in Australia on December 3, 2002 also fails to generate abnormal trading volume. The filing in Canada on October 14, 2004 is met with a very large abnormal trading volume. However, that filing coincides with a very favorable quarterly earnings announcement. Apple stock return on that day exceeded 14%, making it the best day for the stock in the entire decade. We exclude the Canadian trademark filing from our analysis for obvious reasons. Finally, trademark filings to New Zealand and the US in September 2006 fail to generate abnormal trading volume, which leaves us with only a single trademark filing event with abnormal trading

[17] These patents fall into two categories: 1) The publication requirement for patent applications applies only to inventions that are to be patented internationally. Apple may have decided to waive the possibility of international patenting, perhaps because the invention was not patentable outside the United States or perhaps because the invention was not significant enough to warrant a costly international application process. 2) They deal with design patents which arguably have weaker protection than utility patents.

volume to analyze. On the day of trademark filing in Singapore on October 18, 2002, the abnormal return for Apple stock was 0.78%, using the same fixed estimation period as above, and the reaction is statistically insignificant. We therefore exclude trademark filing events also from further analysis.

4. Market Value of Changes

In order to estimate the value of the iPhone product to Apple, we follow Chaney, et al. (1991) and others by observing the market capitalization of Apple, Inc. on the day prior to each event, and multiplying that figure by the abnormal return related to each event day. For a total value of the product, we then sum up these values across all events. We perform this calculation using each of our abnormal return metrics, focusing only on the events that are determined to be significant based on the trading volume data. We thus rely on Tkac's (1999) model that indicates that a change in the relative trading volume of the stock implies a significant arrival of new information to the market.

The results are reported in Table 5, with values in thousands of dollars. Our estimates based on the news announcements vary from $20.0 billion to $24.4 billion, based on different methods of estimation. Our results further indicate that accounting for abnormal reactions to patent application publications contributes another $7.8 billion to the value of the product.[18] Given the Apple market capitalization of $190.6 billion at the end of 2009, the news announcement-based value of iPhone would be between 10% and 13% of the total market capitalization, with the patent application publications contributing another 4% of the market capitalization.

[18] Two of our patent application publication event dates coincides with a news announcement date. We have counted those as news days and excluded them from the market value of patent application publications calculation. Since one of the two events is connected with a positive value effect, and the other event is connected with almost equal negative value effect, their inclusion has a negligible effect on the total value.

We believe that our estimate of the value of iPhone to Apple is likely to establish a lower bound on the value estimate. First, we report all our figures in event day dollars, which ignores the time value of money between each event and December 31, 2009, and are thus biased downwards.[19] Second, the development of iPhone took several years, and some news about the product may have leaked to the market before it was reported in news. Similarly, information about an invention underlying a patent application may leak before the application is published. Third, by excluding patent application publication dates with contaminating data releases, we reduce our estimate of the value of patent applications by over $10 billion. It is clear that events such as quarterly earnings announcements are likely to have a larger impact on Apple's stock than publication of patent applications. However, given that such patent publications can be assumed to have a positive value, that value is ignored in our estimates, as we exclude days with contaminating events completely from our analysis. If we assume that the effect of patent application publications on those days is similar to the average effect among other 22 patent application publication events (= 1.13%), the value of patent applications increases by approximately $632 million.

It is interesting to contrast our estimates to the accounting information on Apple, Inc. According to the company's most recent quarterly 8k filing for the fiscal quarter ending on September 25, 2010, the company's net sales related to "iPhone and related products and services" equal $8.822 billion, which is about 43% of their total sales for the same quarter. This reaffirms that our estimate of the value of iPhone to Apple at 14-17% of the firm's market capitalization is a conservative estimate. Obviously, any current sales figures would ignore future growth potential (in case it differs relative to company's other product lines), and synergy effects across product lines.

[19] Our first news event with abnormal trading volume occurs on January 7, 2005, so for that event, we ignore almost five years of time value of money.

Finally, our estimate captures at most the private value of iPhone to Apple. It does not capture the full social value of the invention nor even its value to the industry. For example, the entry by Apple into the cellular phone market could reduce the market share of the established cellular phone manufacturers (so called "business-stealing effect"). But, Apple's entry could also increase the total market size and create technological spillovers, which could mitigate the business stealing effect. Furthermore, as this is an industry with imprecise and overlapping intellectual property rights ("a patent thicket"), it is difficult to enter into such an industry without violating intellectual property rights of the established manufacturers. The legal costs of patent infringement suits and associated damage or settlement payments could be factored into the stock market reactions. Our findings lend support to a business stealing effect that has been diluted by other considerations: We find that shares of Apple's rivals typically encounter a negative but weak reaction both to iPhone news announcements to publications of patent applications related to iPhone.[20]

5. Conclusions

Innovation requires funding and other resources but without reasonable justification for undertaking innovation, no one is willing to provide the required resources. In order to provide new insights to valuation of innovation, we take advantage of a unique case – the launch of Apple's iPhone - in which a major firm expanded its product portfolio to enter into a market that is characterized by significant implicit barriers to entry. We study the stock market reactions to news announcements related to iPhone from the first hints of the product until December 31, 2009. Moreover, we also

[20] Naturally, the estimations of full social value of iPhone should also incorporate consumer surplus besides industry effects.

study the stock market reactions to the publications of patent documents related to iPhone.

We find the lower bound for the market valuation of iPhone to be high, at roughly 30 billion U.S. dollars, with patentable technology explaining about 25% of the total value. We also find that Apple's rivals experience a predominantly negative stock reaction both to the news about iPhone and to the publication of patent documents concerning iPhone. Our evidence suggests that the value of iPhone primarily stems from Apple's management and marketing abilities and efforts, and to a lesser extent from underlying "hard" technologies and intellectual property.

In this paper, we also complement the existing patent valuation literature, which aims at uncovering the effects of a firm's patent portfolio on its Tobin's Q, by studying the stock market reactions to issued patents and the publication of patent applications using daily stock market data. As one of the key finding of the previous patent valuation literature is that some patent characteristics, notably citations, are correlated with market value, we plan to include patent characteristics in future work.

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Appendix 1. News Announcements

Date	Event
15 December 1999	Apple registers iPhone.org
11 September 2002	Cell phones mentioned in Jobs' interview at Apple Expo
26 July 2004	Motorola and Apple announce iTunes& Motorola cell phones partnership
07 January 2005	Motorola executive previews iTunes phone
01 September 2005	Hint at Motorola and Apple launching the "ROKR"
03 September 2005	More information that Apple will reveal the iPhone leaks out (referring to ROKR)
08 September 2005	Last night the ROKR and iPod nano was revealed
09 September 2005	The ROKR receives bad reviews
22 September 2005	Hint at Apple creating their own "iphone"
14 February 2006	More speculating concerning Apple creating their own Apple iPhone
22 March 2006	Apple Computer expected to unveil a Apple branded iPhone within 12 months
29 March 2006	More rumors regarding the unveiling of Apple iPhone emerge
29 March 2006	Another article regarding rumors of Apple iPhone launch
02 April 2006	Apple may have run into problems
18 May 2006	Some believe the rumors are only rumors
21 July 2006	Apple exec drops major hint regarding iPhone
31 July 2006	Code suggesting the existence of an iPod phone is found
09 September 2006	iphone.org belongs to Apple
11 August 2006	Steve Jobs allegedly talks about iPhone to his inner circles
11 September 2006	Analyst predicts the iPhone announcement will happen within 4 - 6 months
13 September 2006	French newspaper prints fake iPhone picture
26 September 2006	Apple and Cingular teaming up?
18 October 2006	More iPhone predictions
18 October 2006	Brian Cooley expects iPhone to be in stores in early February
27 October 2006	Apple + new patent = iPhone speculation

11 November 2006	Two phones?
15 November 2006	More iPhone speculation
21 November 2006	Apple stock reaches new high
24 November 2006	More speculating concerning two Apple iPhone devices
30 November 2006	Apple seeks patent protection for an iPhone
07 December 2006	iPhone predicted to not be released until later
07 December 2006	Kevin Rose predicts
11 December 2006	Jesse Tortora says production of "iPhone slim" has started
11 December 2006	Forbes estimates iPhone sales
14 December 2006	Rebecca Runkle claims to have inside information
15 December 2006	Shares of Skyworks Solutions Inc. Sky rocket
16 December 2006	Jajah working with Apple?
17 December 2006	Cisco owns the name "iPhone"
18 December 2006	Cisco's linksys release "iPhone"
08 January 2007	Apple updates website
09 January 2007	**iPhone announcement**
11 January 2007	More joint products with Cingular Wireless?
11 January 2007	Telefonica in talks with Apple
06 February 2007	Hint: iPhone may be available on the 15th of june
12 April 2007	iPhone will be released at the end of June
25 May 2007	Media report: iPhone will be released on the 20th of June
03 June 2007	Commercials show iPhone release date
11 June 2007	Jobs unveils more of OS X leopard
18 June 2007	Apple updates iPhone before release
25 June 2007	Pictures of iPhone accessories leaked
29 June 2007	iPhones now in stores
05 July 2007	Web development page for iPhone
05 July 2007	A patent suggests that there may be an iPhone nano
10 July 2007	A cheaper version of the iPhone?
09 September 2007	Apple expected to annouce UK distributor
18 September 2007	Apple announed UK iPhone release date
19 September 2007	iPhone for Germany announced
20 September 2007	iPhone for France announced

17 October 2007	Apple announces Software Development Kit (SDK)
17 October 2007	Apple will release an unlcoked iPhone in France
31 October 2007	iPhone named invention of the year by Time Magazine
09 November 2007	iPhone released in Germany and Britain
20 November 2007	Rumor: Apple planning iPhone 3G release
28 November 2007	Apple plans 3G iPhone
18 December 2007	iPhone launching in Japan?
03 January 2008	More speculation concerning MacWorld
05 February 2008	New iPhone and iPod announced
08 February 2008	New Apple event?
27 February 2008	Apple sets date for announcements
06 March 2008	Apple releases iPhone SDK
06 May 2008	Hint: iPhone 3G release early?
14 May 2008	iPhone 3G coming to England?
20 May 2008	Apple announces iPhone 3G release date
27 May 2008	Teliasonera announce iPhone deal
09 June 2008	Apple unveils iPhone 3G
09 June 2008	Apple announces iPhone 3G release in several countries
11 July 2008	Apple launches iPhone 3G in 22 countries
17 September 2008	Apple may begin to produce own chips
22 December 2008	iPhone nano?
03 February 2009	iPhone 4G rumor
13 February 2009	New product rumors
26 March 2009	Apple to unveil new iPhone?
09 April 2009	More iPhone rumors
16 April 2009	Apple patents suggest iPhone specs
27 April 2009	Apple and Verizon creating two new products
13 May 2009	No new iPhone at WWDC?
19 May 2009	Fishy rumor regarding new iPhone launch date
26 March 2009	New iPhones and iPod nano?
26 March 2009	6 new iPhones?
06 June 2009	New iPhones to be unveiled in 2 days?
08 June 2009	Apple unveils new iPhone
19 June 2009	New iPhone goes on sale
02 July 2009	New Apple patents

Table 1: News announcement events

The table reports the number of events related to iPhone introduction, identified from Lexis-Nexis. The first column reports all news, and the second column those that generate abnormal trading volume, measured as in Tkac (1999).

	total	abn volume
Dec 15, 1999 - Jan 9, 2007	31	13
Jan 10, 2007 - Dec 31, 2009	43	8
	74	21

Table 2: Abnormal returns related to news events for Apple and its competitors

The table reports the average one-day abnormal returns to Apple and those of its rivals that are available in the CRSP database. The asterisks indicate statistical significance at one percent (***), and ten percent (*) levels, respectively.

Average abnormal mean return (t=0)	AAPL	NOK	MOT	ERIC	RIMM
all events (n=74)	0.47%*	0.29%	-0.07%	-0.37%	-0.19%
abnormal volume events (n=22)	1.93%***	0.20%	-0.20%	-0.22%	-0.39%

Table 3: One-day average abnormal returns around news events for Apple

The table reports the average daily abnormal returns for Apple. The model and the estimation window used in estimating expected returns is indicated on each respective row. The asterisks indicate statistical significance at one percent (***), five percent (**), and ten percent (*) levels, respectively.

	day-2	day-1	day0	day+1	day+2
Market model, 2003-2004 estimation period	-0.26%	-0.53%	1.93%***	0.77%	-0.74%
Market model, (-250,-10) estimation period	-0.23%*	-0.55%	1.92%***	0.79%	-0.75%**
Fama-French, 2003-2004 estimation period	-0.11%	-0.57%	1.92%***	0.74%	-0.80%*
Mean return model, (-250,-10) est. period	-0.14%	-0.48%	1.81%***	0.44%	-0.73%**
Mean return model, 2003-2004 est. period	-0.11%	-0.38%	1.86%***	0.48%	-0.86%

Table 4: Daily abnormal returns around patent events

The table reports the average daily abnormal returns for Apple and its rivals. The estimates are based on the market model with years 2003 and 2004 serving as the estimation window. The asterisk indicates statistical significance at the ten percent (*) level.

Panel A: All patent application publication days (n=97)

	aapl	nok	mot	eric	rimm
day-1	0.01%	0.27%	-0.20%	0.31%	-0.03%
day0	0.02%	0.20%	-0.31%	-0.37%	-0.49%
day+1	-0.36%	0.05%	-0.27%	-0.16%	-0.03%

Panel B: Patent application publications with signif. trading volume and no contamination (n=22)

	aapl	nok	mot	eric	rimm
day-1	0.29%	0.08%	-0.17%	0.68%	-0.78%
day0	1.13%*	0.11%	0.37%	-0.50%	-0.93%
day+1	-0.03%	0.13%	-0.53%	-0.09%	-0.42%

Table 5: Market value of iPhone

The table reports estimates of the market value of iPhone. In estimation, we use the abnormal return upon each event, and multiply it by the market capitalization on the day prior to the event. Models used are indicated on each respective row.

Model used	Events used	Total value
Market model	news with significant volume	$ 24,373,869
Market model with Fama-French factors	news with significant volume	$ 23,940,622
Mean return model	news with significant volume	$ 19,986,256
Mean return with fixed est. period	news with significant volume	$ 20,590,347
Market model	patent apps with sign. vol.	$ 7,801,417

Figure 1: AAPL market model beta

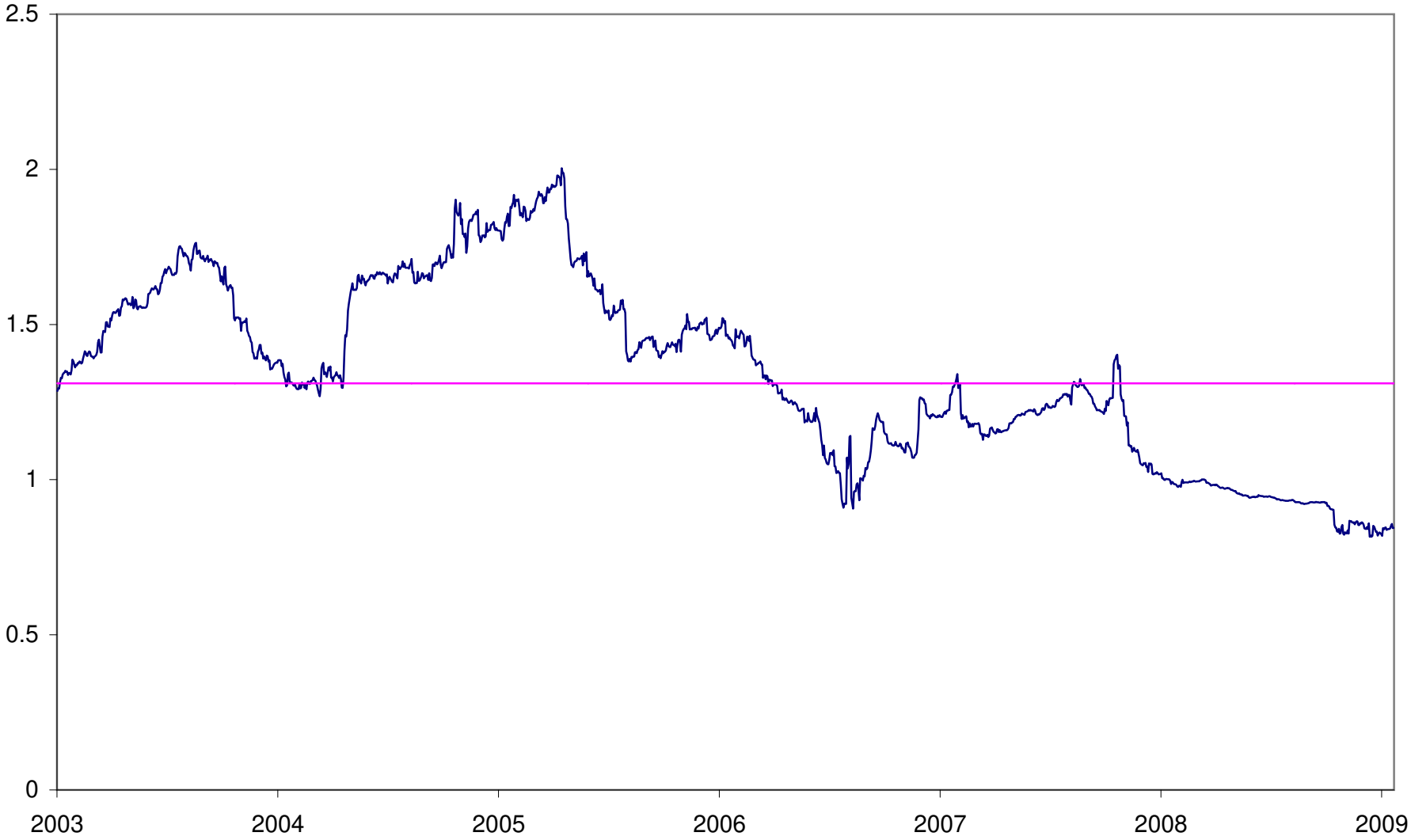

Figure 2: Apple, Inc. abnormal daily trading volume

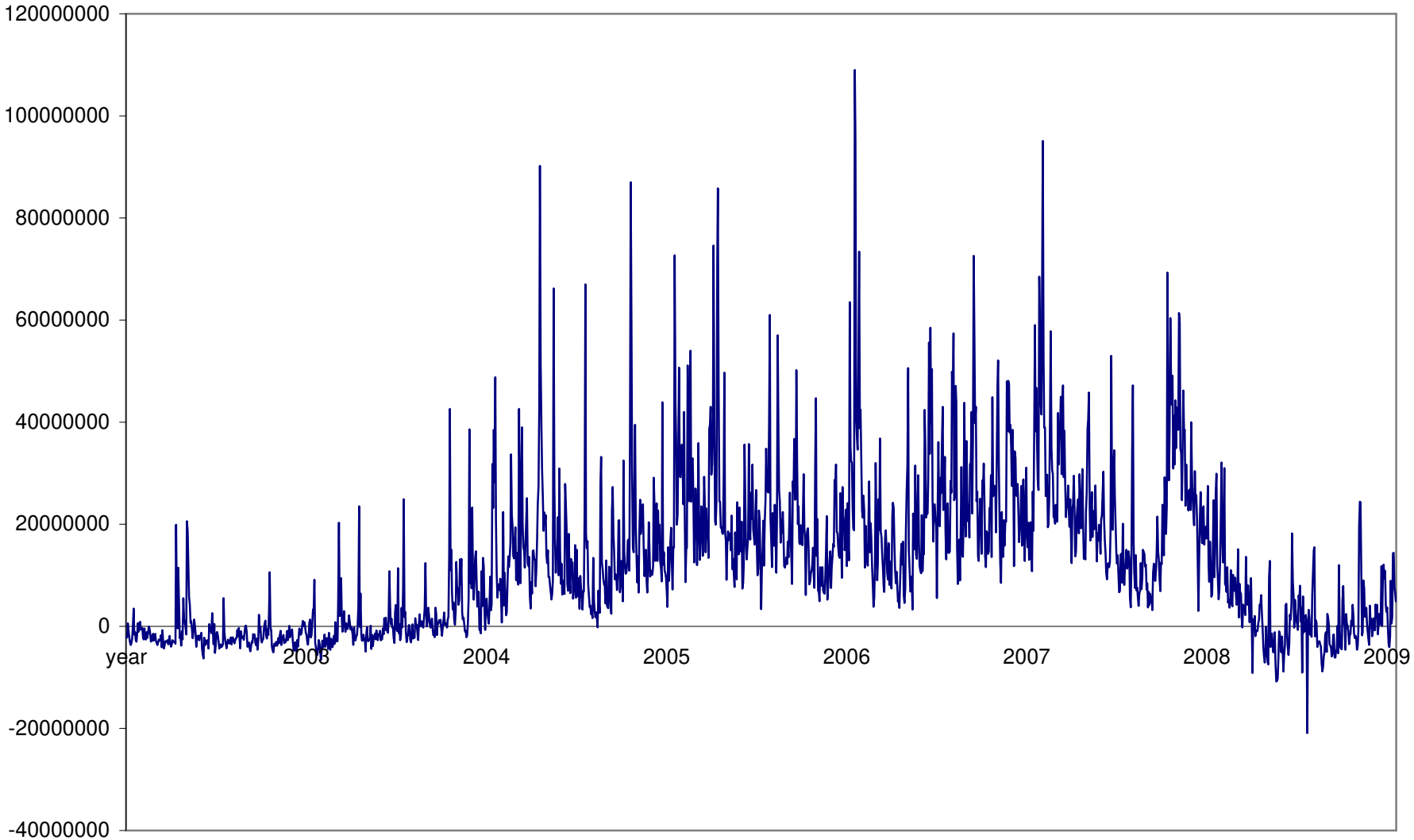

Figure 3: Average AAPL abnormal return on events with significant volume

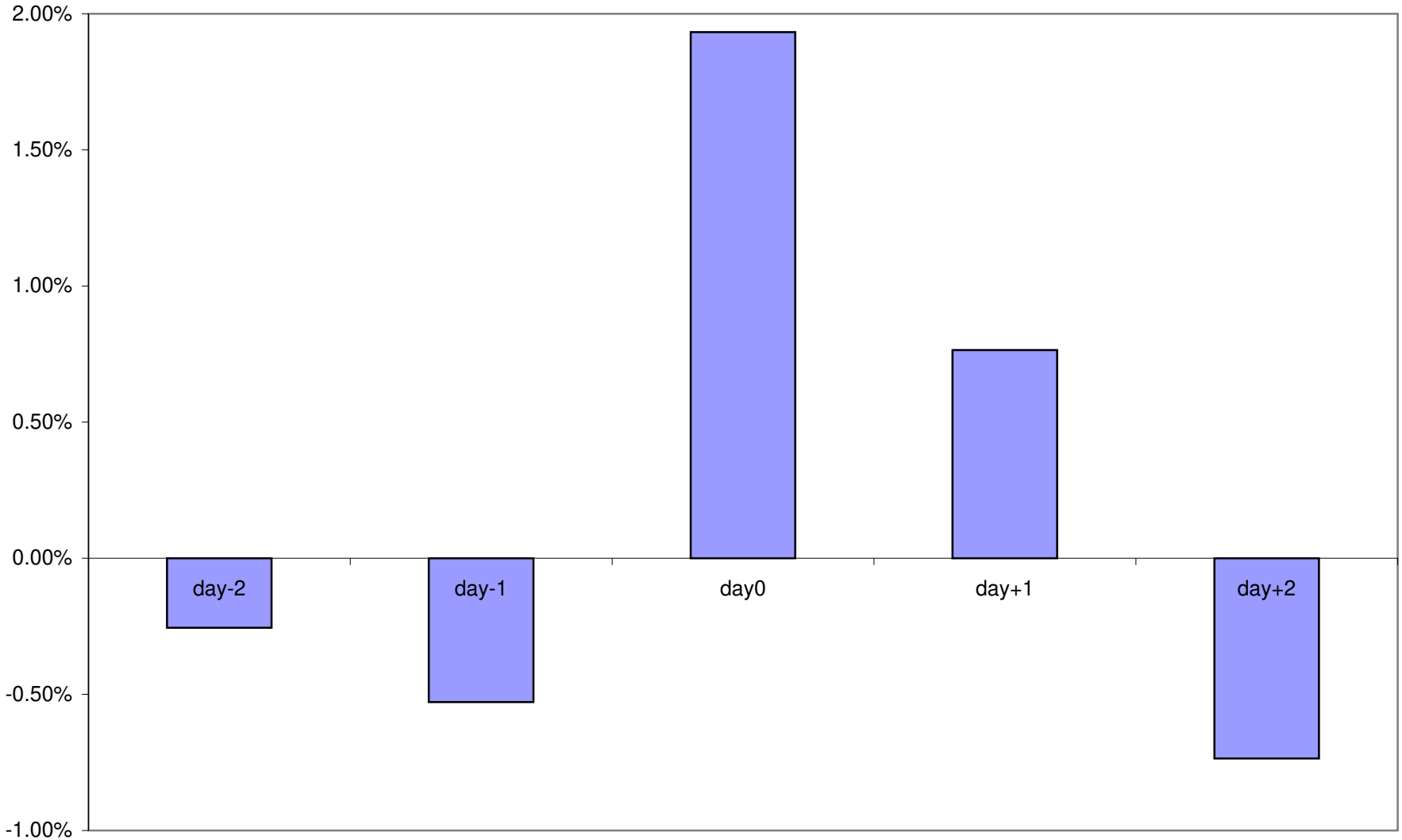

Figure 4: Average abnormal return for Apple and its competitors on events with significant volume

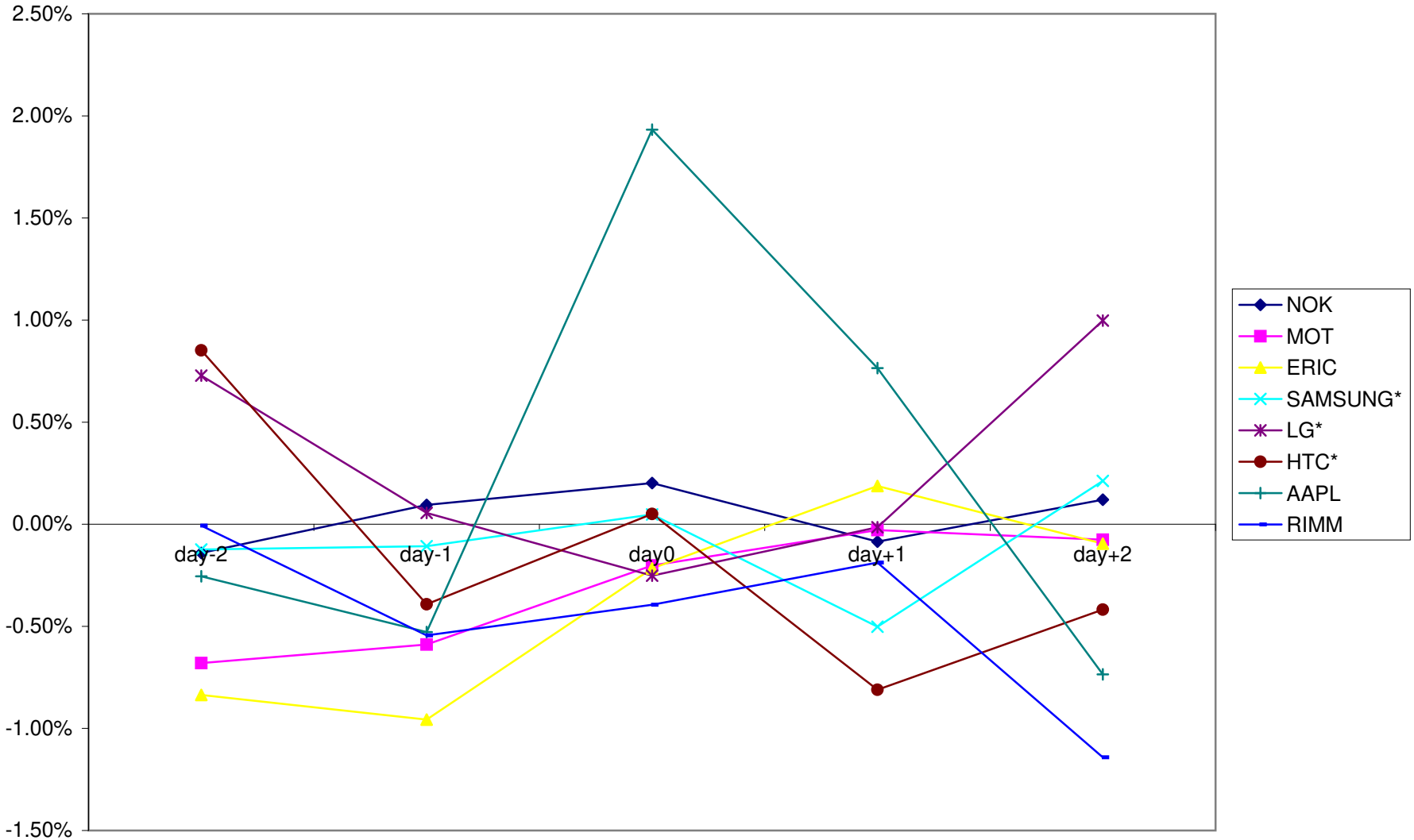

Figure 5: Apple Inc. Market Capitalization (in Billions)