Valuation of Innovation and Intellectual Property: The Case of iPhone*

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Abstract

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Keywords: innovation management; intellectual property rights; valuation; event studies

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Abstract

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1. Introduction

Valuation of individual innovations and intellectual property rights, and determinants of that valuation challenge corporate managers and technology policy makers. For example, a court may need to estimate the value of individual intellectual property rights and associated innovations to determine damage payments in patent litigation trials. The same applies to parties of patent infringement disputes when they try to reach settlement out of court.[1] One method of valuing innovation employs stock market information by observing either market values of innovating firms, or idiosyncratic stock return related to innovation-related events. In larger samples, this valuation effort is often hampered by noise that is present in stock returns. Partially for this reason, the method is rarely applied to valuation of intellectual property. In this study, we tackle the challenges in measurement of the value of innovations and intellectual property by using stock market and internet activity volumes to distinguish significant events from a large number of events.

We then conduct a careful in-depth case study of a single technology product: We consider the value effects of Apple's iPhone, associated patent documents and trademarks on Apple itself, its horizontal rivals, and firms within the global supply chain of iPhone. While being a case study of a single product innovation, it is widely thought that iPhone has been a major factor contributing to the rise of Apple to the world's highest-valued firm of all time, and to the radical transformation of mobile communications industry. But there are no systematic estimates of iPhone's exact contribution in that process, nor do we know much about how that contribution is divided between technology itself and Apple's ability to capitalize the product. Furthermore, our method and findings ought to be generalizable and of wider interest, since they provide information on a number of elusive objects such as value of

[1] A U.S federal court recently ordered Samsung to pay Apple more than a billion U.S. dollars in damages for infringing Apple's six patents (see e.g. *The Wall Street Journal*, August 25, 2012). Most patent disputes are, however, resolved before going to trial.

individual patents and trademarks, significance of various value components of a new product innovation, and value capture within a supply chain.

Our case also has some significant attractive aspects. First, it deals with a drastic innovation made by a visible, publicly traded corporation rather than a small technology entrant. Apple's stock has high trading volume, which should reduce concerns of thin trading that tends to plague innovation valuation studies. The depth of trading in Apple's stock, and the keen interest in the company and its product innovations including underlying intellectual property documents by analysts, journalists, and internet community should reduce pricing errors in the stock. Stock market reactions are also likely to be more informative in case of drastic innovations as identification of an innovation is easier than in the case of incremental innovations (Sorescu and Spanjol 2008).

Second, the cellular phone industry is very patent intensive. It is characterized by cumulative innovation, strong network effects and a high degree of standardization. These features tend to create high implicit barriers to entry, thus leading to market concentration, which should further facilitate the discovery of stock market reactions to a firm's innovative efforts (see, e.g., Doukas and Switzer 1992). For the same reason, it is also relatively easy to identify Apple's horizontal rivals, and study the value effects of iPhone on them. Further, the high patent intensity of the industry makes extensive patenting a pre-requisite for entry, and Apple has faced a need to patent their iPhone-related innovations actively.[2] Apple's active patenting together with the wider following it attracts allows us to study the market value of patents at their interception. Finally, the extensive public interest in iPhone makes information on firms within the iPhone value chain, such as suppliers and local service

[2] For example, the news coverage of the purchase of Motorola by Google highlighted that the deal gave Google a portfolio of 17,000 patents which are seen as important in defending against law suits within the industry (see e.g. *The Wall Street Journal*, August 16, 2011). It is then not surprising that 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". See also footnote 1.

providers, more easily accessible. We take advantage of that information in analyzing value effects of iPhone within its global value chain.

Innovative activity may be tracked through news announcements and rumors, and publications of intellectual property documents, but the two methods are seldom studied together.[3] In this paper, we measure Apple's stock reactions to publications of news, patent documents and trademarks related to iPhone. Using multiple sources should not only give a more accurate estimate of the private 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). One could view stock market reactions to news reflecting value effects related to both soft and hard technology value but the reactions to patent applications arising to a larger extent from the value of hard technology.[4]

It is not a priori clear how much patentable technologies contribute to the private value of iPhone. Given that iPhone is viewed as a "revolutionary" product, a significant fraction of iPhone's value might be expected to come 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 and litigation, which should reduce the value of patents.[5] New cellular phone products also constitute prime examples of cumulative innovation where the value of a new

[3] A prominent exception is Lerner (2006) who uses both news and patent document announcements to identify financial innovations and their determinants.
[4] Naturally the patent-related value effects are not exclusive to hard technology. One can for example posit that firms with high managerial abilities have more value in their patents as well.
[5] The findings of von Graevenitz, et al (2011) confirm that dense patent thickets exit in the cellular phone industry. According to *The Economist* (October 21, 2010), Apple's iPhone is indeed at the center of one the greatest patent controversies in the history.

product may reflect the value of intellectual property over previous innovations rather than the intellectual property of the new product (Green and Scotchmer 1995).

There are also other reasons to think that a major source of iPhone's private value might be acclaimed marketing and management skills of Apple rather than the technology itself or associated intellectual property.[6] 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. Similarly, for competent corporate management, product pre-announcements – which form an essential part of our study – would constitute an important strategic communication tool, especially in a network industry where consumers' expectations play a major role (Dranove and Gandal 2003 and Sorescu, et al. 2007). Finally, competent 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).

Our methodology builds on a long line of literature of using the event study methodology in valuation of innovations (see, e.g., Chaney, et al. 1991 for an early example, and Girotra, et al. 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). We use the methodology suggested by Tkac (1999) to distinguish significant events among a large number of events, using the ratio of daily trading volume to market capitalization as an indicator of significance. Following the idea by Da, et al. (2011), we also use internet activity related to iPhone to gauge the informative value of our events.

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

We extend our analysis to Apple's rivals in the cellular phone industry, similar to Chen, et al. (2005). Besides studying the effects on the competitors, we also consider stock market reactions to iPhone related events among the firms within the supply chain of iPhone. Although we are not aware of previous studies using the event study methodology to evaluate economic consequences of a new product within a global supply chain, accounting data has been used to study value capture within the supply chain of similar new products (see, e.g., Linden, et al. 2009 for the case of Apple's iPod and Ali-Yrkkö, et al. for the Nokia's N95 smartphone).

We use the event-study approach to study intellectual property valuation, following Austin's (1993) seminal paper. This method of intellectual property valuation, while long ignored, is recently advanced by Patel and Ward (2011) who focus on market reactions to patent citations in the pharmaceutical industry. We estimate the value of iPhone-related patent documents to Apple, after which we explore the determinants of that value. The effects of patenting activity on rival firms are also considered. Furthermore, we consider trademark filings. Besides estimating returns on granted patents, which has been the focus of previous literature, we also 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. To the best of our knowledge, no prior study estimates the value of U.S. patent applications by using daily stock return data.[7] This method allows us to study the market value of individual patents, and it should be seen as complementary to the method of estimating the private value of patents by using annual or survey data (see, e.g., Hall, et al. 2005, Gambardella, at al 2008, and Czarnitzki, et al. 2011). Here, our paper comes close to the literature that studies the stock

[7] The prior literature has not considered market reactions to patent applications partially because pending patent applications filed prior to November 29, 2000 were not published in the U.S. and thus the distinction between grants and applications is a moot issue, e.g., in Austin (1993) and in Patel and Ward (2011) (who use patent data up to 1999).

market reactions to patent litigation decisions and settlements, stemming from Cutler and Summers (1988).

We find the private value of iPhone to be at minimum 30 billion U.S. dollars at the end of 2009.[8] The patentable technologies explain about 25% of the total value. This effect arises from patent applications rather than grants. More specifically, our estimates of the private 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 whereas we find no value effect when patents are granted or trademarks filed. 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 find that the shares of some of Apple's rivals in the cellular phone industry react negatively to the news about iPhone. Within the global supply chain of iPhone, we find no systematic value effects besides a positive effect on Apple. Only when the launch event is considered on its own, we detect a statistically significant average abnormal return of 6.8% among suppliers. Taken together our findings suggest that marketing and management abilities and efforts might play an important role in explaining the value of iPhone. Finally, in contrast to earlier research we find that the number of patent claims is negatively correlated with patent value, perhaps reflecting an increased concern for infringement litigation.

[8] At the end of Section 5 we discuss the reasons for why our method biases the value estimates downwards. For example, some information about the innovation may have leaked to the market before news or patent applications are published. We also use a tight filter in selecting the news and patent events to consider, which is likely to leave some value effects unobserved. Furthermore, all our valuation figures are measured in event day dollars. Compounding of those values to the present day would obviously increase the value.

In the next section we describe our data, and in Section 3 we explain our valuation methods. The results concerning valuation determinants and market value are presented in Sections 4 and 5. Conclusions are in Section 6.

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 all rumors and news 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 group of news with more precise information 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 announcements, 31 take place prior to that date. Table 1 indicates the breakdown of our events (a full list of the news items is available from the authors).

Another potential source of information on an upcoming product is patent documents and trademark filings. Indeed, a key rationale for patent system is to enhance information disclosure (see, e.g., Kultti, et al. 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.[9] In the United States, like in

[9] In theory, the situation is somewhat more complicated, especially in the United States, where the first-to-invent rule was used to determine the novelty criterion until the passage of the America Invents Act of 2011. 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

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.[10] We therefore consider 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, et al. 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.[11] Whenever it is unclear 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.

We find patent documents for a total of 213 iPhone related inventions (a full list of the patent documents is available from the authors).[12] For most of Apple's patents related to iPhone, we are able to identify an application publication date, and thus we can use both

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patents, information disclosed in patent applications should generally be new to the market. To the extent this is not the case, our estimates of patent value are biased downwards.

[10] 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 as design patents and the cases in which an applicant waives her right to seek patent protection outside the United States.

[11] 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).

[12] 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 for 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 underestimate the number of iPhone related patent applications as we are bound to overlook some patent applications that concern both iPhone and Apple's other products.

application and grant dates. There are 44 patents that are granted with no prior publication, and they are therefore included in our analysis of granted patents but not in the analysis of patent applications. The sample includes 47 applications published prior to the product pre-announcement on January 9, 2007. The earliest publication date is February 7, 2002. 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. [13]

Given the high degree of concentration of the cellular phone industry, it is relatively easy to identify the main horizontal rivals of Apple. In contrast, identification of firms within the global supply chain of Apple is less straightforward. We use various internet sources including teardown reports from www.isuppli.com, and announcements of supply contracts from both Lexis-Nexis and Bloomberg to compile a set of firms connected to iPhone, mainly consisting of hardware manufacturers and cellular service providers. These firms and Apple's horizontal competitors are listed in Appendix 1.[14]

For stock return and trading volume data, we use the Center for Research in Security Prices (CRSP) as our primary database. However, many important firms in the cellular phone industry and iPhone supply chain are not traded in the U.S. exchanges. Therefore, we use Datastream as an alternative data source for stock returns.

[13] In the U.S., a trademark for iPhone was filed in 1996 by Infogear Technology, Corp., a company that was later acquired by Cisco Systems in 2000. Apple and Cisco settled a trademark infringement lawsuit in 2010. We do not consider these events.

[14] Naturally, iPhone may have affected firms outside cellular phone market and its supply chain. The analysis of the effects of iPhone on such firms, e.g., vertical rivals, is however beyond the scope of this study.

3. Measurement of event-related value changes

In order to establish the dollar value of iPhone to Apple, we complete a number of event studies that explore the abnormal stock returns 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 is to use an estimation 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 those of our tests that employ 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 each event (t = 0). In this effort, we make three assumptions. First, we assume that the events 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. 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. NASDAQ reports closing prices for the day to the CRSP database based on the Market Hours, which end at 4:00 p.m. Eastern Time. 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. Third, we assume that there are no systematic patterns of contaminating events occurring on the event dates that we consider. We check, by using both Lexis-Nexis and Bloomberg, each event date in order to exclude days with obvious contaminating events. While one-day abnormal returns are our main metric for the value effect of each event, we also analyze abnormal returns for days surrounding each event, in order to reduce concerns regarding the assumptions about no information leakage and fast information assimilation, discussed above. To the extent the assumptions fail to hold, our estimates are biased downwards.

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 the ratio of daily market volume to market capitalization), relative to the trading volume for the entire market (measured as the ratio of daily market volume for the market to 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. Following this idea, we 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.[15] We run a separate regression for each event. As

[15] Girotra, et al. (2007) apply a variant of this method in their study of R&D value in the pharmaceutical industry. In contrast to the original method of Tkac (1999), Girotra, et al. (2007) do not weight trading volume by market capitalization. At least in our case adjusting trading volume by market capitalization is important

trading volume of Apple has undergone significant and persistent shifts during our study period (see Figure 2), it is preferable to use an estimation period that is near the event. Thus, we include days (-250,+1) in each regression. 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 heteroskedasticity present in daily trading volume data, we use robust standard errors.

As a robustness check, we also 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. (2011) who use Google trends to measure investor attention to stocks, we construct an index to capture abnormal internet activity as follows:

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

In (4), $ASVI_t$ is the Abnormal Search Volume Index for day t. In contrast to Da, et al. (2011), 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 numerous days with zero values, particularly in the early part of our study period, resulting in the median value of zero for several events.

4. Determinants of valuation

4.1 Stock market reactions to news announcements

We begin by exploring stock returns related to all iPhone news. On the first row of Table 2, we report the abnormal mean return for Apple on all 74 news event days. 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,

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because relative daily market volume for both Apple and the total market exhibit skewness. This is also the reason for why we use the natural log of the relative trading volume in this specification and our tests. However, in Figure 2, we report abnormal trading volume in number of shares.

CRSP returns are available for Ericsson, Motorola, Nokia, and Research In Motion (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%) tend to lose value on event days related to iPhone. None of the competitors' average reactions is statistically significant at the conventional levels.

We then employ equation (3) to identify events that bring new information to the market. Our tests indicate that 22 of our 74 news events are associated with abnormal trading volume. Further, when we use equation (4), we find that the ASVI measure for these 22 events is higher than that for the remaining 52 events that do not exhibit abnormal relative trading volume. The difference is statistically significant at the 10% level. We next take the events that generate abnormal trading volume under a closer examination. Their average abnormal returns are displayed by the second row of Table 2. The effect measured in Apple's stock reaction is now stronger, 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. But again, none of the competitor average returns on day t=0 differs from zero at the conventional levels of statistical significance.

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 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[17] to our market model reduces the average event day abnormal return by one basis point.

4.2. Value of patents

We complete a similar analysis for days on which patent documents related to iPhone have been made public. As described in Section 2, we identify 97 unique patent application publication 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.

We then focus on the patent application publication days that are connected with abnormal trading volume. We find that 31 of the 97 dates fall into that category. When we check the dates of abnormal volume for potential event contamination, we find that nine of

[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.

[17] We obtain daily returns for the Fama-French SMB and HML factors from Kenneth French's website at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

the 31 days coincide with corporate information releases (such as quarterly earnings announcements, high-level managerial changes, and 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.[18] 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 likely to be less valuable[19], 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 small: 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%. Based on the evidence that patent grants do not appear to bring new information to the market in a significant manner, we exclude them from further analysis.

We explore the determinants of value reaction to patent applications by regressing the abnormal returns related to a patent application event on some patent characteristics that are commonly used as proxies of patent value (see e.g. Gambardella, et al. 2008). The results are reported in Table 5. In the first five columns of Table 5, we include abnormal reactions on all 97 patent event days. When the patent characteristics are considered individually in the first

[18] We have not checked out whether Apple's patent applications related to other products than iPhone are published on the same day. If there were such publications, it would bias our estimates of the value of iPhone related patents upwards. However, as explained in Section 2, our search algorithm is likely to miss some patent applications with relevance to iPhone, which in turn biases our estimates downwards.

[19] These patents fall into two categories: 1) The publication requirement for patent applications does not apply to inventions that are only patented domestically. 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.

three columns, only the number of claims exhibits a weakly significant (negative) connection with abnormal returns. However, when all patent characteristics are included in a single regression in column (4), more results emerge. The number of backward citations (defined as log(1+# of backward citations)) is positively related to the abnormal return, whereas claims and forward citations seem to affect abnormal returns negatively[20]. The abnormal reactions seem to become smaller through time, as the time trend variable enters with a negative and significant sign. In column (5), we add a control variable for the 22 patents whose application publication generated abnormal trading volume in Apple stock. The variable enters with a positive and significant coefficient, while leaving the rest of the findings intact. In column (6), we include only events with abnormal trading volume. Even in that subset of patent applications, the number of claims and the time trend variable enter with a negative and significant sign. Neither forward nor backward citations are significant determinants of abnormal returns in that subset.[21] That we fail to find robust positive correlation between forward citations and patent value might be surprising in the light of earlier literature. However, the result is in line with Patel and Ward (2011) who also use daily stock return data and find that markets do not anticipate future citations. Furthemore, forward citations appear to explain only little of variation in patent value (see e.g. Gambardella, et al 2008) and therefore it would be important to distinguish the types of citations (Czarnitzki, et al. 2011).

4.3. Value of trademarks

As described in Section 2, we find six days on which Apple filed a trademark for iPhone. The first two (in Singapore and UK) occur on subsequent trading days, on October

[20] Forward citations are adjusted for citation truncation by using the lag weights implied by Hall, et al (2002) for computers and communications industry. Using the weights from Hall, et al. (2007) for electronics industry yields similar results.

[21] When we compare the two subsets of applications (with and without abnormal trading volume), we find that the applications associated with abnormal trading volume have on average more claims, and forward and backward citations, but the differences are not statistically significant.

18 and October 21, 2002. The filing in Singapore exhibits abnormal trading volume, while the filing in 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. Furthermore, Apple stock return on that day exceeds 14%, making it the best day during the entire decade for the stock. However, the filing coincides with a very favorable quarterly earnings announcement, which renders the Canadian trademark filing irrelevant for our analysis. 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 volume to analyze. On the day of the first trademark filing (Singapore on October 18, 2002), the abnormal return for Apple stock is 0.78%, using the same fixed estimation period as above, but the reaction is statistically insignificant. We therefore do not further consider the trademark filing events in what follows.

4.4. Value effects within the supply chain

To study value capture and economic consequences of the launch of iPhone within its global supply chain, we follow our methodology and measure market reactions to iPhone related news announcements among the firms within the iPhone supply chain (see Section 2 and Appendix 1 for the identification of firms). In contrast to the one-day event window, we use a two-day window of (0,1) as both the supplier and the service provider sets include firms that are not traded within U.S. trading hours. Also, these firms are smaller than Apple and their connection to iPhone is less direct than that of Apple. The two-day event window allows more time for information assimilation.

We set up a hedonic regression, where the dependent variable is the abnormal return for each firm and each event. With role-specific dummies for Apple, its suppliers, and service providers, we intend to measure any systematic value created by the product across the supply chain. Apple's competitors serve as the omitted control group in the regression. The results are reported in Table 6. They suggest that besides the positive value effect on Apple, no other systematic value effects exist. We consider the market reactions both before and after the product pre-announcement on January 9, 2007, and both events with and without abnormal trading volume are considered separately (in unreported results). When the product pre-announcement is considered on its own, we do detect a positive average abnormal return of 6.8% among suppliers, which is statistically significant at the one percent level.

5. Market value of changes

In order to estimate the value of iPhone to Apple, we follow Chaney, et al. (1991) and others by observing the market capitalization of Apple 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 (see Section 4.1 for the identification of these events).

The results are reported in Table 7, with values in thousands of (event-day) 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.[22] 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

[22] 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.

total market capitalization, with the patent application publications contributing another 4% of the market capitalization.

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.[23] 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. Any building anticipation of the product during the time between our events would further generate a downward bias to estimates that rely on discrete events, such as ours. 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 likely that events such as quarterly earnings announcements 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. Similarly, we are overlooking patent grant events and trademark filings as we failed to find statistically significant systematic evidence of market reaction to those events. Thus, we are assuming the economic effect of those events to be zero.

When we contrast our estimates to the accounting information on Apple we find that the company's 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

[23] 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.

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.

6. Conclusions

In this paper, we combine insights from prior research to provide a new method to value individual innovations, intellectual property rights and assess determinants of that valuation, and apply this method to estimate the value of Apple's iPhone and related intellectual property to Apple, its horizontal rivals, and firms within the global supply chain of iPhone.

While the estimates of our method are biased downwards, it should provide a reliable lower bound of valuation. We find this lower bound for the market valuation of iPhone to be at roughly 30 billion U.S. dollars, with patentable technology explaining about 25% of the total value. According to our estimates, Apple itself appears to capture most of the value within the global supply chain of iPhone. This evidence suggests that Apple's management and marketing abilities and efforts contribute significantly to the value of iPhone.

We also complement the existing intellectual property valuation literature by studying the value of individual trademark filings, issued patents and the publication of patent applications by using daily stock market data. We find that the publication of patent applications rather than grants or trademarks release valuable new information to the market, and that the number of claims is negatively correlated with patent value, perhaps reflecting an increased concern for infringement litigation.

Our results predominantly indicate private value of iPhone to Apple. While we fail to find consistent significant effects on Apple's rivals and firms in the iPhone supply chain (save for the day of the product pre-announcement on January 9. 2007) such effects may nevertheless exist. For example, the introduction of iPhone has probably involved complex and offsetting effects on rivals: it has certainly reduced the market share of some established cellular phone manufacturers (a "business-stealing effect") but it has also probably increased the total size of the market and created technological spillovers, which have mitigated the business stealing effects. Furthermore, as this is an industry with imprecise and overlapping intellectual property rights, it is not surprising that Apple as an entrant has been at the center of extensive litigation concerning iPhone related intellectual property. The legal costs of intellectual property infringement suits and associated damage or settlement payments could be factored into the stock market reactions, and could explain the negative correlation between the patent value and the number of claims in our data. 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 to news about iPhone. Naturally, the estimations of full social value of iPhone should also incorporate consumer surplus besides industry and supply chain effects.

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Appendix 1: Suppliers, Service Providers, and Competitors

Suppliers

Balda AG
Broadcom Corp.
Catcher Technology Company Limited
Compeq Manufacturing Company Limited
Everlight Electronics Company Limited
Infineon Technologies AG
Marvell Technology Group Limited
National Semiconductor Corp.
Quanta Computer Inc
Sharp Corp.
Toshiba Corporation
Wintek Corporation

Service Providers

Deutsche Telekom AG
America Movil Sab De CV
AT&T Inc
France Telecom
NTT Docomo Inc
Singapore Telecommunications Limited
Sprint Nextel Corp
Telefonica SA
Teliasonera AB
U.S. Cellular Corp
Verizon Communications Inc

Competitors

Ericsson Telephone AB
HTC Corp.
LG Corp.
LG Electronics Inc
Motorola Inc
Nokia Corporation
Samsung Electronics
Research in Motion Limited

Figure 1
AAPL market model beta

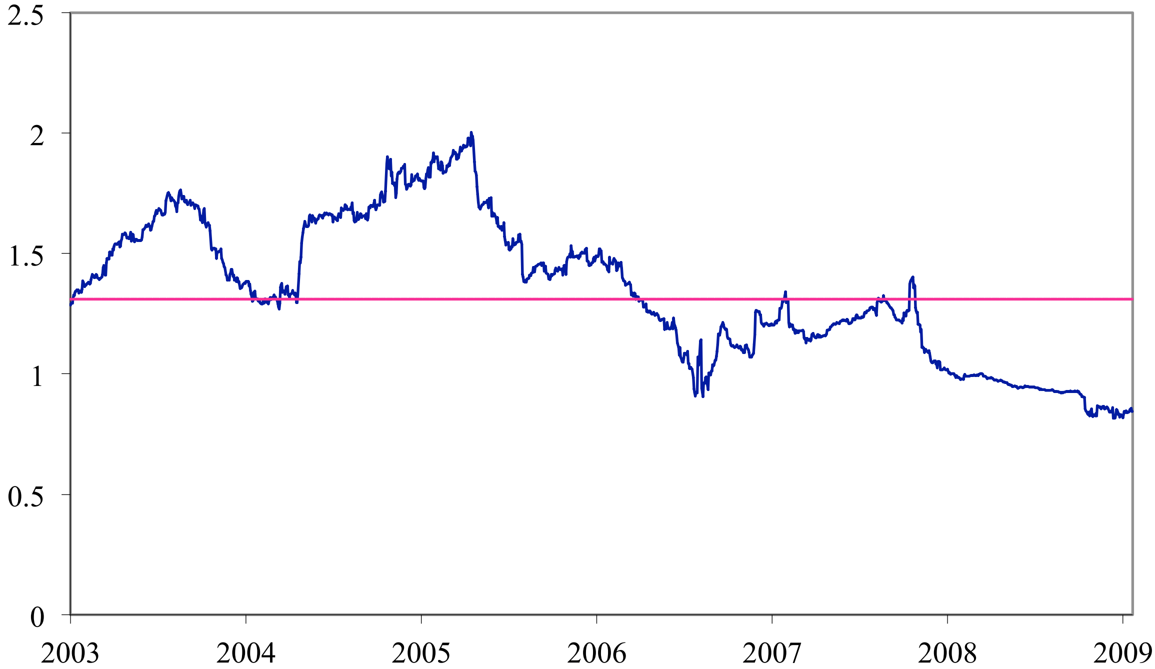

Figure 2
Apple, Inc. abnormal daily trading volume

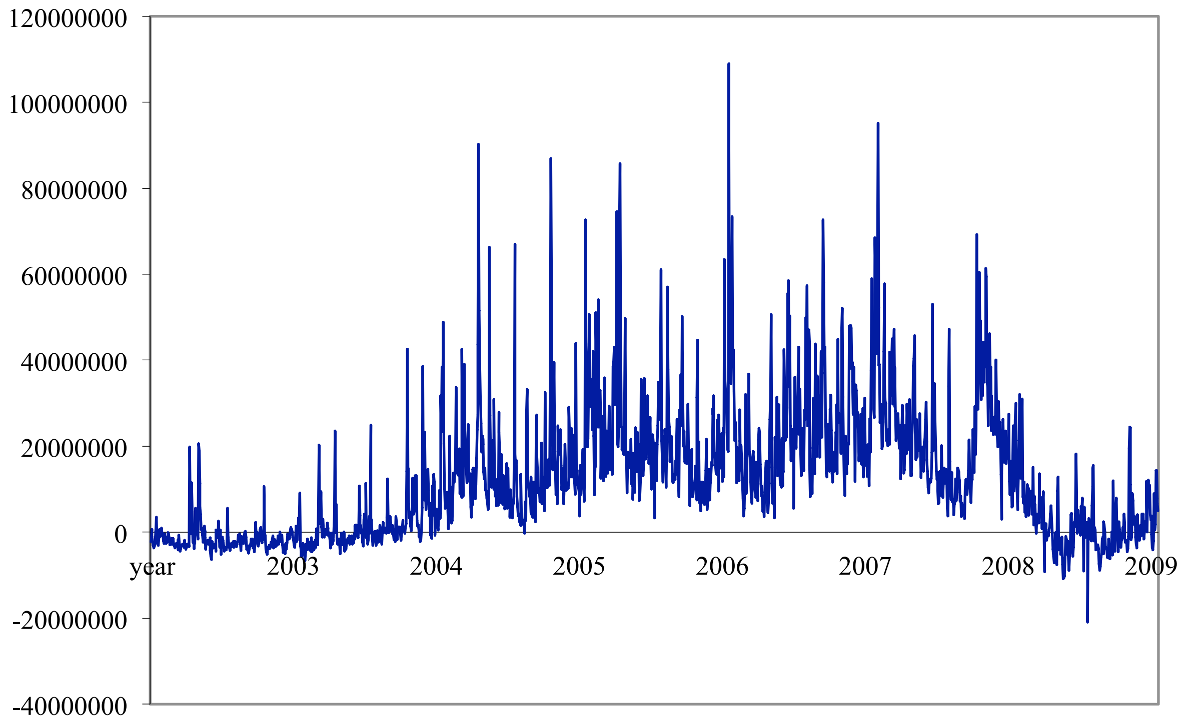

Figure 3
Average AAPL abnormal return on events with significant volume

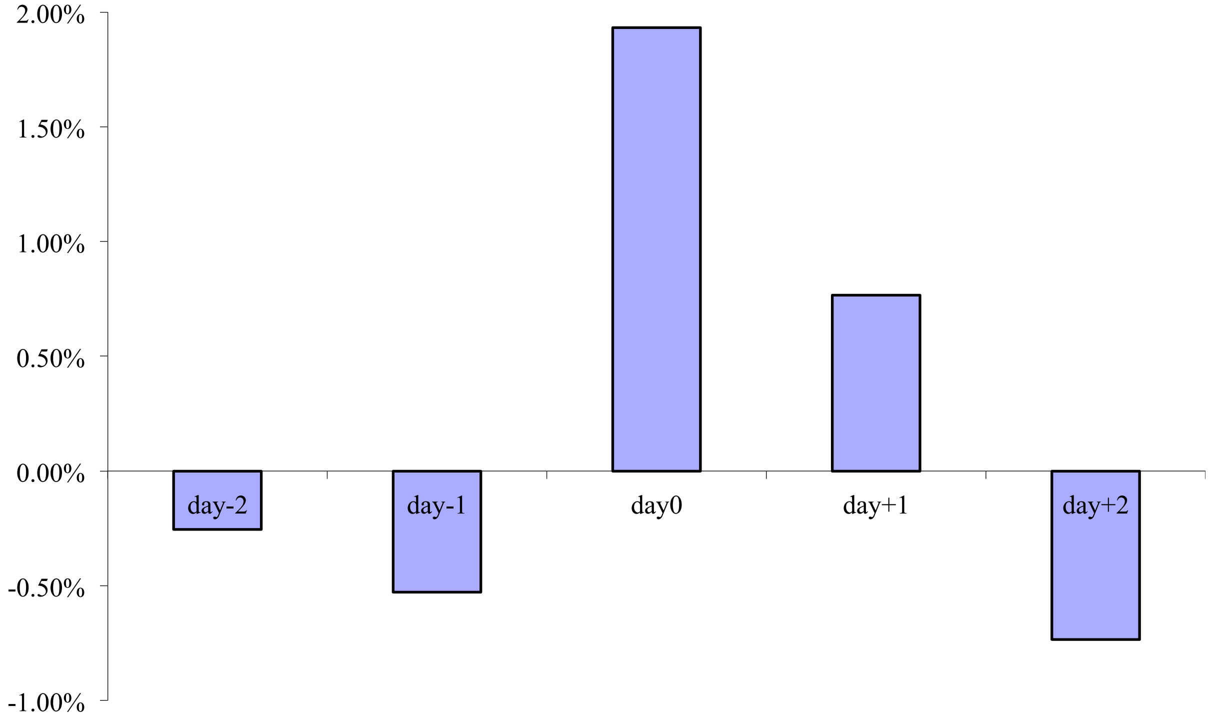

Figure 4
Average abnormal return for Apple and its competitors on events with significant volume

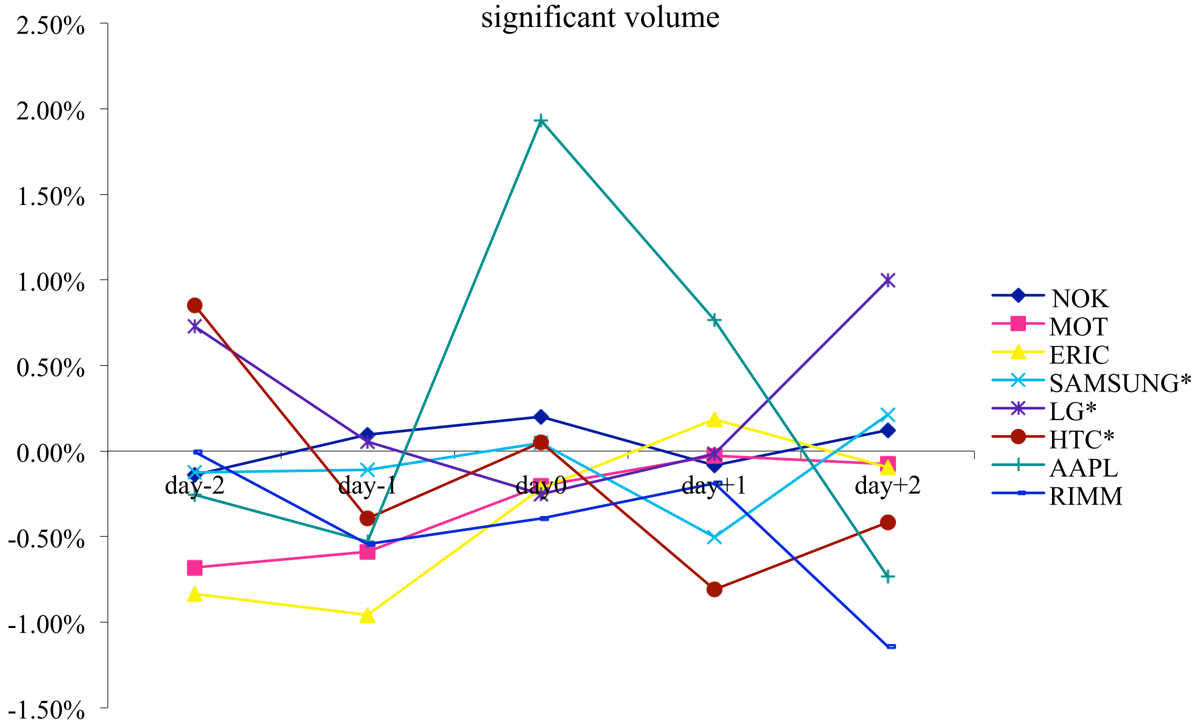

Table 1
News announcement events

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	**abnormal 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 those of its rivals that are available in the CRSP database. 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
Determinants of value reaction to patent application publications

The table reports estimates of regressions, where the abnormal return for Apple is the dependent variable. Backward and Forward citations are defined as log(1+# of citations), respectively. Time trend is log(# of days between application publication and the end of 2008). Claims is log(1+# of claims), and Signif. volume is an indicator variable that takes the value of one for events with abnormal volume. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Backward citations	0.0018			0.0042**	0.0038*	0.0038
	(0.002)			(0.002)	(0.002)	(0.004)
Forward citations		-0.0012		-0.0053**	-0.0054**	-0.005
		(0.002)		(0.002)	(0.002)	(0.004)
Time trend				-0.0087**	-0.0079**	-0.0242**
				(0.003)	(0.003)	(0.010)
Claims			-0.0089*	-0.0122**	-0.0116**	-0.0165*
			(0.005)	(0.005)	(0.005)	(0.008)
Signif. Volume					0.0127*	
					(0.006)	
Constant	-0.0049	0.0022	0.0292*	0.0966***	0.0875**	0.2251**
	(0.004)	(0.004)	(0.016)	(0.035)	(0.033)	(0.091)
Observations	97	97	97	97	97	22
Adjusted R^2	0.008	-0.005	0.021	0.075	0.104	0.155

Table 6
Value effects within the supply chain

The table reports estimates of hedonic regressions, where the abnormal return of each firm in the supply change is explained by whether the firm is a cellular service provider or a supplier linked to iPhone. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	before pre-announcement	**pre-announcement**	**After pre-announcement**
Apple	0.0289***	0.1609***	0.0195***
	(0.003)	(0.008)	(0.004)
Service provider	0.0019	0.0195	-0.0034
	(0.003)	(0.012)	(0.005)
Supplier	0.0012	0.0638***	0.0033
	(0.003)	(0.019)	(0.005)
Constant	-0.0044	-0.0370***	0.0011
	(0.003)	(0.008)	(0.004)
Observations	31	31	31
Adjusted R^2	0.354	0.371	0.078

Table 7
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