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

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Abstract

We use data on both daily stock returns and internet activity to estimate the value of Apple's iPhone and related intellectual property. We find the private value of iPhone to be 10% - 13% of Apple's market cap, but this is likely to constitute a low estimate for iPhone's value. Grounded in the resource-based theory, we argue that much of this value stems from Apple's managerial capabilities to capitalize on the product, as proprietary technology explains about 25% of the private value. This effect arises from patent applications, rather than grants or trademarks. Our analysis of the global supply chain of iPhone suggests that besides Apple, firms in the supply chain are able to capture very limited value from iPhone. These results support the theory of dynamic capabilities, maintaining that a firm's unique dynamic managerial and organizational capabilities are crucial for value creation in globally competitive innovative industries.

Keywords: innovation management; intellectual property rights; valuation; event studies; resource-based theory

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1. Introduction

Valuation of individual innovations and intellectual property rights, and determinants of that valuation challenge corporate managers. We estimate the value of a path-breaking individual innovation – Apple’s iPhone – and intellectual property rights connected to it by using data on both daily stock market returns and internet activity. We consider the value of iPhone to both Apple and firms in the global supply chain of iPhone.

Valuation based on stock market reactions is known to be sensitive to a number of issues such as identification of an innovation and relevant dates, estimation period, trading volume, and market structure (e.g., Doukas and Switzer 1992, MacKinlay 1997, Tkac 1999, and Sorescu and Spanjol 2008). In comparison to large sample quantitative studies, focusing on a single, highly visible product innovation allows us to employ more detailed information and careful controls, and thus reduce the noise that tends to hamper efforts to use stock market reactions to value innovations.¹ The depth of trading in Apple’s stock and the analyst following that the company attracts should also reduce pricing errors in the stock.

We measure stock reactions to publications of news and various types of patent and trademark publications related to iPhone. Considering multiple sources of potential value should not only give a more accurate estimate of the private value of iPhone but also shed additional light on the determinants of that value. Based on the resource-based view of the firm, the value of a drastic innovation, like iPhone, may reflect both tradable proprietary technologies, and the firm’s unique capabilities to deploy its own and its competitors’ R&D efforts (e.g., Amit and Schoemaker 1993, Teece, et al. 1997, and Makadok 2001). We argue that stock reactions to news are more related to value effects related to firm-specific

¹ For example, we use multiple sources to manually check that our events are free of contamination from unrelated simultaneous events.

management and organizational capabilities whereas value effects related to tradable proprietary technologies are more reflected in reactions to publications of patent documents.²

The role of proprietary technologies as contributors of value of innovation is not clear a priori. Even if such technologies have become increasingly tradable over the past decades, they may constitute a valuable, unique resource that forms a basis for a firm's sustained competitive advantage if they involve heterogeneity, imperfect imitability and imperfectly competitive accumulation process (Barney 1991, Peteraf 1993, and Arora, et al. 2001). All these features are arguably present in the iPhone's case.

However, prior studies also emphasize idiosyncratic dynamic managerial and organizational capabilities to deploy firm's resources as the fundamental source of value creation, in particular in globally competitive innovative industries (e.g., Nelson 1991, Teece, et al. 1997, and Teece 2007). In Apple's case, reputation with its existing products (Mac and iPod) can be viewed as a valuable asset as such (Barney 1991 and Peteraf 1993), the company's managerial capabilities would enable it to further lever such reputation in introduction of iPhone. Competent management should also 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).

Apple and its late, visionary CEO Steve Jobs are commonly seen as particularly successful in deriving value from diverse resources (e.g., *Fortune* selected him as the CEO of the decade in 2009). As his bibliography documents, Jobs was focused on organizing Apple to create a lasting culture of innovation instead of merely investing in R&D (Isaacson 2011).³ He also emphasized marketing strategy, and perfected the principle of 'imputing' i.e.,

² Naturally, reactions to news may also reflect the value of underlying tradable assets and reactions to patent documents managerial and organizational capabilities.

³ Jobs's innovation management philosophy may be summarized as follows: "Innovation has nothing to do with how many R&D dollars you have...It's about the people you have, how you're led, and how much you get it." (*Fortune*, 9 November 1998). Despite its apparent innovative success, Apple has historically spent much less in R&D as a percentage of sales than its rivals (see, e.g., Dediu and Schmidt 2012).

carefully planned communication to make a great first impression. Such strategy is particularly important in network industries where managing consumers' expectations, e.g., via quality and timing of product pre-announcements (which form a part of our study), is vital (Dranove and Gandal 2003 and Sorescu, et al. 2007).

Our empirical approach builds on a long line of literature using the event study methodology in valuation of innovations (see, e.g., Chaney, et al. 1991, Girotra, et al. 2007, and Sood and Tellis 2009). A limited number of previous studies also employ daily stock return data to value intellectual property (e.g., Austin 1993, and Patel and Ward 2011). We contribute by including not only patent grant events, but also dates when patent applications were first published by the USPTO. We also consider design patents and trademark filings. The event study method allows us to study the market value of individual patents and its determinants, and it should be seen as complementary to the popular method of estimating the private value of patents by using annual stock market return data that goes back at least to Griliches (1981).⁴ Bessen (2009) argues that estimations based on annual data provide an upper bound for the market value of patents whereas our estimations by using daily data should provide a low estimate.⁵

We use the ratio of daily trading volume to market capitalization to distinguish significant events among a large number of events, as suggested by Tkac (1999). Following the idea by Da, et al. (2011), we also use internet activity related to iPhone to gauge the informative value of our events. These methods have rarely been used in valuation of innovation and intellectual property.⁶

We also consider stock market reactions to iPhone related events among the firms within the supply chain of iPhone. This enables us to judge whether iPhone has generated

⁴ Other important methods of patent valuation use patent renewal data (Schankerman and Pakes 1986) or survey data (e.g., Gambardella, et al. 2008).

⁵ We discuss the reasons for why our method biases the value estimates downwards at the end of Section 6.

⁶ A notable exception is Girotra, et al. (2007) who apply a variant of Tkac's (1999) method in their study of R&D value in the pharmaceutical industry.

value for the supply chain, or whether the value effect is predominantly captured by Apple. Although we are not aware of previous studies using the event study methodology to evaluate consequences of a new product within a global supply chain, there is closely related work using accounting data (Linden, et al. 2009 and Ali-Yrkkö, et al. 2011).

In the empirical resource-based view literature, our paper is close to Zahra and Nielsen (2002), who evaluate numerous resource determinants of technology commercialization. We focus on a firm's proprietary technologies and management abilities (including integration procedures) that are among the most important determinants uncovered by their study.

Our estimates of the private value of iPhone (at the end of 2009) based on news events vary from \$20 billion to \$24.4 billion U.S. dollars, depending on the estimation method. Accounting for abnormal reactions to patent application publications adds \$7.8 billion to the value of iPhone whereas we find no value effect connected to patent grants or trademarks filings. Given the Apple market capitalization of \$190.6 billion at the end of 2009, the news event-based value of iPhone would be 10%-13% of the market capitalization, with the patent applications contributing another 4% of the market capitalization.

Within the global supply chain of iPhone, we find no systematic value effects besides the positive effect on Apple itself. 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 while both proprietary technologies and Apple's marketing and management abilities and efforts matter, the latter play a more important role in explicating the value of iPhone.

In the next section we provide theoretical background for our analysis. In Section 3 we describe our data, and in Section 4 we explain our valuation methods. The results

concerning valuation determinants and market value are presented in Sections 5 and 6. Conclusions are in Section 7.

2. Theoretical background

The resource-based view – inspired by Penrose (1959) and developed subsequently by Wernerfelt (1984), Rumelt (1984), Barney (1986, 1991), Peteraf (1993), and others – emphasizes the role of a firm’s resources and capabilities that are valuable but rare and difficult to copy and substitute in obtaining sustained competitive advantage for the firm. While our aim is to value an individual product, we argue that the resource-based theory can be used to shed light on the determinants of value. In the context of iPhone, we are interested in the division of the value contribution between Apple’s proprietary technologies, and its managerial and organizational capability to capitalize on the product.

The resource-based view theory distinguishes between those resources and capabilities that are idiosyncratic to the firm and those that are homogenous and can be acquired in the marketplace. Homogenous resources or capabilities cannot be a source of sustained competitive advantage, as competition will erode above-normal profits (Barney 1986). Instead, the exploitation of the firm-specific resources is considered crucial for value creation for the firm (Wernerfelt 1984). Such firm-level idiosyncrasies are also seen as the main source for large and persistent interfirm differences in innovative outcomes (Dosi 1998 and Nelson 1991). In this respect, the cellular phone industry is very patent intensive, and 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 limited *ex ante* and *ex post* competition. However, standardization and associated commitment to patent licensing under ‘fair, reasonable and non-discriminatory’ terms also mean that acquisition of essential patents is a competitive process.

A related distinction is between tradable resources and firm-specific, non-transferable management and organizational capabilities that are used to deploy those resources (Amit and Schoemaker 1993 and Makadok 2001).⁷ A firm's unique managerial talent, and managerial capability to deploy other resources are identified as particularly valuable strategic resources already by Penrose (1959). These management and organizational capabilities are at the heart of the theory of 'dynamic capabilities' proposed by Teece, et al. (1997) which extends the resource-based theory in environments of rapid technological change characterized by Schumpeterian competition of creative destruction (see also Nelson 1991). This theory views competitive advantage as arising from a firm's unique and difficult-to-replicate dynamic managerial and organizational capabilities to leverage the firm's tradable asset position. Teece (2007) argues that this theory fits particularly well for globally competitive innovative industries of which the cellular phone industry is a prime example.

In their empirical study of the determinants of technology commercialization, Zahra and Nielsen (2002) divide a firm's resources into internal and external human-capital and technology-based sources. They further consider formal and informal integration procedures. Our data does not permit such fine-tuned division of resources. Rather, we focus on a firm's internal technology-based resources and the firm's management and marketing capabilities. The latter should be interpreted more broadly than integration procedures emphasized by Zahra and Nielsen (2002). Importantly, they also include the management's ability to leverage external sources.

The firm's ability to sustain its competitive advantage depends partly on 'isolating mechanisms' put in place to prevent competitors from replicating the firm's unique resource position (Rumelt 1984). The possession and evolution of these unique resources and isolating mechanisms depend on the path of strategic choices and cumulative investment that the firm

⁷ Recent economics literature (see e.g. Bloom and Van Reenen 2010) has made an analogous distinction between soft (e.g. management and organizational capabilities) and hard technologies (e.g. hardware and software).

has followed (Nelson and Winter 1982). This path-dependent nature of investment and resource accumulation may in itself constitute an important isolating mechanism in the cellular phone industry, which is characterized by platform competition with high switching costs for both consumers and manufacturers. In such an environment, to build a distinctive, valuable position of resources and capabilities requires a history of systematic investment and nurturing by management. In contrast, even a large patent portfolio does not automatically function as an isolating mechanism since rivals may be able to innovate and design around that portfolio (Teece 1986). Apple's entry in the cellular phone industry where the incumbents' asset positions were protected by extensive patent portfolios is a case in point.

The resource-based theory has been criticized of being too vague and tautological (see, e.g., Kraaijenbrink, et al. 2010). In our case, too, some ambiguity exists between our empirical measures and the theoretical constructs. Patent documents exclusively focus on detailed description of technology. Stock market reactions to publications of patent documents could thus be viewed as more reflective of the value of Apple's tradable proprietary technology, and they should be only to a lesser affected by its managerial and organizational capabilities. The reverse could hold for reactions to news events, as they rarely describe the underlying technology and intellectual property in detail.

However, reactions to both news and publications of patent documents are likely to reflect all capabilities and resources of Apple. For example, building managerial and marketing capabilities and gathering intellectual property portfolio might be complementary rather than substitute rent-creation strategies (Teece 1986, Makadok 2001, and Arora, et al. 2001). In that case, reactions to patent document publications should also manifest Apple's managerial and organizational capabilities. Viewing reactions to different sources of information as reflecting value effects of different sources of capabilities and resources should be taken as suggestive.

3. 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 events is Lexis-Nexis, with Bloomberg and Google being used as secondary sources. There, we search for all news that are related to iPhone. In total, we find 74 days on which news about iPhone occur. These events include both Apple-initiated press releases and news generated by journalists reporting on iPhone. The earliest of these news events dates back to December 15, 1999, when Apple registered iPhone.org website. The first 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 news events, 31 take place prior to that date. Table 1 indicates the breakdown of our events (a detailed 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.⁸ In the U.S., like in other countries, the average lag from the filing of a patent application to a patent grant is several

⁸ In theory, the situation is somewhat more complicated, especially in the U.S., 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 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.

years but pending applications are often made public 18 months after the earliest filing date.⁹ 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.¹⁰ Whenever it is unclear whether the patent is related to cellular phones, we scrutinize the entire patent application that includes information such as pictures of the invention to be patented.

We find patent documents for a total of 213 iPhone related inventions (a detailed list of these documents is available from the authors). This is consistent with Apple's own estimate: At the pre-announcement event of iPhone on January 9, 2007, Steve Jobs mentioned that Apple "has filed over 200 patents for all the inventions in iPhone". For most of Apple's patents related to iPhone, we are able to identify an application publication date, and thus we can use both application and grant dates.¹¹ There are 44 patents that are granted

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 as the cases in which an applicant waives her right to seek patent protection outside the U.S.

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).

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 of the iPhone patents 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, our figure is likely to underestimate the number of iPhone

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. The earliest publication date is February 7, 2002. Since some 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 trademark filings on iPhone in various countries. The first trademark filing in Singapore takes place on October 18, 2002, and filings in the UK and Australia follow within the same year. In total, we find six trademark filings, all of them occurring prior to the product pre-announcement.¹²

In order to identify the firms within the global supply chain of Apple, we use various internet sources including teardown reports from www.isuppli.com, and news about supply contracts from both Lexis-Nexis and Bloomberg. The identified suppliers, which include mainly hardware manufacturers and cellular service providers, are listed in Appendix 1, along with a set of Apple's cellular phone industry competitors that are used as a control group.

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 iPhone supply chain are not traded in the U.S. exchanges. Therefore, we use Datastream as an alternative data source for stock returns.

4. Measurement of event-related value changes

In order to establish the dollar value of iPhone to Apple, we use the event study methodology (see MacKinlay, 1997 for a survey) to explore the abnormal stock returns that

related patent applications as we are bound to overlook some patent applications that concern both iPhone and Apple's other products.

¹² 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.

various information releases cause on Apple's stock. Our primary event study method is based on the market model.

Since the market model parameter estimates can be sensitive to the 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, 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 abnormal returns. The CRSP value-weighted market index serves as a proxy for the market portfolio.¹³

The market model 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 also use the more standard estimation window of (-250,-10).

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

¹³ Fama and French (1993) offer an improvement to traditional models of expected returns by adding factors for size and market-to-book in their so called Fama-French three-factor model. We use their model as a robustness check. In the Fama-French three-factor model, the expected returns are based on the stock's sensitivity to market returns, and size (SMB) and market-to-book (HML) factors.

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 ($t = 0$). For those news that became public after 4:00 p.m. Eastern time, we use $t = +1$ as the event day. 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 news that is published after that time should be reflected in the following day's CRSP stock return. Out of the total of 74 news events, five fall into this category.

In our valuation 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. 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. To the extent the assumptions fail to hold, our estimates are biased downwards.

To identify 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 increase 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). Following this idea, we identify event days with abnormal trading volume for Apple by estimating the equation

$$V_{it} = \gamma_i + \delta_i V_{mt} + \lambda_i D_t + \varepsilon_{it}, \quad (1)$$

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 In other words, while our abnormal returns are estimated using daily stock returns, the abnormal volume estimation employs the daily ratio of trading volume over market capitalization. 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), 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 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:

$$ASVI_t = \log(SVI_t) - \log[\text{Mean}(SVI_{t-1}, \dots, SVI_{t-60})]. \quad (2)$$

In equation (2), $ASVI_t$ is the Abnormal Search Volume Index for day t . In contrast to Da, et al. (2011), who use weekly data, we use daily data. Also, they specify normal internet activity

¹⁴ 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 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.

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.

5. Determinants of valuation

5.1 Stock market reactions to news events

We begin by exploring stock returns related to all iPhone news. The average one-day abnormal return for Apple is 0.47%, which is statistically significant at the 10% level. Then, when employing equation (1), our tests indicate that 22 of our 74 news events are associated with abnormal relative trading volume. Further, when we use equation (2), we find that the ASVI measure for these 22 events is higher than that for the remaining 52 events that exhibit no abnormal 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. 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. 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.

Next, we compare our findings across different estimation periods and methods. The results, reported in Table 2, indicate 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 is obtained from the market model with

a fixed estimation period. Adding the Fama-French factors¹⁵ to our market model reduces the average event day abnormal return by one basis point.

5.2. Value of patents

We complete a similar analysis for days on which patent documents related to iPhone have been made public. In Table 3, we report average abnormal returns for Apple. The upper part of Table 3 shows that the average abnormal returns across all 97 unique patent application publication days is slightly positive, but falls far short of statistical significance.

When we use equation (1), we find that 31 of the 97 the patent application publication days are connected with abnormal trading volume. After checking the dates of abnormal volume for potential event contamination, we find that nine of 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 patent application publication days with significant trading volume, which are free of contamination.¹⁶ 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. Various reasons exist for why the informational value of patent grants is limited, particularly in Apple's case. First, patent applications are not published, e.g., if Apple has no intention of international patenting (see also footnote 9). This would indicate either that the invention is not patentable outside the U.S., or that the invention is not significant enough to

¹⁵ 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.

¹⁶ 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 3, our search algorithm is likely to miss some patent applications with relevance to iPhone, which in turn biases our estimates downwards.

warrant a costly international application process. Second, information about the patents with prior publications becomes public when the corresponding applications are published. Apple's patent applications tend to be exceptionally intensely discussed within the internet community immediately upon their publication, which should help information assimilation in Apple's case. Finally, patent grant uncertainty in the case of a large and professional patent applicant like Apple is likely to be small.¹⁷

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 4. In the first five columns of Table 4, we include abnormal reactions on all 97 patent event days. When the patent characteristics are considered individually in the first 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), the number of backward citations is positively related to the abnormal return, whereas claims and forward citations seem to affect abnormal returns negatively. 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

¹⁷ Gans, et al. (2008) report evidence that average applicant success rate at the USPTO may be as high as 90% but that grant uncertainty may nonetheless matter for start-ups in certain industries.

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.¹⁸

The results suggest that particularly patent applications from the earlier stages of the iPhone's invention process release valuable information to the market about Apple's upcoming invention. We also find a robust negative correlation between the number of claims and patent value. Although there is evidence about positive correlation (see, e.g., Bessen 2008 and Gambardella, et al. 2008), the relationship between claim count and patent value is generally complex (see, e.g., Allison and Lemley 2002 and van Zeebroeck et al. 2009).¹⁹ More surprising is the absence of robust positive correlation between forward citations and patent value. However, our result is in line with Patel and Ward (2011) who also find that stock markets do not anticipate future citations. Citations may also have become a more noisy indicator of patent value: For example, overburdened patent examiners may inadvertently miss citations whereas patentees may withhold citations strategically (Cockburn, et al. 2003, Sampat 2010, and Lampe 2012). More generally, forward citations appear to explain only little of variation in patent value (see, e.g., Bessen 2008 and Gambardella, et al 2008) and therefore it would be important to distinguish the types of citations (Czarnitzki, et al. 2011).²⁰

5.3. Value of trademarks

¹⁸ When we compare the 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.

¹⁹ As a reviewer pointed out, many claims may also be an indicator of a marginal invention as one goal of writing claims is to position the patent against prior art.

²⁰ Also, we work with quite recent data where the forward citation and patent value relationship is less reliable because of citation truncation, although we do attempt to correct this 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.

As described in Section 3, 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 18 and October 21, 2002. The filing in Singapore exhibits abnormal trading volume. The abnormal return for Apple stock is 0.78% but the reaction is statistically insignificant. The subsequent filings in the UK, in Australia in December 2002, in New Zealand and in the US in September 2006 fail to generate abnormal trading volume. In contrast the filing in Canada on October 14, 2004 is met with a very large abnormal trading volume, and 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. It therefore appears that trademark filings bring no new information to the market.

5.4. Value effects within the supply chain

To study consequences of the launch of iPhone within its global supply chain, we use our methodology to measure market reactions to iPhone related news events among the firms within the iPhone supply chain (see Section 3 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 indirect. 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 horizontal competitors (see Appendix 1) serve as the omitted control

group in the regression.²¹ 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).

The results are reported in Table 5. They suggest that besides the positive value effect on Apple, no other systematic value effects exist. 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. Similar to the findings from studies of value capture using accounting data (e.g. Linden, et al. 2009 and Ali-Yrkkö, et al. 2011), our results suggest that Apple's complementors are only able to capture limited value from iPhone.

6. Market value of the events

In order to estimate the value of iPhone to Apple, we follow Chaney, et al. (1991) and others by multiplying the market capitalization of Apple on the day prior to each event by the abnormal return related to the 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).²²

The results are reported in Table 6, with values in thousands of (event-day) dollars. Our news event-based estimates vary from \$20.0 billion to \$24.4 billion, depending on different methods of estimation. Accounting for abnormal reactions to patent application

²¹ In unreported results, we also consider value effects of iPhone-related events on these competitors. In theory the introduction of iPhone should generate two contrasting effects on competitors, namely positive market expansion and spillover effects, and negative business-stealing effects. Against this background, it is not surprising that we find no significant competitor effects.

²² We have not performed a content analysis of news articles. A thorough analysis of the content of news articles would allow an evaluation of Apple's capability to build media reputation (see, e.g., Deephouse 2000, Tetlock, 2007, and Rindova, et al 2010). Studying the market sentiment effects of the news articles in the light of resource-based theory is an interesting idea for future research.

publications adds another \$7.8 billion to the value of the product.²³ Given the Apple market capitalization of \$190.6 billion at the end of 2009, the news event-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 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, 2009.²⁴ Second, the development of iPhone took several years, and some information about the product is likely to 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 between our discrete events would further generate a downward bias to our estimates.²⁵ 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 that ignore contaminating events completely. 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

²³ Two of our patent application publication event dates coincides with a news event 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 one is connected with almost equal negative value effect, they have a negligible effect on the total value.

²⁴ 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.

²⁵ These concerns are mitigated by the fact that Apple is extremely actively traded and analyzed stock. Besides the established financial analysts, the firm is followed by several tech-savvy internet sites. This should prevent wide stock price swings stemming from unsubstantiated rumors and reduce other pricing errors.

filings as we failed to find statistically significant systematic evidence of market reaction to those events. Thus, we are assuming their economic effect 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 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, current sales figures ignore future growth potential, and synergy effects across product lines.

7. Conclusions

We estimate the value of Apple's iPhone and related intellectual property to Apple and firms within the global supply chain of iPhone. We use both daily stock market return and internet activity data and consider reactions to publications of both news and various intellectual property rights related to iPhone.

Our method produces downwards-biased estimates that 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, with stock market reactions to patent publications explaining about 25% of the total value. If we are willing to assume that reactions to news events (patent publications) reflect more (less) Apple's marketing and managerial capabilities and efforts than its proprietary technology, this suggests that those abilities and efforts contribute significantly to the value of iPhone. In our view, our results support the theory of dynamic capabilities (Teece, et al. 1997 and Teece 2007) maintaining that a firm's unique dynamic managerial and organizational capabilities are crucial for value creation in globally competitive innovative industries.

We also find that Apple itself captures most of the value within the global supply chain of iPhone, which supports both findings from the prior literature of value capture using different methods and data, and predictions of the resource-based theory. Namely, rents within global supply chain of innovative new products tend to accrue to firms possessing unique, difficult-to-copy capabilities and resources rather than to firms with more easily substitutable capabilities and resources.

We also complement the existing intellectual property valuation literature by studying the value of individual trademark filings, issued patents and publications of patent applications by using daily stock market data. We find that the publication of patent applications, especially at the earlier stages of iPhone's invention process, rather than grants or trademarks release valuable new information to the market, and that the number of claims is negatively correlated with patent value.

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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

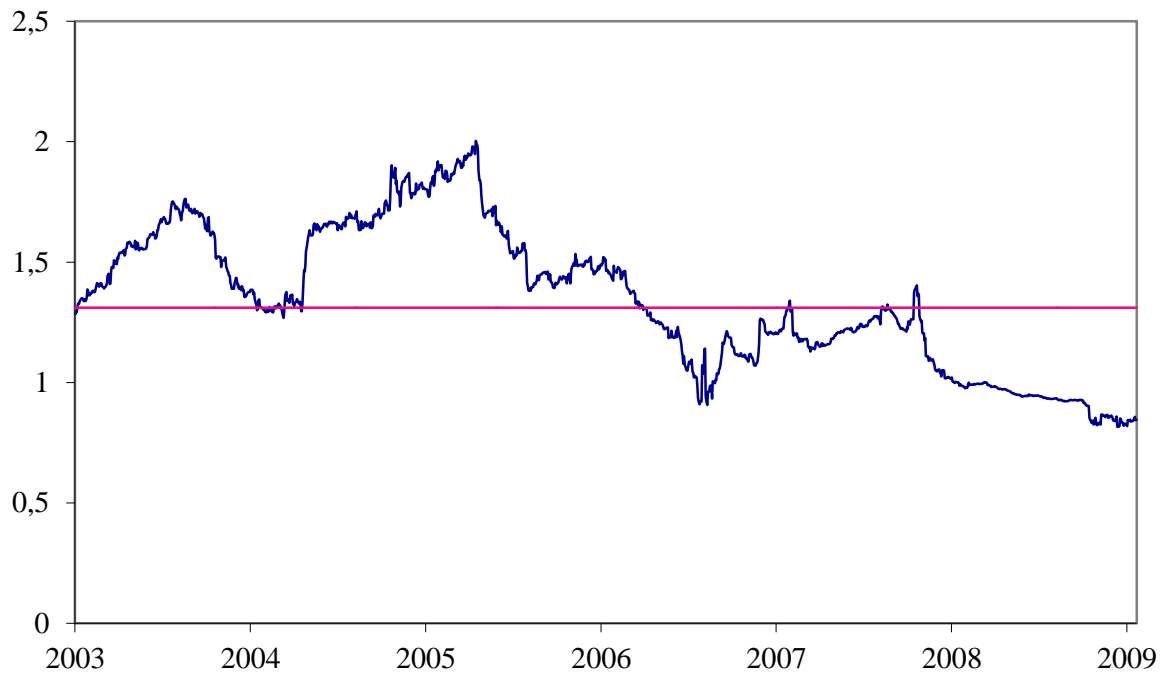


Figure 2
Apple, Inc. abnormal daily trading volume

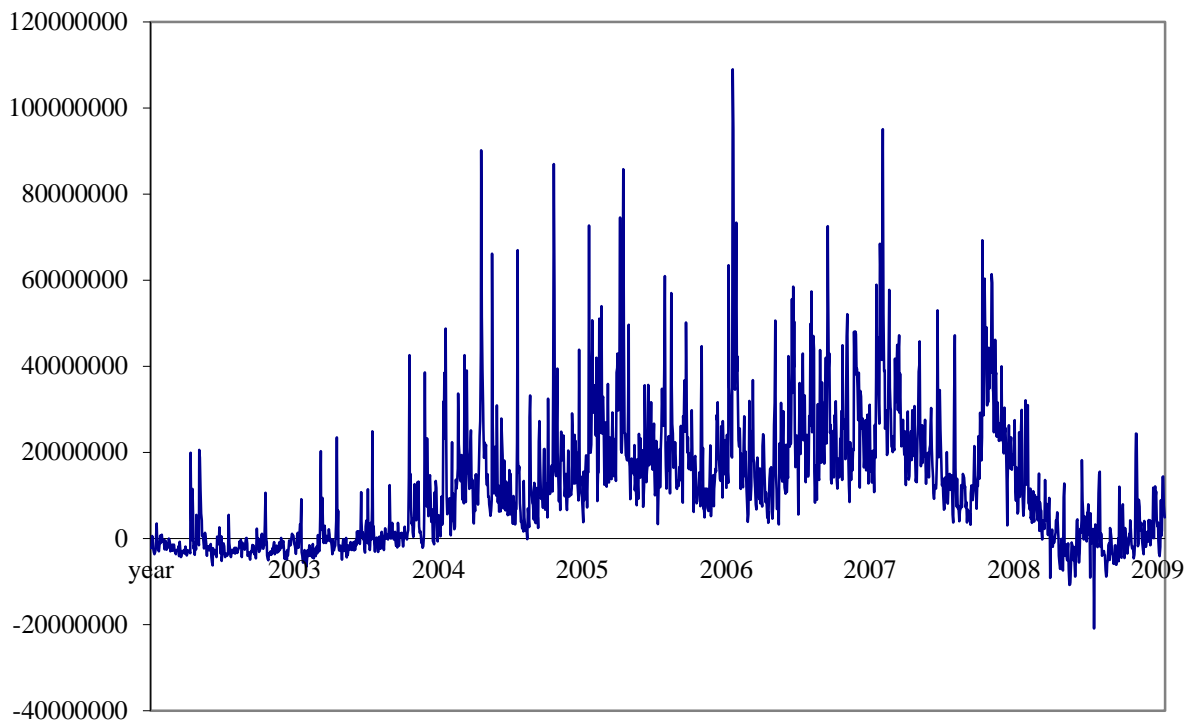


Figure 3
Average AAPL abnormal return on events with significant volume

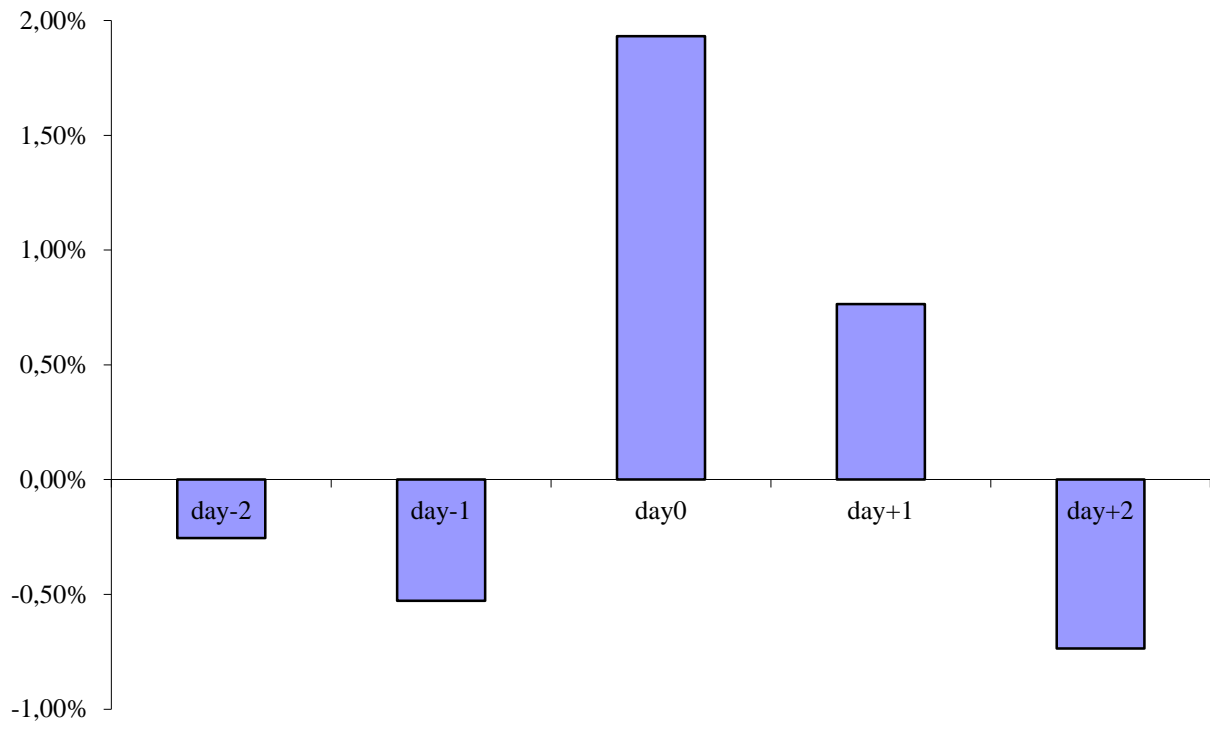


Table 1
News events

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
	<hr/> 74	<hr/> 21

Table 2
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 3**Daily abnormal returns around patent events**

The table reports the average daily abnormal returns for Apple. 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.

All patent application publication days (n=97)

day-1	0.01%
day0	0.02%
day+1	-0.36%

Patent application publications with significant trading volume and no contamination (n=22)

day-1	0.29%
day0	1.13% *
day+1	-0.03%

Table 4**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 $\log(1+\# \text{ of citations})$, respectively. Time trend is $\log(\# \text{ of days between application publication and the end of 2008})$. Claims is $\log(1+\# \text{ of claims})$, 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 (0.002)			0.0042** (0.002)	0.0038* (0.002)	0.0038 (0.004)
Forward citations		-0.0012 (0.002)		-0.0053** (0.002)	0.0054** (0.002)	-0.005 (0.004)
Time trend				-0.0087** (0.003)	0.0079** (0.003)	-0.0242** (0.010)
Claims			0.0089* (0.005)	-0.0122** (0.005)	0.0116** (0.005)	-0.0165* (0.008)
Signif. Volume					0.0127* (0.006)	
Constant	-0.0049 (0.004)	0.0022 (0.004)	0.0292* (0.016)	0.0966*** (0.035)	0.0875** (0.033)	0.2251** (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 5
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*** (0.003)	0.1609*** (0.008)	0.0195*** (0.004)
Service provider	0.0019 (0.003)	0.0195 (0.012)	-0.0034 (0.005)
Supplier	0.0012 (0.003)	0.0638*** (0.019)	0.0033 (0.005)
Constant	-0.0044 (0.003)	-0.0370*** (0.008)	0.0011 (0.004)
Observations	31	31	31
Adjusted R ²	0.354	0.371	0.078

Table 6
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