Product Life-Cycle and Initial Public Offerings

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Abstract

This paper studies how the product life-cycle (PLC) of a firm affects its corporate finance decisions during and post its initial public offering (IPO). We construct the PLC measure for firms by performing a textual analysis on their S-1 filings. The analysis reveals that firms with a more product-innovative PLC are more likely to follow through the IPO even though they face higher underpricing and offer a lower fraction of equity at IPO. These firms conduct less seasoned equity offerings, pay out fewer dividends, and conduct fewer acquisitions after IPO. Our instrumental variable analysis, with the average PLC of similar public firms as the instrument for an IPO firm's PLC, shows that the above results are causal. Information asymmetry and product market competition are two potential underlying channels.

Keywords: Product life-cycles, initial public offerings, textual analysis, product market competition, information asymmetry

1 Introduction

Product life-cycle (PLC) is one of the fundamental variables shaping firms' strategic dynamics, such as market opportunities, competitive challenges, and strategy responses (Abernathy & Utterback, 1978; Hofer, 1975). It relates theoretically to a firm's growth and investment opportunities throughout the entire life of the firm (Hajda & Nikolov, 2020; Hoberg & Maksimovic, 2019; Loderer, Stulz, & Waelchli, 2017). One of the crucial decisions in the private life of a firm is going public, where companies face a trade-off between benefits and costs. On the one hand, the benefits of going public include raising relatively cheaper capital from the public market compared to the private market (Hertzel & Smith, 1993), increasing visibility and grabbing market shares (Chemmanur, He, & Nandy, 2010). On the other hand, the costs such as losing confidentiality and increasing financial transparency (Bhattacharya & Ritter, 1983; Maksimovic & Pichler, 2001), reducing exploratory innovation (Ferreira, Manso, & Silva, 2014), less control and more board of directors' influence (Brau & Fawcett, 2006) are also non-negligible. These benefits and costs depend highly on the product life-cycle of a firm. However, no empirical research exists so far analyzing the relationship between firms' product life-cycle and their corporate finance decisions during and after its initial public offering (IPO), mainly due to the challenge of measuring product life-cycles for IPO firms.[1]

In this paper, we construct a measure of product life-cycle for firms filing an IPO using the textual analysis methodology developed in Hoberg and Maksimovic (2019). We implement the methodology on S-1 filings, which is a filing form for companies to complete registration of securities with the Securities and Exchange Commission (SEC). The intuition

[1]Previous studies have used age (Arikan & Stulz, 2016), dividends (Grullon, Michaely, & Swaminathan, 2002), retained earnings over assets (DeAngelo, DeAngelo, & Stulz, 2006) and size (Klein & Marquardt, 2006) to measure firm life-cycles. However, these measures suffer from criticisms that firms do not progress deterministically down the life-cycle (Miller & Friesen, 1984) (e.g., old firms could still maintain a young product life-cycle by researching and developing new products and services). In addition, the life-cycle of a firm may change due to external forces such as regulations or technology breakthroughs.

of the proposed product life-cycle measure is that many companies own diverse products, which do not necessarily belong to the same life-cycle stage. That is why, each company is modeled as a four-element vector of product life-cycles, following Abernathy and Utterback (1978). The first element of the vector represents the proportion of products in the innovation stage, where the company emphasizes the development and introduction of a new product. The second element of the vector stands for the proportion of products in the process innovation stage, when the company focuses on the improvement of the process of production and lowering its costs. The third element incorporates all the products in the mature stage, where the attention turns to stability in products, suppliers, and customers. Finally, the last element indicates a company's exposure to the product discontinuation phase. Over time, each component might increase or decrease in response to shocks or product market competition, which is a novelty compared to the traditional life-cycle variables, such as firm age.

Implementing this product cycle-cycle measure on a sample consisting of 3,297 IPO filings between 1994 to 2018 in the U.S., we document that most of the companies filing for IPO own products in all four life-cycle stages. Nonetheless, we find that firms with a higher fraction of products in the stage of product innovation (i.e., a younger product life-cycle) are more likely to complete their IPO process, but at the same time experience higher underpricing and offer a lower fraction of equity to outside investors at IPO. Specifically, a 1% higher fraction of products in the stage of product innovation is associated with a 0.18% increase in the likelihood of an IPO follow-through, a 0.15% increase in IPO underpricing, and 0.14% decrease in the fraction of equity offered at IPO.

Moreover, for firms that successfully conduct their IPO, we show that when they have more products in the earliest product life-cycle, they are more likely to perform seasoned equity offerings, less likely to pay out dividends, and less likely to acquire other firms after the IPO. In particular, a 1% higher fraction of products in the stage of product innovation is related to a 0.26% higher likelihood of conducting seasoned equity offerings, paying out 1.15% lower amount of dividends, and a 0.46% lower chance of acquiring another firm within three years of the firm's IPO.

After the baseline findings, we undertake several tests to provide evidence that the above relationship is causal. First, our previous findings still hold when we add control variables related to corporate innovation measured by the number of patents and the number of citations per patent before IPO. Second, to alleviate the concern that the above relationship between product life-cycle and corporate decisions during and post IPO could be driven by unobservable firm characteristics, we perform an instrumental variable analysis with the average product life-cycle of similar public firms in the same year as the instrument for an IPO firm's product life-cycle. The results of the instrumental variable analysis suggest that the previous findings can be interpreted as causal.

Next, we explore potential underlying mechanisms for firms' product life-cycle at IPO to affect their corporate finance decisions. We first identify that the above results are much stronger for firms in industries with higher information asymmetry, estimated by the average analyst earnings forecast dispersion. Because firms with a higher fraction of products in an early stage of product innovation usually face higher information asymmetry and are eager for capital to fund their research and development, these firms are more likely to follow through their IPO filings and at the same time, willing to accept higher underpricing and keeping more equity to themselves as a signal to outside investors (Allen, Faulhaber, et al., 1989; Leland & Pyle, 1977). We also find that the above results are much stronger for firms in industries with higher market concentration, proxied by the industry average Herfindahl-Hirschman Index. Given that public incumbent firms enjoy higher oligopoly rents in a more concentrated market and IPO firms usually grab market shares after being public (Chemmanur & He, 2011), firms with a higher fraction of products in an early stage of innovation have larger incentive to go public both to raise capital and gain market shares and they are also willing to bear the cost of higher underpricing at IPO and offer a lower fraction of their equity. The results imply that both information asymmetry and product market competition can be potential underlying channels. To summarize, this paper provides evidence that the product life-cycle at IPO governs the benefits and the costs of the IPO, and therefore, it suggests that the incentives to go public differ depending on the product life-cycle of companies.

2 Related literature

Our paper contributes to several strands of literature. First, our findings contribute to the literature on the importance of a company's life-cycle in financial decision making. DeAngelo et al. (2006) argue that firms early in the life-cycle have ample investment opportunities and they retain all the funds because of their limited earned equity, while mature companies with fewer attractive investment opportunities and more internal capital pay out dividends. DeAngelo, DeAngelo, and Stulz (2010) conclude that life-cycle and firm's market-timing opportunities affect the decision of seasoned equity offering. Arikan and Stulz (2016) demonstrate that acquisition decisions follow a U-shape pattern over firms' life-cycle: the acquisition rate falls sharply after the IPO, stays relatively constant for a number of years, and then increases. We provide evidence that the product life-cycle influences also the IPO completion, underpricing, shares offering, and post-IPO corporate finance decisions.

Second, our paper speaks to the growing literature that implements textual analysis of companies' documents to explain firm investment policies. Using 10-K product descriptions, Hoberg and Maksimovic (2019) show that conditioning on the product life-cycle substantially improves the explanatory power of investment-Q models, while Chen, Hoberg, and Maksimovic (2020) reveal that the firm's and its rivals' disclosures are shaped by their exposure to their product life-cycle. Analyzing S-1 initial public offering prospectuses, Hanley and Hoberg (2010) decompose information into standard and informative components, and reveal that greater informative content, as a proxy for premarket due diligence, results in more accurate offer prices and less underpricing. Hanley and Hoberg (2012) suggest that issuers tradeoff underpricing and strategic disclosure as potential hedges against litigation risk. We analyze S-1 fillings and establish that companies differ in their product life-cycle when performing their IPO.

Third, our paper adds to the literature related to firms' decisions at IPO. Previous theoretical literature suggests that IPO firms face a trade-off between raising cheap capital from the public market and releasing confidential information to competitors (Maksimovic & Pichler, 2001) or the decreasing tolerance for failure of investors in the public market (Ferreira et al., 2014). Our paper provides empirical evidence regarding the IPO follow-through decision and shows that the above trade-off is more intense for IPO firms with more products in an early life-cycle.[2] In terms of IPO underpricing, previous theoretical studies have provided several types of explanations: asymmetric information, litigation, control theories, and behavioral theories (Ljungqvist, 2007). The strand of literature related to asymmetric information assumes one of the parties has information advantages and argues that IPO underpricing could be due to agency conflict between the issuer and underwriters (Baron, 1982), the signaling of high-quality issuers (Allen et al., 1989; Welch, 1989), compensation for information production or revelation of outside investors (Benveniste & Spindt, 1989; Chemmanur, 1993), or reward for the participation in IPO of uninformed investors (Rock, 1986). Our paper builds on this strand of literature and suggests that firms with more prod-

[2]There are other papers empirically examine the decision of going public (but not related to product life-cycle). Pagano, Panetta, and Zingales (1998) use data in Italy and find that the likelihood of going public is increasing in firm size and companies appear to go public not to finance future investments and growth, but to rebalance their accounts after high investment and growth. Chemmanur et al. (2010) use the Longitudinal Research Database and find that a private firm's product market characteristics, which include total factor productivity, size, sales growth, market share, industry competitiveness, capital intensity, and cash flow riskiness, significantly affect its likelihood of going public, which confirms the predictions from Bayar and Chemmanur (2011). Chemmanur and He (2011) provide theoretical and empirical analysis of the role of product market competition plays in the going public decision.

ucts in the innovative life-cycle experience more underpricing.[3] In addition, our paper is also related to the literature on IPO long-run performances and corporate finance decisions. The signaling models built by Welch (1989) and Allen et al. (1989) predict that firms with higher underpricing payout more dividend yields and they do more SEOs. Jegadeesh, Weinstein, and Welch (1993) empirically show that the likelihood of issuing seasoned equity is positively correlated with IPO underpricing. Our paper shows that firms with different product life-cycles at IPO distinguish themselves in seasoned equity offering, acquisitions, and dividend payout and suggests that the impact of product life-cycle on IPO cannot simply be explained by signaling models.

Overall, our paper is the first one in the literature to study the relationship between product life-cycle and corporate behaviors and performances at IPO and post IPO.

3 Data

3.1 Sample Selection

The data of this study are compiled from various sources. We gather readable S-1 filings from Security and Exchange Commission (SEC) Edgar database. S-1 is the initial registration form for companies to register new securities under the Securities Act of 1933. In this form, companies offering securities are required, under the regulation S-K item 101, to disclose a description of the company's properties and business, key products and services, material product research and development to be performed during the period covered in the plan, etc. We use S-1 filings to construct product life-cycle measures, following the same procedure as described in Section 3.2.1 to identify, extract, and parse firm product and business descriptions. We obtain other IPO information from SDC Platinum and only include IPOs

[3] Ritter and Welch (2002) and Ljungqvist (2007) provide literature reviews of empirical studies on IPO underpricing.

offered in U.S. exchanges. We match S-1 with requests for a withdrawal of a previously filed IPO (RW forms) for the analysis on withdrawn IPOs. We use SDC Platinum also for domestic acquisition data from January 1, 1994 to November 30, 2020, where the acquirer is a U.S. public firm. To measure IPO issuer's innovation capacity, we obtain patent data from the United States Patent and Trademark Office (USPTO). We collect the data on firms' seasonal equity offerings (SEO) and dividend payout after their IPO from Compustat. To test the potential underlying channels, we download the summary file of analyst earnings forecast from Institutional Brokers Estimate System (I/B/E/S) and the size of total assets of public firms from Compustat.

Following existing literature studying IPOs (Hanley & Hoberg, 2010; Loughran & Ritter, 2004; Ritter, 1991), we exclude firms in the financial or energy industries (with SIC code 6000-6900 or 4900-4999) and exclude real estate investment trusts (REITs), spin-offs, unit offerings, American depositary receipts (ADRs), and IPOs with an offering price lower than $5. Our sample period is from 1994 to 2018 (the sample starts when the S-1 filings are available electronically). Our main sample contains 3,297 unique firms filing IPOs, with 665 withdrawn IPOs.

3.2 Variable Construction

3.2.1 Measuring Product Life-Cycle

The finance literature has predominantly used the firm's age as a proxy for the life-cycle. Loderer et al. (2017) argue that firms become optimally more rigid as they age to focus on managing assets in place efficiently rather than on finding new growth opportunities. Arikan and Stulz (2016) show that acquisition activity follows a U-shaped pattern with respect to age. However, companies of the same age can diverge significantly in their life-cycle; some companies can be innovative and prosperous, while other companies with the same age can already face innovative and financial difficulties. Hence, these low dimensional constructs target one attribute (age) of a firm that evolves over the life-cycle, but they neglect other important features that define an individual life-phase.

Therefore, we adopt a recently developed methodology by Hoberg and Maksimovic (2019) to characterize the product life-cycle of each firm. This methodology performs textual analysis of the companies' financial statements. A key methodological contribution is that a company's life-status is determined by the description of the company's present business and products, and not by an attribute that moves mechanically (every company is one year older today than it was a year ago). Hence, the life-cycle reflects the current condition of the company. We implement the methodology on S-1 fillings. We specifically rely on the regulation S-K, item 101, which requires a company to describe the business, its products and services, and provide the explanation of material product research and development in the S-1 document.

In SEC Edgar database, we download S-1 documents from 1994 to 2018. We use textual queries to extract paragraphs from the documents that relate to one of the four states: product innovation (Life 1), process innovation (Life 2), stability and maturity (Life 3), and product discontinuation (Life 4). The textual queries are based on the lists of words specified in Hoberg and Maksimovic (2019) and listed in the Appendix A. These paragraphs discuss product research and development, results from operations, continuation and market share, obsolescence and product discontinuation. We diverge from the exact Hoberg and Maksimovic (2019) procedure in two points: first, we eliminate the names of cities in the documents starting with the word *new* (for example New York), second, we take into account paragraphs containing words 'research and development' and 'capital expenditures'. Appendix B offers an example of a paragraph in each of the four product life-cycle phases in Fitbit's S-1. First, we count the number of paragraphs appertaining to each of the four phases. Next, we divide each of the four numbers by the sum of the four counts. This procedure yields a four-element vector [Life1, Life2, Life3, Life4], summing up to unity, with each number representing the exposure to a particular life-cycle. For example, Fitbit with [0.36, 0.34, 0.23, 0.07] and Dole Foods with [0.11, 0.30, 0.16, 0.43], contain products in all the life-phases. The difference is that Fitbit is classified earlier in the life-stage because it weights more on the first stage compared to Dole Foods.

3.2.2 Construction of Dependent Variables and Control Variables

We construct several dependent variables related to the going public decision, the first-day IPO performance, and post-IPO corporate finance decisions. We first look at the relationship between product life-cycle and whether firms withdraw their IPO. We construct a dummy variable, *1(Effective_IPO)*, which equals one if a firm follows through its registration with the SEC to IPO and zero if it withdraws the registration. We then examine the fraction of equity offering at IPO, defined as shares offered at IPO divided by the total number of shares after the IPO. Lastly in our baseline specification, we consider IPO underpricing (*Underpricing*), defined as the first day's closing price minus the offering price and divided by the offering price.

We also examine the relationship between firms' product life-cycle at IPO and their later SEO, dividend payout, and acquisition decisions in the public market. We construct two variables to measure SEO, one dummy which equals one if a firm conducts an SEO within three years after its IPO (SEO_3yrs) and another dummy which equals one if a firm conducts an SEO within five years after its IPO (SEO_5yrs). The variables constructed to measure the dividend payout of a firm are: the natural logarithm of one plus the amount of total dividends paid out in millions within three years after the IPO (Div_3yrs) and five years after the IPO (Div_5yrs). We examine the acquisition decisions in one and three years after the IPO because newly public firms make acquisitions at a torrid pace (Celikyurt, Sevilir, & Shivdasani, 2010). We define (Acq_3yrs) as a dummy variable equal to one if a company acquires another firm within three years of its IPO, and (Acq_5yrs) as a dummy equal to one if a company acquires another firm within five years since its IPO.

To understand how innovation capacity plays a role in the relationship between an issuer's product life-cycle and its IPO underpricing, we construct variables using patent data from the USPTO. We define the variable *lnpat* as the natural logarithm of one plus the number of patents applied prior to a firm's IPO. We also construct another variable *lnciteperpat* as the natural logarithm of one plus the number of citations per patent for the above patents. Both the number of patents and the number of citations are adjusted for potential truncation bias following Hall, Jaffe, and Trajtenberg (2001).

We control for a number of factors in the regressions including the natural logarithm of the amount offering in the IPO (*lnamntoffer*), the natural logarithm of the age of a firm (*lnage*), whether a firm is VC-backed or not (*VC_back*), whether the IPO's underwriters have prestigious reputation (*underwriter_repu*), and Nasdaq two-month returns after a firm files for an IPO (*Nasdaq2MonthRet*). The information on the amount offering is collected from the SDC Platinum. We obtain the firms' age from SDC Platinum and Jay Ritter's website,[4] and we handcollect data for firms that remain with missing age. *VC_back* is a dummy which equals one if an IPO firm has VC-backing and the information on VC financing is collected from the VentureXpert data set and merged with our IPO sample using firm name and incorporation state. *underwriter_repu* is also a dummy which equals one if at least one of the IPO underwriters has been graded with a score of nine in a ranking from zero (least prestigious) to nine (most prestigious) from 1992 to 2015. We download the underwriter rankings from Jay Ritter's website. To control for the short-term market fluctuation which might affect the IPO completion decision (Bernstein, 2015), we control for the two-month NASDAQ returns from the date of the IPO filing ($Nasdaq2MonthRet$).

[4]The website that contains the IPO database of Jay Ritter is `https://site.warrington.ufl.edu/ritter/ipo-data/`.

3.3 Summary Statistics

Summary statistics are reported in Table 1. We winsorize all variables at the 1st and 99th percentiles in the regressions to alleviate the concern that the results may be driven by outliers. The sample firms on average have 30.5% of their products in the earliest life-cycle (*life1*), 37.5% of products belonging to the process-innovation stage (*life2*), 29.1% products in the stability and maturity phase (*life3*), while very small proportion of products (2.7%) in the discontinuation stage (*life4*).We note that most of the companies at the time of S-1 submission own products in all four product life-cycle stages. 80.4% of the IPOs in our sample complete their IPO successfully. The companies that follow through the IPO on average experience 27.3% of underpricing in the first trading day and they on average offer 28.9% of their total number of shares after the IPO.

[Insert Table 1 about Here]

Figure 1 displays the comparison between the average product life-cycle of IPO firms and public companies over the sample years.[5] IPO firms are more exposed to products in the innovation and maturity phase, while public companies load more on process innovation and product discontinuation stage.[6]

[Insert Figure 1 about Here]

Figure 2 plots the comparison between the average product life-cycle of effective and withdrawn IPO companies. Without taking into account industry and year effects, effective and withdrawn IPO companies exhibit similar product life-cycles in the entire sample.

[Insert Figure 2 about Here]

Figure 3 presents the average product life-cycle for firms in four sectors, drugs, medical instruments, and biotechnology (with three-digit SIC code 283 and 384 or four-digit SIC

[5] The average product life-cycle of public companies is calculated using the textual analysis described in Section 3.2.1 of 10-K financial statements following Hoberg and Maksimovic (2019).

[6] We note that Figure 1 and Figure 2 present the average percentages over the entire sample of companies and they do not take into consideration industry or year effects.

code 8731 and 8733), software (with three-digit SIC code 737), communications equipment (with three-digit SIC code 366), and restaurant (with three-digit SIC code 581). The average product life-cycles in the four sectors diverges significantly. While pharmaceutical and biotech companies are focused on developing new products, restaurants center on minimizing the costs, and the software industry focuses on existing clients with their regular updates and after-sale support. Moreover, companies in different sectors are subject to different shocks, which can impact the product life-cycle of the companies (e.g. changes in the regulation for data privacy in the software sector).

[Insert Figure 3 about Here]

4 Baseline Results

In this section, we examine how a firm's product life-cycle relates to its IPO withdrawal decision, the fraction of equity offering, and the underpricing at IPO. We also investigate how the product life-cycle at IPO is associated with seasoned equity offering (SEO), dividend payout, and acquisition decisions after IPO.

Specifically, we estimate the following models:

$$\begin{aligned} Y_{f,i,t} &= \alpha + \beta_1 life1_{f,i,t} + \Gamma X_{f,i,t} + \mu_t + \eta_i + \delta_{f,i,t} \\ Y_{f,i,t} &= \alpha + \beta_1 life1_{f,i,t} + \beta_3 life3_{f,i,t} + \beta_4 life4_{f,i,t} + \Gamma X_{f,i,t} + \mu_t + \eta_i + \delta_{f,i,t} \end{aligned} \quad (1)$$

where f stands for a firm in industry i that files its IPO in year t. The dependent variables are: a dummy for IPO completion (*1(IPO_Effective)*), the fraction of equity offering at IPO (*SharesOffered/SharesAfter*), IPO underpricing (*Underpricing*), dummies for post-IPO SEO activity (*SEO_3yrs* and *SEO_5yrs*), the amount of post-IPO dividend payouts (*Div_3yrs* and *Div_5yrs*), and dummies for post-IPO acquisition activity (*Acq_3yrs* and *Acq_5yrs*). The key variables of interest are the fractions of products in different product life-cycle stages: the stage of product innovation (*life1*), the stage of stability and maturity (*life3*), and the stage of product discontinuation (*life4*). In the first specification, we include only *life1* as the key left-hand side variable given that IPO firms have most of their products in $life1$ as shown in Figure 1. Hence, the coefficient estimate on this variable should be interpreted compared to other three product life-cycles combined. In the second specification, we include other two product life-cycle variables *life3* and *life4*, and we set the fraction of products in the stage of process innovation (*life2*) as the reference category in the regressions, to avoid the problem of multicollinearity. That is why the coefficient estimates on the product life-cycle variables in the second specification should be interpreted with respect to the process innovation phase and keeping other two product life-cycle variables constant. In both columns, we control for a vector of variables that might impact firms' IPO decision and performances suggested by previous literature (Bernstein, 2015; Carter & Manaster, 1990; Chambers & Dimson, 2009; Hoberg, 2003; Lee & Wahal, 2004; Loughran & Ritter, 2004). Particularly, we include the natural logarithm of the offering amount (*lnamntoffer*), the natural logarithm of the firm age at IPO (*lnage*), a dummy for VC-backing (*VC_back*), a dummy for prestigious underwriters (*underwriter_repu*), and the two-month Nasdaq returns after a firm files the IPO (*Nasdaq2MonthRet*). We include year and 2-digit primary SIC code fixed effects to account for time-specific shocks and time-invariant unobservable industry characteristics that may affect the relationship between product life-cycle and corporate finance decisions. We report standard errors robust to heteroskedasticity.

4.1 Product Life-Cycle and IPO Completion

We start by examining the relationship between product life-cycle and the decision of whether to proceed with the IPO or cancel the IPO filing. Specifically, we estimate equation (1) when the dependent variable is *1(Effective_IPO)*, a dummy which equals one if firm f follows through its IPO filing, and zero if it withdraws its IPO filing.

[Insert Table 2 about Here]

Results are presented in Table 2. In column (1), the variable of interest is *life1*. The magnitude of estimate on *life1* is 0.178 and statistically significant at 5% level, suggesting that when the fraction of products in the stage of product innovation increases one standard deviation compared to other product life-cycles, the likelihood of a firm to follow through with its IPO increases by 0.07 standard deviations. In column (2), we add *life3* and *life4*, and set *life2* as the reference category. The results are similar to those illustrated in column (1). The coefficient is positive and statistically significant at 5% significance level, suggesting that when firms have a higher fraction of products in the stage of product innovation, they are more likely to follow through its IPO filings (i.e., less likely to withdraw their IPO). The coefficient estimates on β_3 and β_4 are not statistically significant. The above results reflect the trade-off faced by firms with a higher fraction of products in the stage of product innovation (hereafter, a firm with younger product life-cycle): On the one hand, these firms need to raise cheap money from the public market (Hertzel & Smith, 1993) to fund the product innovation; on the other hand, these firms may leak product innovation information to the competitors when going public (Spiegel & Tookes, 2008) and they are secretive, consistent with the feature of inward-focused organic investment and the need for mitigating competitive threats (Chen et al., 2020). In our context, a firm with a younger product life-cycle has a higher cost disclosing its prospectus (or filing its IPO S-1) while at the same time a larger benefit of raising capital. Thus, when a firm has decided to disclose its prospectus, it is more likely to complete the IPO given the information has already been released to the public. We provide more evidence in the channel test related to product market competition as shown in section 6.2.

4.2 Product Life-Cycle and Fraction of Equity Offered at IPO

For firms that follow through their IPO, we examine the relationship between product life-cycle and the fraction of equity being offered at IPO. We estimate equation (1) and replace the dependent variable with *SharesOffered/SharesAfter*, which is defined as the number of shares offered at IPO divided by the total number of shares after IPO.

[Insert Table 3 about Here]

Table 3 shows the results. Column (1) includes only *life1* as the variable of interest and column (2) adds *life3* and *life4*. The coefficient estimates on *life1* are both negative and statistically significant at 1% significance level. The economic magnitude is also sizable: when a firm has a 1% higher fraction of products in the stage of product innovation at IPO, it on average offers 0.14% less equity at IPO. The coefficient estimate on *life3* is negative and the estimate on *life4* positive, although both of them are statistically insignificant.

One explanation for the above finding that a firm with a younger product life-cycle at IPO offers a lower fraction of equity is related to information asymmetry. Firms with a higher fraction of products still in the early stage of innovation are more obscure for outside investors to learn about their businesses, hence, insiders need to hold more equity to signal the quality of their firm when conducting IPO (Leland & Pyle, 1977). We test this conjecture of the channel of information asymmetry in section 6.1.

4.3 Product Life-Cycle and IPO Underpricing

For firms that go through the IPO process, we also examine how the firm's product life-cycle is associated with its IPO underpricing. Following the literature, we define the underpricing as the difference between the closing price and the opening price in the first trading day divided by the opening price in the first trading day.

[Insert Table 4 about Here]

Table 4 presents the results. When we include *life1* as the only product life-cycle as shown in column (1), the coefficient estimate on *life1* is significantly positive at 10% significance level and the coefficient estimate is 0.148. In column (2) where we add also maturity and product discontinuation phase to the regression, the coefficient estimate on *life1* is positive and significant at 5% level, suggesting that when a firm has 1% higher fraction of products in the product innovation compared to the process innovation stage, it on average experiences 0.18% higher underpricing. This finding confirms our conjecture that firms with higher fraction of products in the stage of product innovation have higher information asymmetry between the firm and the outside investors, and therefore, these firms need to offer higher compensation (i.e., higher underpricing) to investors purchasing shares at the IPO.

4.4 Product Life-Cycle and Post-IPO Corporate Finance Decisions

Previous studies have predicted the relationship between IPO underpricing and firms' future corporate finance decisions such as SEOs, dividend payouts, and acquisitions. The signaling theory specifically contends that firms with higher quality underprice the IPO to signal the favorable dividend yield in future (Allen et al., 1989) and these firms recoup the signaling cost by doing more SEOs (Welch, 1989). In this section, we examine the relationship between firms' product life-cycle at IPO and its SEO and dividend payout to see if product life-cycle can simply be interpreted as a way of signaling. We also present evidence that firms' incentive to acquire after IPO (Celikyurt et al., 2010) differs significantly by phases of product life-cycles.

[Insert Table 5 about Here]

Table 5 shows the results of the analysis on SEO. In columns (1) and (3), dependent variable is the dummy, *SEO_3yrs*, which equals one if a firm has conducted an SEO within three years since its IPO and zero otherwise. The dependent variable is replaced in columns (2) and (4) with *SEO_5yrs*, which equals one if a firm has conducted a SEO within five years since its IPO and zero otherwise. As in previous tables, we show estimation results with *life1* in the first two columns and add *life3* and *life4* in the last two columns. One can observe that in all four columns, the coefficient estimates on *life1* are all positive and statistically significant at 1% level. The magnitude of the estimates in columns (1) and (2) suggest that when a firm has a 1% higher fraction of products in the stage of product innovation at the time of its IPO, it on average experiences 0.31% higher likelihood to conduct an SEO within three years and a 0.32% higher likelihood to conduct an SEO within five years after its IPO. The coefficient estimates on *life3* are all negative, but statistically insignificant. Finally, the coefficient estimates on *life4* are all negative and statistically significant at 1% level. The results in Table 5 show that the likelihood of a firm conducting an SEO after its IPO is positively correlated with the fraction of its products in the youngest stage and negatively correlated with the fraction of its products in the later stages of the product life-cycle at the time of the IPO.

[Insert Table 6 about Here]

Table 6 presents the results of the analysis related to post-IPO dividend payout. In the first two columns, we include only IPO year and industry fixed effects. In the last two columns, we embed additional controls to the analysis. The dependent variable is the natural logarithm of one plus the total amount of dividend paid out in millions within three years after the IPO (Div_3yrs) in columns (1) and (3) and within five years after the IPO (Div_5yrs) in columns (2) and (4). The coefficient estimates on *life1* are negative and statistically significant at 1% level in all the columns, which reveals that when a firm has a higher fraction of products in the product innovation stage, it pays out significantly less dividends after the IPO.

[Insert Table 7 about Here]

Table 7 presents the analysis on firms' post-IPO acquisitions. The empirical specification is similar as in the previous tables and the dependent variable is a dummy which equals one if a company conducts at least one acquisition within three years after its IPO (Acq_3yrs) in columns (1) and (3) and within five years after the IPO (Acq_5yrs) in columns (2) and (4). The coefficient estimates on $life1$ are all negative and statistically significant at 1% significance level in all four columns, which suggests that firms with more products in the earliest life-cycle are less likely to acquire other firms after IPO. When we include $life3$ and $life4$ into the regressions as shown in columns (3) and (4), we observe that the coefficient estimates on $life3$ are significantly positive and negative but insignificant on $life4$. The result on $life3$ are consistent with Celikyurt et al. (2010) that firms with more mature products, which can generate stable cash flow, are more likely to conduct acquisition. However, the above estimates also show that not all firms, especially not the firms with a large fraction of products in the innovation stage, go public to acquire.

The above findings in Tables 5, 6, and 7 not only show the relationship between product life-cycle at IPO and post-IPO corporate finance decisions, but also suggest that product life-cycle at IPO may not be simply interpreted as a way for firms to signal, as the findings are not consistent with the predictions given by Allen et al. (1989) and Welch (1989).

5 Additional Tests

In the previous section, we established that a firm's product life-cycle is correlated with corporate finance decisions at and post IPO. However, there still exists the possibility that the product innovation phase encapsulates the same information provided by other innovation measures, nor did we exclude the potential endogeneity in our regressions. This section first demonstrates that product life-cycle measures capture different meaning as patent-based measures. We then use an instrumental variable approach and show the relationship between product life-cycle and decisions at and post IPO is causal.

5.1 Comparing Patent Measures and Product Life-Cycle Measures

Some may question if product life-cycle measures, especially the fraction of products in the phase of product innovation ($life1$), capture the same concept as other measures of innovation constructed using patent data.[7] Below we perform a test which includes both the patent-based measures and the interaction terms with the product life-cycle measure $life1$. If we observe that the coefficient estimate on $life1$ is still significant after including patent-based measures and the interaction terms, the results would suggest that the product life-cycle measure captures some aspect of corporate innovation that patent-based measures are not able to capture.

[Insert Table 8 about Here]

Table 8 presents the results of tests where we add patent-based measures to the baseline regressions as shown in equation (1). The dependent variables are *1(IPO_Effective)* in columns (1) and (2), *Underpricing* in columns (3) and (4), and *SharesOffered/SharesAfter* in columns (5) and (6). We include the natural logarithm of one plus the number of patents applied prior to a firm's IPO (*lnpat*) and its interaction term with the fraction of products in the first life-cycle ($life1$#*lnpat*) in columns (1), (3), and (5). We include the natural logarithm of one plus the number of citations per patent for the patents that firms applied prior to filing their IPO (*lnciteperpat*) and its interaction term with the fraction of products in the first life-cycle ($life1$#*lnciteperpat*) in columns (2), (4), and (6). We observe that in all columns, the coefficient estimates on $life1$ maintain the same signs as those in the baseline

[7]Many papers have used the number of patents or the number of patent citations to measure the quantity and quality of innovation, some examples include Seru (2014), Tian and Wang (2014), and Bernstein (2015).

regressions shown in Tables 2, 3, and 4 and they are all statistically significant at least at 5% significance level. Besides, the magnitude of the estimates on $life1$ only decreases a small fraction compared to that shown in the baseline results (e.g., when the dependent variable is *1(IPO_Effective)*, the magnitude is 0.176 and 0.178 in Table 8 columns (1) and (2) and is 0.181 Table 2 in column (2)). The above results support our hypothesis that product life-cycle measures capture some aspects that patent-based measure is unable to do, such as novel technologies and innovative business practices (Bellstam, Bhagat, & Cookson, 2020).

5.2 Instrumental Variable Analysis

Our goal is to identify the causal effect of product life-cycle on firms' financial decisions at and post its IPO. The remaining challenge is that some unobservable firm characteristics could drive the relationship between its product life-cycles and corporate finance decisions. For example, a firm that both has more products in the product innovation stage and follows through its IPO process could be due to the CEO's overconfidence (Galasso & Simcoe, 2011) or sensation-seeking (Sunder, Sunder, & Zhang, 2017). To alleviate this type of endogeneity concerns, we use the average product life-cycles of similar public firms as the instrument for a company's product life-cycle. Specifically, we define similar public companies as those within the same 4-digit SIC industry of the IPO firm.

For an instrument to be valid, it needs to satisfy both the relevance condition (it must be a strong predictor of an IPO company's product life-cycle) and the exclusion restriction (it should not affect the company's IPO through any channel other than the company's product life-cycle). We argue that the average product life-cycle of similar public companies to the IPO firm meets both requirements. First, the average product life-cycle is likely to satisfy the relevance condition because similar public companies usually share correlated product life-cycles to the IPO firm. In Figure 4, we compare the average product life-cycle of public firms and firms filing an IPO by sectors, specifically, we categorizing firms into high-tech versus low-tech industries and manufacturing versus non-manufacturing industries.[8] One can observe that even though the product life-cycles vary significantly across different sectors, the average product life-cycles are very similar between public firms and firms filing for an IPO. Later in this section, we will present the first-stage results of our IV analysis which show that the instrument indeed satisfies the relevance condition. The average product life-cycle of similar public firms is also likely to satisfy the exclusion restriction because it is not determined by the IPO firm's unobservable characteristics and is likely to affect an IPO firm's corporate finance decisions only through its product life-cycle.

[Insert Figure 4 about Here]

To implement the instrumental variable approach, we estimate the following first-stage regression:

$$\begin{aligned} Life1_{f,i,t} &= \alpha + \beta_1 SimiPublic\_life1_{i,t} + \beta_2 SimiPublic\_life3_{i,t} \\ &\qquad + \beta_3 SimiPublic\_life4_{i,t} + \gamma X_{f,i,t} + \mu_t + \eta_i + \epsilon_{f,i,t} \\ Life3_{f,i,t} &= \alpha + \beta_1 SimiPublic\_life1_{i,t} + \beta_2 SimiPublic\_life3_{i,t} \\ &\qquad + \beta_3 SimiPublic\_life4_{i,t} + \gamma X_{f,i,t} + \mu_t + \eta_i + \epsilon_{f,i,t} \\ Life4_{f,i,t} &= \alpha + \beta_1 SimiPublic\_life1_{i,t} + \beta_2 SimiPublic\_life3_{i,t} \\ &\qquad + \beta_3 SimiPublic\_life4_{i,t} + \gamma X_{f,i,t} + \mu_t + \eta_i + \epsilon_{f,i,t} \end{aligned} \tag{2}$$

where f stands for a firm in industry i that files its IPO in year t. The dependent variables in the three regressions are the three product life-cycle variables of the IPO firm: *life1*, *life3*, and *life4*. The main independent variables are: the average fraction of products of an IPO firm's similar public firms in the innovation phase ($SimiPublic\_life1$), in the mature stage ($SimiPublic\_life3$), and in the discontinuation phase ($SimiPublic\_life4$). Again,

[8] we define high-tech industries as drugs (3-digit SIC code 283), medical instruments (3-digit SIC code 384), office and computing equipment(3-digit SIC code 357), communications equipment (3-digit SIC code 366), electronic components (3-digit SIC code 367), scientific instruments (SIC 382), software (3-digit SIC code 737), and biotech (4-digit SIC code 8371 and 8373) following Brown, Fazzari, and Petersen (2009). The manufacturing industries are those with SIC code 2000 to 3999.

to avoid the problem of multicollinearity, we set the fraction of products in the stage of process innovation of similar public firms ($SimiPublic\_life2_{i,t}$) as the reference category in all four regressions. We include other control variables, $lnamntoffer$, $lnage$, VC_back, $underwriter\_repu$, and $Nasdaq2MonthRet$, which are defined in equation (1). We incorporate both the IPO year and 2-digit primary SIC code fixed effects. The standard errors are robust to heteroskedasticity.

In the second stage of the instrumental variable analysis, we estimate the following model:

$$Y_{f,i,T} = \alpha + \theta_1 life\hat{1}_{f,i,t} + \theta_2 life\hat{3}_{f,i,t} + \theta_3 life\hat{4}_{f,i,t} + \gamma X_{f,i,t} + \mu_t + \eta_i + \delta_{f,i,t} \tag{3}$$

The dependent variables remain the same as in the baseline regressions: a dummy for IPO completion (*1(IPO_Effective)*), fraction of equity offering at IPO (*SharesOffered/SharesAfter*), IPO underpricing (*Underpricing*), dummies for SEO within three or five years after IPO (*SEO_3yrs* and *SEO_5yrs*), the natural logarithm of the amount of post-IPO dividend payouts (*Div_3yrs* and *Div_5yrs*), and dummies for post-IPO acquisition activity (*Acq_3yrs* and *Acq_5yrs*). The key variables of interest are the predicted values from the first stage: $li\hat{f}e1$, $li\hat{f}e3$, and $li\hat{f}e4$.

Table 9 reports the results of instrumental variable analysis with the IPO follow-through dummy as the main outcome variable. The first three columns of Tables 9 report the first stage of the analysis, where the dependent variables are the endogenous variables, $life1$, $life3$, and $life4$ and the instruments are $SimiPublic\_life1$, $SimiPublic\_life3$, and $SimiPublic\_life4$ with other control variables. We observe that all of the coefficient estimates on the instruments, $SimiPublic\_life1$, $SimiPublic\_life3$, and $SimiPublic\_life4$, are positive and at least one of these coefficient estimates is significant at a 1% significance level, suggesting that the average product life-cycle measures of similar firms are positively correlated with the IPO firms' product life-cycle measures thus satisfying the relevance restriction necessary for a valid instrument. We report the Sanderson-Windmeijer F-statistics as a diagnostic for weak identification (Sanderson & Windmeijer, 2016), given that we have multiple endogenous variables and instruments in the estimation.[9] The Sanderson-Windmeijer F-statistics take values of 256.46, 87.70, and 10.96 in columns (1) to (3), respectively, with a p-value equal or less than 0.001. The Sanderson-Windmeijer F-statistics suggest that we can reject the null-hypothesis that our first-stage regressions suffer from weak identification at a 0.1% significance level. Column (4) in Table 9 shows the result of the second-stage analysis when the dependent variable is *1(IPO_Effective)*, which equals one if a company follows through its IPO filing and zero if it withdraws the IPO. The coefficient estimate on the predicted value of the endogenous variable, $li\hat{f}e1$, in the last column captures the causal effect of the IPO firm's product innovation stage on the decision to follow through the IPO. The coefficient is both positive and statistically significant at 5% level, indicating that when companies have a higher fraction of products in the stage of product innovation, they are significantly more likely to follow through with their IPO. This result corresponds to our finding in the baseline regressions shown in Table 2.

[Insert Table 9 about Here]

Table 10 repeats the instrumental analysis with the replacement of the dependent variable in the second stage with the fraction of equity offered at IPO (*SharesOffered/SharesAfter*). The results of the first-stage analysis are shown in columns (1) to (3). One can observe that the instruments and the endogenous variables are highly correlated and the analysis passes the weak identification test. Column (4) shows the second-stage estimation in which the coefficient estimate on $li\hat{f}e1$ is both negative and statistically significant at 10% level. Therefore, the results of the instrumental analysis continue to support the finding in Table 3 that firms with a younger product life-cycle at IPO offer lower fraction of equity. The coefficients are

[9] Kleibergen-Paap rk Wald statistic would be used when there is a single endogenous regressor and when standard errors are not i.i.d.

not the same across the tables due to different number of observations in each table.

[Insert Table 10 about Here]

Table 11 adopts the same specification with IPO underpricing as the dependent variable. The coefficient on $li\hat{f}e1$ in the last column is positive and highly statistically significant, corroborating the findings from Table 4 that firms with higher fraction of products in the product innovation stage offer higher compensation to purchase shares at the IPO.

[Insert Table 11 about Here]

Table 12 focuses on post-IPO corporate finance decisions. The first-three columns present the results of first-stage regressions. Columns (4) and (5) show the coefficient estimates when the dependent variable is the dummy, *SEO_3yrs* or *SEO_5yrs*, respectively. Coefficients on $li\hat{f}e1$ are positive and statistically significant at 5% level, further substantiating our baseline findings that the likelihood of a firm conducting an SEO is positively correlated with the fraction of the company's products in the youngest product life-cycle stage. In columns (6) and (7), the dependent variables are related to dividend payout, *Div_3yrs* and *Div_5yrs*, respectively. We observe that the coefficient on $li\hat{f}e1$ is negative and statistically significant at 10% and 5% level, showing that the negative relation between the product innovation phase and dividends is robust under the IV setting. Finally, columns (8) and (9) display the second-stage results when the dependent variable is the acquisition dummy, *Acq_3yrs* or *Acq_5yrs*, respectively. The coefficient on $li\hat{f}e1$ is negative and statistically significant at 1% level in both columns, demonstrating that the negative relation between the product innovation phase and post-IPO acquisitions persists also in the IV setting.

[Insert Table 12 about Here]

Overall, the instrumental variable approach helps us rule out potential endogeneity concerns about our baseline results, supporting the causal interpretation of our findings regarding the relationship between the product life-cycle of an IPO firm and its corporate finance decisions during and post IPO.

6 Potential Underlying Channels

Having established the relationship between IPO firms' product life-cycle and its corporate finance decisions at and post IPO, we next explore the potential underlying channels. Specifically, we test information asymmetry and product market competition as two possible mechanisms.

6.1 Information Asymmetry as a Potential Channel

As discussed before, firms with a higher fraction of products in an earlier product life-cycle may have higher information asymmetry. As these firms usually need more external funding to finance their product innovation, they would be more likely to follow through their IPO filings. At the same time, to successfully complete the IPO, these firms need to pay a higher cost of underpricing at IPO to signal their quality (Allen et al., 1989) or use the underpricing to attract outside investors to engage in information production (Chemmanur, 1993). Furthermore, insiders need to hold higher fraction of equity to signal their quality (Leland & Pyle, 1977). If information asymmetry indeed is an underlying channel of how product life-cycle affects firms' corporate finance decisions during and after IPO, we expect our baseline results to be stronger in industries with higher information asymmetry.

[Insert Table 14 about Here]

Table 14 shows the results of testing information asymmetry as a potential underlying channel. Using data from the Institutional Brokers Estimate System, we calculate the average analysts' earnings forecast dispersion for each 2-digit SIC industry each year and use it as a measure of information asymmetry (Leuz, 2003). We then categorize our sample IPO firms into two groups every year based on the average forecast dispersion of their primary industry. We run the same regressions as specified in equation (1). Columns (1), (3), and (5) show the results on a sample where firms in industries with relatively low analyst forecast dispersion (i.e., low information asymmetry) are included, and columns (2), (4), and (6) present the results on a sample where firms in industries with relatively high information asymmetry are included. The dependent variable is $1(IPO\_Effective)$ in columns (1) and (2). We observe that the coefficient estimates on $life1$ in these two columns are both positive, which is consistent with our previous findings. The coefficient estimate in column (2) is statistically significant at 1% level in the sample with relatively high information asymmetry, but insignificant for the sample with low information asymmetry as shown in column (1). The magnitude of estimate in column (2) is also five times larger than the one in column (1). When examining the effects on IPO underpricing and the fraction of equity offered at IPO, we observe similar patterns: The signs of the coefficient estimates on $life1$ are consistent with those in the baseline results; the coefficient estimates are statistically significant in the sample with relatively high information asymmetry but insignificant in the sample with relatively low information asymmetry; and the magnitude of coefficient estimates on $life1$ is larger in the high-information-asymmetry sample than that in the low-information-asymmetry sample.

6.2 Product Market Competition as a Potential Channel

Going public is expected to increase an IPO firm's market share (Chemmanur & He, 2011; Chemmanur et al., 2010; Chod & Lyandres, 2011), while at the same time obtain cheaper financing compared to remaining private (Hertzel & Smith, 1993). However, going public may leak information to a firm's competitors to copy their product innovation (Spiegel & Tookes, 2008). Therefore, we conjecture that product market competition might be a potential underlying channel. We expect our previous finding to be more significant in industries with higher market concentration. IPO firms will attract more attention from their public rivals because these public incumbent firms enjoy larger oligopoly rents in these markets and fear more about losing market shares to the IPO firms. In other words, the cost of disclosing the prospectus for IPO firms is higher in markets with higher concentration. Therefore, once a firm facing high market concentration with more products in the phase of product innovation files an IPO, it is more likely to follow through its IPO, willing to accept higher underpricing to go public, and offering lower fraction of equity.

[Insert Table 13 about Here]

Table 13 presents the results of testing product market competition as a potential underlying channel. Following the previous literature, we use the asset of public firms to calculate the Herfindahl-Hirschman Index (HHI) for each 2-digit SIC industry and divide our sample IPO firms into two groups every year based on the HHI of their primary industry. The empirical specification is the same as the baseline regressions. Columns (1), (3), and (5) show the results of the observations whose market concentration is relatively low and columns (2), (4), and (6) present the results of the observations whose market concentration is relatively high. The dependent variable in columns (1) and (2) is $1(IPO\_Effective)$. We observe that the coefficient estimates on $life1$ in these two columns are both positive, which is consistent with our previous findings. The coefficient estimate in column (2) is statistically significant at 1% level in the sample with high market concentration, but insignificant for the sample with low market concentration as shown in column (1). The magnitude of estimate in column (2) is also five times larger than the one in column (1). When examining the effects on IPO underpricing and the fraction of equity offered at IPO, we observe similar patterns: The signs of the coefficient estimates on $life1$ are consistent with those in the baseline results; the coefficient estimates are statistically significant in the sample with relatively high market concentration but insignificant in the sample with relatively low market concentration; and the magnitude of coefficient estimates on $life1$ is larger in the high-market-concentration sample than that in the low-market-concentration sample.

Overall, we provide supportive evidence that information asymmetry and product market competition can be two possible underlying channels for how product life-cycle of a firm affects its corporate finance decisions during and after its IPO.

7 Conclusion

This paper shows that product life-cycles of companies that file IPO diverge significantly, which affects companies' decisions and performance during and post IPO. We measure the product life-cycle using textual analysis of companies' S-1 filings, and we categorize products into four stages: product innovation, process innovation, stability, and product discontinuation. We note that most of the companies at the time of S-1 submission possess products in all four product life-cycle stages. However, companies that own more products in the product innovation phase are more likely to follow through the IPO, even if they face higher underpricing and offer a lower fraction of equity. Moreover, these firms conduct less seasoned equity offerings, pay lower dividends, and conduct fewer acquisitions after the IPO. Using the instrumental variable approach, we show that the above relationship is causal. The channel tests suggest that both information asymmetry and product market competition play a role in how product life-cycles affect corporate finance decisions at and post IPO. Our paper provides evidence that the trade-off of going public varies for firms exposed to different product life-cycles.

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Figures and Tables

Figure 1. IPO product life-cycle vs public company product life-cycle
The figure shows the difference between average product life-cycle between IPO firms and public companies. life1 is the fraction of the products in the product innovation stage, life2 is the fraction of products in the process innovation stage, life3 is the fraction of products in the maturity phase, and life4 is the fraction of products in the product discontinuation stage. Section 3.2.2 provides the description of variable construction.

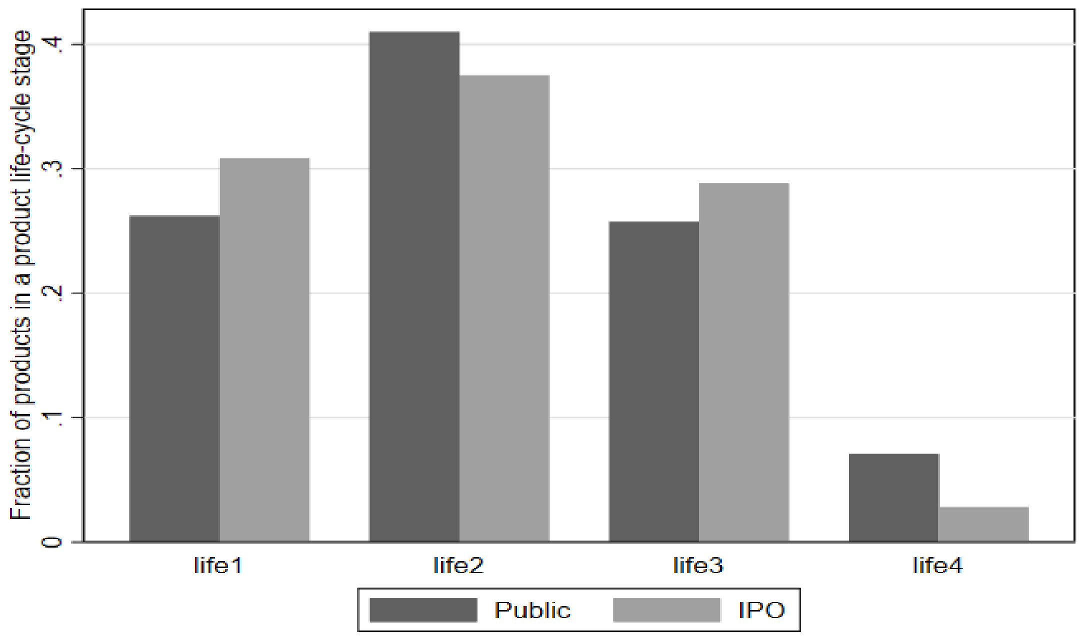


Figure 2. Successful IPO product life-cycle vs withdrawn IPO product life-cycle
The figure shows the difference between average product life-cycle between IPO firms and firms that withdrew their IPO filings. life1 is the fraction of the products in the product innovation stage, life2 is the fraction of products in the process innovation stage, life3 is the fraction of products in the maturity phase, and life4 is the fraction of products in the product discontinuation stage. Section 3.2.2 provides the description of variable construction.

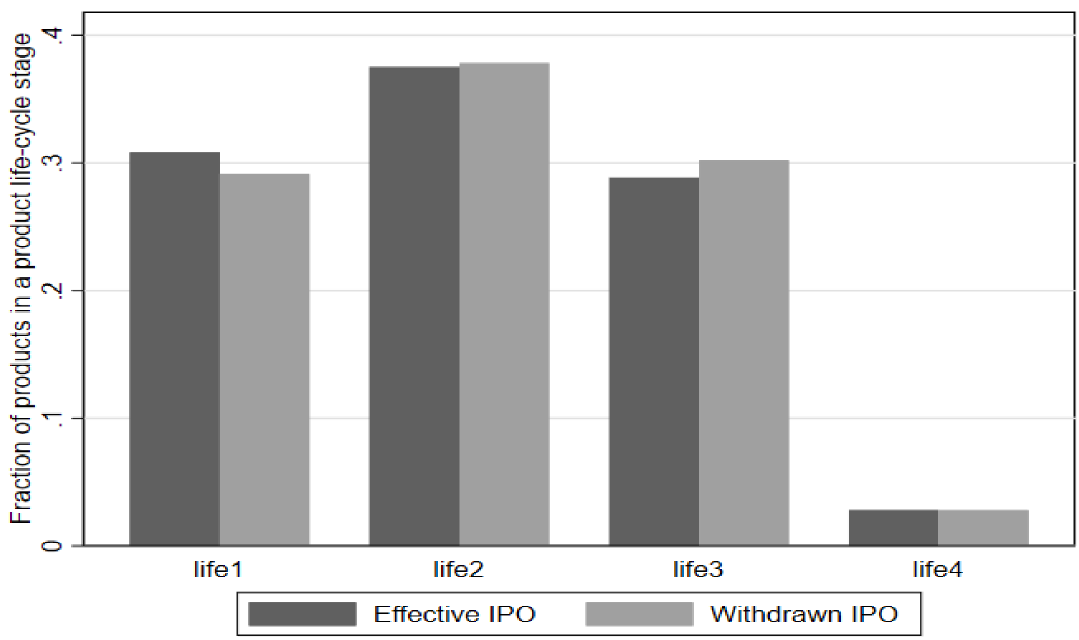


Figure 3. Product Life-Cycle at IPO by Sectors
The figure shows the difference between average product life-cycle between four sectors: drugs, software, communications equipment, and restaurants. Red bar is the fraction of the products in the product innovation stage, blue bar is the fraction of products in the process innovation stage, green bar is the fraction of products in the maturity phase, and yellow bar is the fraction of products in the product discontinuation stage. Section 3.2.2 provides the description of variable construction.

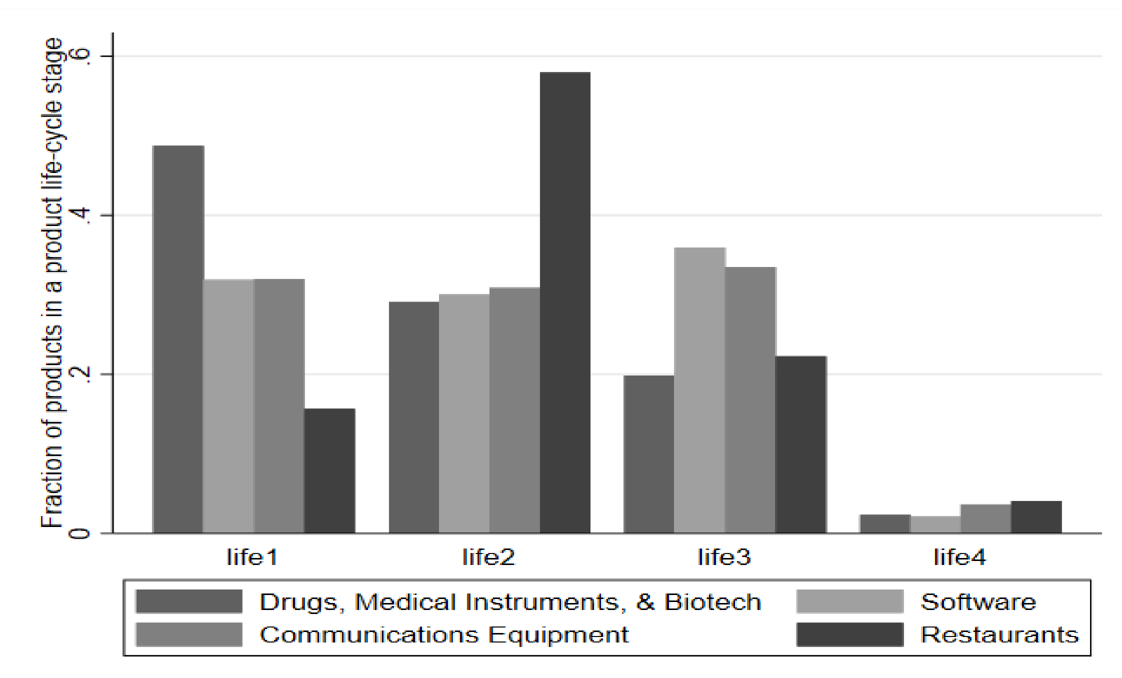
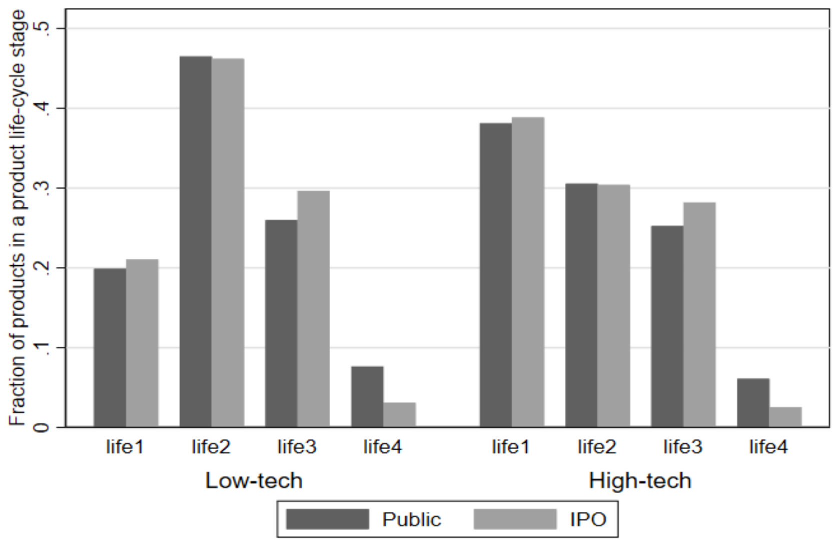


Figure 4. Comparing Product Life-Cycles of Public vs. IPO firms by Sector
The figure comparing the average product Life-Cycle of public and firms filing for an IPO of different sectors. The upper panel of the figure shows the comparison of public and IPO firms in low-tech and high-tech industries. Following Brown et al. (2009), we define high-tech industries as drugs (SIC 283), medical instruments (SIC 384), office and computing equipment(SIC 357), communications equipment (SIC 366), electronic components (SIC 367), scientific instruments (SIC 382), software (SIC 737), and biotech (SIC 8371 and 8373). The lower panel of the figure shows the comparison of public and IPO firms in manufacturing and non-manufacturing industries. life1 is the fraction of the products in the product innovation stage, life2 is the fraction of products in the process innovation stage, life3 is the fraction of products in the maturity phase, and life4 is the fraction of products in the product discontinuation stage. Section 3.2.2 provides the description of variable construction.



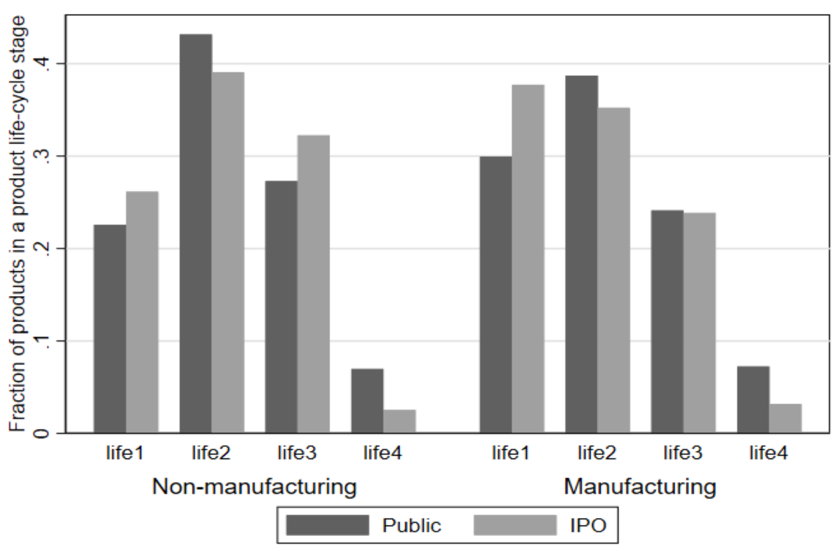


Table 1. Summary Statistics

This table displays the summary statistics for the variables used in this study. Definition of the variables and their sources are introduced in section 3.

	N	mean	sd	min	p50	max
life1	3,297	0.305	0.149	0.045	0.289	0.670
life2	3,297	0.375	0.151	0.148	0.341	0.848
life3	3,297	0.291	0.116	0.049	0.287	0.591
life4	3,297	0.027	0.038	0.000	0.016	0.223
1(IPO_Effective)	3,297	0.804	0.397	0.000	1.000	1.000
Underprcing	2,577	0.273	0.500	-0.234	0.112	2.828
SharesOffered/SharesAfter	2,408	0.289	0.169	0.048	0.255	1.000
SEO_3yrs	2,651	0.307	0.462	0.000	0.000	1.000
SEO_5yrs	2,651	0.341	0.474	0.000	0.000	1.000
Div_3yrs	2,651	0.800	1.497	0.000	0.000	6.075
Div_5yr	2,651	0.906	1.615	0.000	0.000	6.410
Acq_3yrs	2,651	0.506	0.500	0.000	1.000	1.000
Acq_5yrs	2,651	0.564	0.496	0.000	1.000	1.000
lnpat	3,297	0.134	0.371	0.000	0.000	1.994
lnciteperpat	3,297	0.007	0.023	0.000	0.000	0.153
lnamntoffer	3,297	4.277	0.885	1.792	4.317	6.620
lnage	3,297	2.109	0.956	0.000	2.079	4.595
VC_back	3,297	0.559	0.497	0.000	1.000	1.000
underwriter_repu	3,297	0.521	0.500	0.000	1.000	1.000
NasdaqRet2Month	3,297	0.017	0.102	-0.384	0.030	0.419

Table 2. Product Life-Cycle and IPO Follow-through

This table examines the relationship between product life-cycle and the decision to follow through with the IPO. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The dependent variable is *1(Effective_IPO)*, a dummy which equals one if a firm follows through its IPO filing, and zero if it withdraws its IPO filing. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)* is the natural logarithm of the amount offering in the IPO, *ln(age)* refers to the natural logarithm of the age of a firm, *VC_back* is defined as a dummy variable equal to one if a firm is VC-backed and zero otherwise, *underwriter_repu* is a dummy variable if the IPO's underwriters have prestigious reputation and zero otherwise, *Nasdaq2MonthRet* represents the two-month Nasdaq cumulative return after a firm files an IPO. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1) *1(IPO_Effective)*	(2) *1(IPO_Effective)*
life1	0.178**	0.181**
	(0.069)	(0.074)
life3		0.044
		(0.081)
life4		-0.220
		(0.189)
lnamntoffer	0.044***	0.045***
	(0.010)	(0.010)
lnage	0.009	0.009
	(0.008)	(0.008)
VC_back	-0.033**	-0.035**
	(0.017)	(0.017)
underwriter_repu	0.014	0.013
	(0.016)	(0.016)
NasdaqRet2Month	0.467***	0.465***
	(0.078)	(0.078)
Constant	1.025***	1.046***
	(0.094)	(0.093)
Observations	3,297	3,297
R-squared	0.126	0.127
IPO Year	Controlled	Controlled
Industry	Controlled	Controlled

Table 3. Product Life-Cycle and Fraction of Equity Offered at IPO

This table examines the relationship between product life-cycle and the fraction of equity being offered at IPO. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The dependent variable is *SharesOffered/SharesAfter*, defined as the the number of shares offered at IPO divided by the total number of shares after IPO. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)* is the natural logarithm of the amount offering in the IPO, *ln(age)* refers to the natural logarithm of the age of a firm, *VC_back* is defined as a dummy variable equal to one if a firm is VC-backed and zero otherwise, *underwriter_repu* is a dummy variable if the IPO's underwriters have prestigious reputation and zero otherwise, *Nasdaq2MonthRet* represents the two-month Nasdaq cumulative return after a firm files an IPO. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects.The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1) *SharesOffered/SharesAfter*	(2) *SharesOffered/SharesAfter*
life1	-0.143***	-0.147***
	(0.031)	(0.034)
life3		-0.016
		(0.041)
life4		0.014
		(0.107)
lnamntoffer	0.010*	0.010*
	(0.006)	(0.006)
lnage	0.006	0.006
	(0.004)	(0.004)
VC_back	-0.017**	-0.016**
	(0.007)	(0.008)
underwriter_repu	-0.060***	-0.060***
	(0.007)	(0.007)
NasdaqRet2Month	0.067**	0.068**
	(0.032)	(0.032)
Constant	0.344***	0.346***
	(0.082)	(0.084)
Observations	2,408	2,408
R-squared	0.225	0.225
IPO Year	Controlled	Controlled
Industry	Controlled	Controlled

Table 4. Product Life-Cycle and IPO Underpricing

This table examines the relationship between product life-cycle and IPO underpricing. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The dependent variable is *Underpricing*, defined as the difference between the closing price and the opening price in the first trading day divided by the opening price in the first trading day. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)* is the natural logarithm of the amount offering in the IPO, *ln(age)* refers to the natural logarithm of the age of a firm, *VC_back* is defined as a dummy variable equal to one if a firm is VC-backed and zero otherwise, *underwriter_repu* is a dummy variable if the IPO's underwriters have prestigious reputation and zero otherwise, *Nasdaq2MonthRet* represents the two-month Nasdaq cumulative return after a firm files an IPO. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1) *Underpricing*	(2) *Underpricing*
life1	0.148*	0.182**
	(0.082)	(0.085)
life3		0.133
		(0.101)
life4		-0.119
		(0.163)
lnamntoffer	-0.026**	-0.025**
	(0.012)	(0.012)
lnage	-0.034***	-0.034***
	(0.009)	(0.009)
VC_back	0.125***	0.121***
	(0.020)	(0.020)
underwriter_repu	0.127***	0.126***
	(0.022)	(0.022)
NasdaqRet2Month	0.523***	0.522***
	(0.136)	(0.137)
Constant	0.124*	0.111
	(0.070)	(0.080)
Observations	2,577	2,577
R-squared	0.271	0.272
IPO Year	Controlled	Controlled
Industry	Controlled	Controlled

Table 5. Product Life-Cycle and Seasonal Equity Offerings

This table examines the relationship between product life-cycle at IPO and SEO. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The dependent variable in Columns 1 and 3 (2 and 4) is *SEO_3yrs* (*SEO_5yrs*), a dummy variable equal to one if a firm conducts an SEO within three (five) years since its IPO an zero otherwise. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)* is the natural logarithm of the amount offering in the IPO, *ln(age)* refers to the natural logarithm of the age of a firm, *VC_back* is defined as a dummy variable equal to one if a firm is VC-backed and zero otherwise, *underwriter_repu* is a dummy variable if the IPO's underwriters have prestigious reputation and zero otherwise, *Nasdaq2MonthRet* represents the two-month Nasdaq cumulative return after a firm files an IPO. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1) *SEO_3yrs*	(2) *SEO_5yrs*	(3) *SEO_3yrs*	(4) *SEO_5yrs*
life1	0.313***	0.318***	0.261***	0.265***
	(0.090)	(0.092)	(0.096)	(0.098)
life3			-0.052	-0.045
			(0.105)	(0.107)
life4			-0.847***	-0.922***
			(0.222)	(0.227)
lnamntoffer	0.007	0.002	0.007	0.002
	(0.013)	(0.013)	(0.013)	(0.013)
lnage	0.001	0.001	0.003	0.003
	(0.010)	(0.010)	(0.010)	(0.010)
VC_back	0.036*	0.028	0.033	0.024
	(0.022)	(0.022)	(0.022)	(0.022)
underwriter_repu	-0.044**	-0.054**	-0.044**	-0.054**
	(0.021)	(0.022)	(0.021)	(0.022)
NasdaqRet2Month	-0.121	-0.134	-0.126	-0.140
	(0.095)	(0.098)	(0.095)	(0.098)
Constant	0.624*	0.597*	0.753***	0.734***
	(0.319)	(0.309)	(0.278)	(0.264)
Observations	2,651	2,651	2,651	2,651
R-squared	0.116	0.127	0.120	0.131
IPO Year	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled

Table 6. Product Life-Cycle and Dividend Payout

This table examines the relationship between product life-cycle at IPO and post-IPO dividend payout. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The dependent variable in Columns 1 and 3 (2 and 4) is *Div_3years* (*Div_5years*), defined as the natural logarithm of one plus the total amount of dividend paid out in millions within three (five) years after the IPO. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)* is the natural logarithm of the amount offering in the IPO, *ln(age)* refers to the natural logarithm of the age of a firm, *VC_back* is defined as a dummy variable equal to one if a firm is VC-backed and zero otherwise, *underwriter_repu* is a dummy variable if the IPO's underwriters have prestigious reputation and zero otherwise, *Nasdaq2MonthRet* represents the two-month Nasdaq cumulative return after a firm files an IPO. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1) *Div_3yrs*	(2) *Div_5yrs*	(3) *Div_3yrs*	(4) *Div_5yrs*
life1	-1.147***	-1.249***	-1.156***	-1.246***
	(0.272)	(0.293)	(0.303)	(0.326)
life3			-0.205	-0.178
			(0.338)	(0.361)
life4			1.175	1.273
			(0.927)	(0.988)
lnamntoffer	0.363***	0.404***	0.360***	0.401***
	(0.045)	(0.048)	(0.045)	(0.048)
lnage	-0.015	-0.014	-0.017	-0.016
	(0.036)	(0.039)	(0.036)	(0.039)
VC_back	-0.467***	-0.522***	-0.456***	-0.511***
	(0.057)	(0.062)	(0.058)	(0.063)
underwriter_repu	0.049	0.067	0.050	0.068
	(0.061)	(0.065)	(0.061)	(0.065)
NasdaqRet2Month	-0.605**	-0.787**	-0.598**	-0.779**
	(0.296)	(0.314)	(0.296)	(0.314)
Constant	0.244	0.206	0.125	0.068
	(0.812)	(0.735)	(0.769)	(0.696)
Observations	2,651	2,651	2,651	2,651
R-squared	0.265	0.271	0.266	0.272
IPO Year	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled

Table 7. Product Life-Cycle and Post-IPO Acquisitions

This table examines the relationship between product life-cycle at IPO and SEO. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The dependent variable in Columns 1 and 3 (2 and 4) is *Acq_3yrs* (*Acq_5yrs*), a dummy variable equal to one if a firm conducts an acquisition within three (five) years since its IPO an zero otherwise. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)* is the natural logarithm of the amount offering in the IPO, *ln(age)* refers to the natural logarithm of the age of a firm, *VC_back* is defined as a dummy variable equal to one if a firm is VC-backed and zero otherwise, *underwriter_repu* is a dummy variable if the IPO's underwriters have prestigious reputation and zero otherwise, *Nasdaq2MonthRet* represents the two-month Nasdaq cumulative return after a firm files an IPO. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1) *Acq_3yrs*	(2) *Acq_5yrs*	(3) *Acq_3yrs*	(4) *Acq_5yrs*
life1	-0.508***	-0.481***	-0.461***	-0.423***
	(0.092)	(0.092)	(0.099)	(0.099)
life3			0.206*	0.219**
			(0.110)	(0.109)
life4			-0.314	-0.157
			(0.249)	(0.243)
lnamntoffer	0.043***	0.040***	0.045***	0.042***
	(0.014)	(0.014)	(0.014)	(0.014)
lnage	0.006	0.017*	0.006	0.016*
	(0.010)	(0.010)	(0.010)	(0.010)
VC_back	-0.033	-0.023	-0.040*	-0.029
	(0.022)	(0.022)	(0.022)	(0.022)
underwriter_repu	0.018	0.011	0.018	0.010
	(0.021)	(0.021)	(0.021)	(0.021)
NasdaqRet2Month	-0.059	-0.037	-0.062	-0.038
	(0.104)	(0.103)	(0.104)	(0.103)
Constant	1.105***	0.947***	1.103***	0.921***
	(0.125)	(0.170)	(0.126)	(0.165)
Observations	2,651	2,651	2,651	2,651
R-squared	0.203	0.191	0.205	0.193
IPO Year	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled

Table 8. Product Life-Cycle, Innovation Capacity, and IPO Underpricing

This table displays the difference between product life-cycle and patents. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The dependent variable in Column 1 and 2 is *IPO_Effective*, defined in Table 2; in Column 3 and 4 is *Underpricing*, defined in Table 4 and in Column 5 and 6 is *SharesOffered/SharesAfter*, defined in Table **??**. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)* is the natural logarithm of the amount offering in the IPO, *ln(age)* refers to the natural logarithm of the age of a firm, *VC_back* is defined as a dummy variable equal to one if a firm is VC-backed and zero otherwise, *underwriter_repu* is a dummy variable if the IPO's underwriters have prestigious reputation and zero otherwise, *Nasdaq2MonthRet* represents the two-month Nasdaq cumulative return after a firm files an IPO. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	1(IPO_Effective)		*Underpricing*		*SharesOffered/SharesAfter*	
life1	0.176**	0.178**	0.223**	0.196**	-0.147***	-0.143***
	(0.075)	(0.076)	(0.087)	(0.085)	(0.035)	(0.035)
life3	0.048	0.035	0.115	0.113	-0.019	-0.013
	(0.082)	(0.081)	(0.101)	(0.102)	(0.041)	(0.041)
life4	-0.215	-0.223	-0.111	-0.121	0.008	0.016
	(0.190)	(0.189)	(0.164)	(0.164)	(0.107)	(0.107)
lnpat	0.041		0.130**		-0.031*	
	(0.055)		(0.058)		(0.018)	
lnciteperpat		1.606		3.118*		-0.692**
		(1.218)		(1.684)		(0.321)
life1#lnpat	-0.027		-0.359***		0.033	
	(0.139)		(0.119)		(0.042)	
life1#lnciteperpat		-2.699		-6.682		0.932
		(3.366)		(4.251)		(0.856)
Controls	Yes	Yes	Yes	Yes		
Observations	3,297	3,297	2,577	2,577	2,408	2,408
R-squared	0.127	0.128	0.273	0.274	0.226	0.227
IPO Year	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled

Table 9. IV Analysis: Product Life-Cycle and IPO Follow-through

This table reports the instrumental variable (IV) regression results of the decision to follow through with the IPO on the product life-cycle. The instruments *SimiPublic_life1*, *SimiPublic_life3*, and *SimiPublic_life4* are described in Section 5.2. The first three columns show the first stage regression results, regressing product life-cycle variables *life1*, *life3*, and *life4* on the instruments, other controls, and year and industry fixed effects as in Equation 2. The last column shows the second stage regression results from Equation 3 with the dependent variable *1(Effective_IPO)*, a dummy which equals one if a firm follows through its IPO filing, and zero if it withdraws its IPO filing. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. *ln(amntoffer)*, *ln(age)*, *VC_back*, *underwriter_repu*, *Nasdaq2MonthRet* are defined in Section 3.2.2. The continuous control variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The last row of the table reports the Sanderson-Windmeijer F-statistics for weak identification test with the p-val in parentheses. Standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
		1st-stage		2nd-stage
	life1	*life3*	*life4*	*1(IPO_Effective)*
SimiPublic_life1	0.602***	0.110***	0.015	
	(0.037)	(0.033)	(0.013)	
SimiPublic_life3	0.124***	0.623***	0.012	
	(0.044)	(0.047)	(0.019)	
SimiPublic_life4	0.141**	0.265***	0.140***	
	(0.071)	(0.073)	(0.040)	
$\hat{life}1$				0.454**
				(0.226)
$\hat{life}3$				0.190
				(0.296)
$\hat{life}4$				-2.100
				(2.371)
lnamntoffer	-0.021***	-0.001	0.002*	0.055***
	(0.003)	(0.003)	(0.001)	(0.014)
lnage	-0.002	0.000	0.002*	0.013
	(0.002)	(0.002)	(0.001)	(0.011)
VC_back	0.023***	0.006	-0.007***	-0.064**
	(0.005)	(0.004)	(0.002)	(0.028)
underwriter_repu	0.006	-0.000	-0.002	0.015
	(0.004)	(0.004)	(0.002)	(0.019)
NasdaqRet2Month	-0.056***	-0.007	-0.000	0.428***
	(0.020)	(0.019)	(0.007)	(0.093)
Constant	0.181***	0.056**	0.047***	0.891***
	(0.024)	(0.022)	(0.015)	(0.144)
Observations	2,640	2,640	2,640	2,640
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
SW F-stat (p-val)	256.46 (0.000)	87.70 (0.000)	10.96 (0.001)	-

Table 10. IV Analysis: Product Life-Cycle and Fraction of Equity Offered at IPO

This table reports the instrumental variable (IV) regression results of the fraction of equity offered at the IPO on the product life-cycle. The instruments *SimiPublic_life1*, *SimiPublic_life3*, and *SimiPublic_life4* are described in Section 5.2. The first three columns show the first stage regression results, regressing product life-cycle variables *life1*, *life3*, and *life4* on the instruments, other controls, and year and industry fixed effects as in Equation 2. The last column shows the second stage regression results from Equation 3 with the dependent variable *SharesOffered/SharesAfter*, defined as the the number of shares offered at IPO divided by the total number of shares after IPO. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. *ln(amntoffer)*, *ln(age)*, *VC_back*, *underwriter_repu*, *Nasdaq2MonthRet* are defined in Section 3.2.2. The continuous control variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The last row of the table reports the Sanderson-Windmeijer F-statistics for weak identification test with the p-val in parentheses. Standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	1st-stage			2nd-stage
	life1	*life3*	*life4*	*SharesOffered/SharesAfter*
SimiPublic_life1	0.596***	0.074*	0.029	
	(0.046)	(0.040)	(0.017)	
SimiPublic_life3	0.148**	0.542***	0.017	
	(0.060)	(0.055)	(0.027)	
SimiPublic_life4	0.166**	0.321***	0.155***	
	(0.082)	(0.085)	(0.045)	
$li\hat{f}e1$				-0.207*
				(0.117)
$li\hat{f}e3$				0.019
				(0.199)
$li\hat{f}e4$				0.475
				(1.091)
lnamntoffer	-0.018***	-0.000	0.002	0.000
	(0.003)	(0.003)	(0.002)	(0.007)
lnage	-0.001	0.000	0.001	0.009*
	(0.003)	(0.002)	(0.001)	(0.005)
VC_back	0.028***	0.005	-0.010***	-0.005
	(0.006)	(0.005)	(0.002)	(0.016)
underwriter_repu	0.008	-0.000	-0.002	-0.059***
	(0.005)	(0.005)	(0.002)	(0.008)
NasdaqRet2Month	-0.065**	0.003	-0.008	0.071*
	(0.025)	(0.024)	(0.009)	(0.038)
Constant	0.172***	0.043*	0.049***	0.243***
	(0.029)	(0.023)	(0.017)	(0.085)
Observations	1,941	1,941	1,941	1,941
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
SW F-stat (p-val)	86.59 (0.000)	36.45 (0.000)	8.71 (0.003)	-

Table 11. IV Analysis: Product Life-Cycle and IPO Underpricing
This table reports the instrumental variable (IV) regression results of IPO underpricing on the product life-cycle. The instruments *SimiPublic_life1*, *SimiPublic_life3*, and *SimiPublic_life4* are described in Section 5.2. The first three columns show the first stage regression results, regressing product life-cycle variables *life1*, *life3*, and *life4* on the instruments, other controls, and year and industry fixed effects as in Equation 2. The last column shows the second stage regression results from Equation 3 with the dependent variable *Underpricing*, defined as the difference between the closing price and the opening price in the first trading day divided by the opening price in the first trading day. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. *ln(amntoffer)*, *ln(age)*, *VC_back*, *underwriter_repu*, *Nasdaq2MonthRet* are defined in Section 3.2.2. The continuous control variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The last row of the table reports the Sanderson-Windmeijer F-statistics for weak identification test with the p-val in parentheses. Standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
		1st-stage		2nd-stage
	life1	*life3*	*life4*	*Underpricing*
SimiPublic_life1	0.620***	0.104***	0.020	
	(0.043)	(0.039)	(0.015)	
SimiPublic_life3	0.142***	0.626***	0.019	
	(0.052)	(0.055)	(0.023)	
SimiPublic_life4	0.206**	0.334***	0.150***	
	(0.082)	(0.086)	(0.044)	
$li\hat{f}e1$				0.723***
				(0.267)
$li\hat{f}e3$				0.287
				(0.329)
$li\hat{f}e4$				2.863
				(2.204)
lnamntoffer	-0.019***	-0.002	0.002	-0.011
	(0.003)	(0.003)	(0.002)	(0.017)
lnage	-0.001	0.000	0.002	-0.048***
	(0.002)	(0.002)	(0.001)	(0.011)
VC_back	0.023***	0.010**	-0.008***	0.129***
	(0.005)	(0.005)	(0.002)	(0.032)
underwriter_repu	0.009*	-0.000	-0.002	0.134***
	(0.005)	(0.005)	(0.002)	(0.025)
NasdaqRet2Month	-0.048**	-0.001	-0.006	0.692***
	(0.024)	(0.023)	(0.009)	(0.159)
Constant	0.175***	0.042*	0.052***	-0.247
	(0.026)	(0.023)	(0.017)	(0.156)
Observations	2,064	2,064	2,064	2,064
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
SW F-stat (p-val)	164.90 (0.000)	46.56 (0.000)	8.99 (0.002)	-

Table 12. IV Analysis: Product Life-Cycle and Post-IPO Corporate Finance Decisions

This table reports the instrumental variable (IV) regression results of post-IPO corporate finance decisions on the product life-cycle. The instruments *SimiPublic_life1*, *SimiPublic_life3*, and *SimiPublic_life4* are described in Section 5.2. The first three columns show the first stage regression results, regressing product life-cycle variables *life1*, *life3*, and *life4* on the instruments, other controls, and year and industry fixed effects as in Equation 2. Columns (4) to (9) show the second stage regression results from Equation 3. The dependent variables in columns (4) and (5) are *SEO_3yrs* and *SEO_5yrs*, two dummy variables equal to one if a firm conducts an SEO within three and five years since its IPO an zero otherwise. The dependent variables in columns (6) and (7) are *Div_3years* and *Div_5years*, defined as the natural logarithm of one plus the total amount of dividend paid out in millions within three and five years after the IPO. The dependent variables in columns (8) and (9) are *Acq_3yrs* and *Acq_5yrs*, dummy variables which equal to one if a firm conducts an acquisition within three or five years since its IPO an zero otherwise. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. *ln(amntoffer)*, *ln(age)*, *VC_back*, *underwriter_repu*, *Nasdaq2MonthRet* are defined in Section 3.2.2. The continuous control variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects. The last row of the table reports the Sanderson-Windmeijer F-statistics for weak identification test with the p-val in parentheses. Standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1st-stage			2nd-stage					
	life1	*life3*	*life4*	*SEO_3yrs*	*SEO_5yrs*	*Div_3yrs*	*Div_5yrs*	*Acq_3yrs*	*Acq_5yrs*
SimiPublic_life1	0.602***	0.102***	0.025						
	(0.042)	(0.038)	(0.016)						
SimiPublic_life3	0.150***	0.620***	0.021						
	(0.051)	(0.054)	(0.023)						
SimiPublic_life4	0.205**	0.316***	0.153***						
	(0.080)	(0.084)	(0.043)						
life1				0.760**	0.818**	-1.768*	-2.153**	-1.053***	-0.957***
				(0.313)	(0.322)	(0.946)	(1.024)	(0.325)	(0.329)
life3				0.351	0.358	-1.392	-1.758	0.581	0.655
				(0.392)	(0.402)	(1.418)	(1.515)	(0.414)	(0.423)
life4				-4.062	-4.165	-1.623	1.169	1.341	2.782
				(2.677)	(2.763)	(9.417)	(10.466)	(2.935)	(2.946)
lnamntoffer	-0.018***	-0.002	0.002	0.030*	0.024	0.294***	0.321***	0.028	0.021
	(0.003)	(0.003)	(0.002)	(0.018)	(0.018)	(0.056)	(0.061)	(0.019)	(0.019)
lnage	-0.001	0.000	0.001	0.007	0.003	0.015	0.011	0.005	0.011
	(0.002)	(0.002)	(0.001)	(0.013)	(0.013)	(0.045)	(0.048)	(0.013)	(0.012)
VC_back	0.025***	0.009*	-0.008***	-0.011	-0.028	-0.394***	-0.405***	-0.011	0.010
	(0.005)	(0.005)	(0.002)	(0.038)	(0.039)	(0.111)	(0.124)	(0.040)	(0.041)
underwriter_repu	0.007	0.001	-0.002	-0.030	-0.041	0.042	0.078	0.027	0.015
	(0.005)	(0.004)	(0.002)	(0.025)	(0.025)	(0.067)	(0.072)	(0.025)	(0.025)
NasdaqRet2Month	-0.055**	0.002	-0.003	-0.105	-0.120	-0.586*	-0.820**	-0.235*	-0.216*
	(0.023)	(0.022)	(0.009)	(0.115)	(0.118)	(0.317)	(0.339)	(0.120)	(0.120)
Constant	0.171***	0.047**	0.052***	0.241	0.243	-1.385**	-1.592**	0.632***	0.599***
	(0.025)	(0.022)	(0.016)	(0.189)	(0.193)	(0.583)	(0.668)	(0.194)	(0.199)
Observations	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SW F-stat (p-val)	113.40 (0.000)	46.18 (0.000)	9.28 (0.002)	-	-	-	-	-	-

Table 13. Potential Channel: Product Market Competition

This table examines product market competition as an underlying channel of how product life-cycle affects firms' corporate finance decisions during IPO. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The product market competition measure is defined as the Herfindahl-Hirchman Index (HHI) for each 2-digit SIC industry. The sample of IPO firms is categorized into Low and High group based on the HHI of firms' primary industries. The dependent variable in columns 1 and 2 is *IPO_Effective*, in columns 3 and 4 *Underpricing*, and in columns 5 and 6 *SharesOffered/SharesAfter*, defined as in Table 2, 4, and 3 respectively. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)*, *ln(age)*, *VC_back*, *underwriter_repu*, and *Nasdaq2MonthRet* are defined in the previous tables. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects.The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Market Concentration	**Low**	**High**	**Low**	**High**	**Low**	**High**
	1(IPO_Effective)		*Underpricing*		*SharesOffered/SharesAfter*	
life1	0.052	0.310***	0.124	0.213*	-0.138***	-0.144**
	(0.101)	(0.113)	(0.116)	(0.126)	(0.042)	(0.057)
life3	-0.042	0.111	0.169	0.074	0.044	-0.086
	(0.113)	(0.118)	(0.155)	(0.132)	(0.052)	(0.062)
life4	-0.347	-0.067	-0.512	0.114	0.198	-0.071
	(0.330)	(0.233)	(0.318)	(0.184)	(0.159)	(0.144)
lnamntoffer	0.041***	0.047***	-0.054**	-0.008	0.007	0.014*
	(0.015)	(0.014)	(0.021)	(0.015)	(0.008)	(0.008)
lnage	0.017	0.002	-0.048***	-0.025**	0.010	0.002
	(0.013)	(0.011)	(0.016)	(0.011)	(0.007)	(0.006)
VC_back	0.011	-0.075***	0.085***	0.159***	-0.021**	-0.016
	(0.023)	(0.025)	(0.030)	(0.027)	(0.010)	(0.012)
underwriter_repu	-0.007	0.029	0.184***	0.071**	-0.056***	-0.061***
	(0.022)	(0.024)	(0.030)	(0.032)	(0.009)	(0.012)
NasdaqRet2Month	0.342***	0.587***	0.244	0.809***	0.066*	0.062
	(0.112)	(0.109)	(0.204)	(0.171)	(0.039)	(0.051)
Constant	0.633***	1.028***	0.288	-0.070	0.280***	0.430***
	(0.139)	(0.119)	(0.237)	(0.086)	(0.096)	(0.110)
Observations	1,626	1,668	1,296	1,279	1,222	1,184
R-squared	0.110	0.166	0.265	0.312	0.171	0.285
IPO Year	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled

Table 14. Potential Channel: Information Asymmetry

This table examines the the information asymmetry as an underlying channel of how product life-cycle affects firms' corporate finance decisions during IPO. The IPO sample includes IPOs from 1994 to 2018. The detailed description of the sample is provided in Section 3. The information asymmetry measure is defined as the average analysts' earnings forecast dispersion for each 2-digit SIC industry. The sample of IPO firms is categorized into Low and High group based on the average forecast dispersion of a firms' primary industries. The dependent variable in columns 1 and 2 is *IPO_Effective*, in columns 3 and 4 *Underpricing*, and in columns 5 and 6 *SharesOffered/SharesAfter*, defined as in Table 2, 4, and 3 respectively. *life1*, *life2*, *life3*, and *life4* are the product life-cycle variables described in Section 3.2.1. *ln(amntoffer)*, *ln(age)*, *VC_back*, *underwriter_repu*, and *Nasdaq2MonthRet* are defined in the previous tables. The continuous independent variables are winsorized at 1% and 99% levels. All specifications include year and industry fixed effects.The standard errors are robust to heteroskedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Information Asymmetry	**Low**	**High**	**Low**	**High**	**Low**	**High**
	1(IPO_Effective)		*Underpricing*		*SharesOffered/SharesAfter*	
life1	0.059	0.272***	0.169	0.218*	-0.130**	-0.166***
	(0.109)	(0.102)	(0.137)	(0.112)	(0.056)	(0.045)
life3	-0.027	0.031	0.153	0.122	-0.100*	0.080
	(0.114)	(0.114)	(0.160)	(0.140)	(0.060)	(0.056)
life4	-0.062	-0.356	-0.135	-0.110	-0.104	0.183
	(0.235)	(0.332)	(0.226)	(0.251)	(0.133)	(0.187)
lnamntoffer	0.036**	0.038**	-0.031*	-0.017	0.010	0.010
	(0.014)	(0.015)	(0.017)	(0.018)	(0.007)	(0.009)
lnage	0.014	0.005	-0.031**	-0.039***	0.009	-0.002
	(0.011)	(0.012)	(0.012)	(0.014)	(0.006)	(0.006)
VC_back	-0.024	-0.027	0.157***	0.088***	-0.016	-0.022*
	(0.023)	(0.024)	(0.029)	(0.030)	(0.010)	(0.012)
underwriter_repu	0.017	0.008	0.132***	0.121***	-0.066***	-0.054***
	(0.023)	(0.023)	(0.032)	(0.030)	(0.011)	(0.010)
NasdaqRet2Month	0.238**	0.726***	0.549**	0.494***	0.100**	0.059
	(0.114)	(0.100)	(0.220)	(0.173)	(0.043)	(0.049)
Constant	1.160***	0.940***	0.050	0.062	0.319***	0.281***
	(0.104)	(0.101)	(0.108)	(0.111)	(0.090)	(0.089)
Observations	1,627	1,660	1,300	1,270	1,204	1,197
R-squared	0.156	0.174	0.279	0.278	0.306	0.200
IPO Year	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled

A Appendix A

Similar to Hoberg and Maksimovic (2019), we measure the firm product life-cycle vector based on all paragraphs in S-1 that contain at least one word from each of the following two lists.

Life1 List A: product OR products OR service OR services

Life1 List B: development OR launch OR launches OR introduce OR introduction OR introductions OR new OR introducing OR innovation OR innovations OR expansion OR expanding OR expand

Life2 List A: cost OR costs OR expense OR expenses

Life2 List B: labor OR employee OR employees OR wage OR wages OR salary OR salaries OR inventories OR inventory OR warehouse OR warehouses OR warehousing OR transportation OR shipping OR freight OR materials OR overhead OR administrative OR manufacturing OR manufacture OR production OR equipment OR facilities OR

Life4 List A: product OR products OR service OR services OR inventory OR inventories OR operation OR operations

Life4 List B: obsolete OR obsolescence OR discontinued OR discontinue OR discontinuance OR discontinuation OR discontinues OR discontinuing

To measure Life3 weight, we require three word lists. A firm's S-1 must contain at least one word from List A and List B, and must not contain any words from the List C.

Life3 List A: product OR products OR service OR services

Life3 List B: line OR lines OR offerings OR mix OR existing OR portfolio OR current OR categories OR category OR continue OR group OR groups OR customer OR customers OR core OR consists OR continues OR provide OR providing OR provided OR providers OR includes OR continued OR consist

Life3 List C(exclusions): development OR launch OR launches OR introduce OR introduction OR introductions OR new OR introducing OR innovation OR innovations OR expansion OR expanding OR expand OR future OR obsolete OR obsolescence OR discontinued OR discontinue OR discontinuance OR discontinuation OR discontinues OR discontinuing OR cost OR costs OR expense OR expenses

B Appendix B

An example of Fitbit's S-1 paragraphs appertaining to the four product life-cycles:

Life 1: Continue to introduce innovative products. We will continue to develop the world's most innovative and diverse connected health and fitness devices. Furthermore, we plan to continue to make significant investments in research and development to further strengthen our platform through both internally-developed and acquired technologies. In 2013 and 2014, we introduced five new connected health and fitness devices and added features including automatic sleep detection, heart rate tracking, call and text notifications, music control, and GPS tracking for speed, distance, and exercise routes.

Life2: Research and development expenses increased $26.3 million, or 94%, from $27.9 million for 2013 to $54.2 million for 2014. The increase was primarily due to a $13.9 million increase in personnel-related expenses due to a 110% increase in headcount, a $12.9 million increase in consultant and contractor expenses, and a $3.6 million increase in allocated overhead, which was partially offset by a decrease in expenses for tooling and prototype materials of $4.2 million.

Life3: We rely on a limited number of suppliers, contract manufacturers, and logistics providers, and each of our products is manufactured by a single contract manufacturer.

Life4: The increase in net change in operating assets and liabilities was primarily due to a $77.9 million increase in accounts payable and accrued liabilities and other liabilities related to growth of expenditures to support general business growth, and a $72.7 million increase in Fitbit Force recall liabilities, partially offset by a $55.6 million increase in accounts receivable due to increased sales in the fourth quarter of 2013 as a result of increased product demand, and a $47.4 million increase in inventories driven by higher levels of inventory to support demand. Non-cash adjustments primarily consisted of provisions for inventory obsolescence related to the Fitbit Force recall and the revaluation of the redeemable convertible preferred stock warrant liability. Our days sales outstanding in accounts receivable decreased from 73 days as of December 31, 2012 to 69 days as of December 31, 2013 due to stronger collections in the fourth quarter of 2013 compared to the fourth quarter of 2012.