Zooming In or Zooming Out:
Entrants' Product Usage Breadth in the Nascent Drone Industry

Anavir Shermon
University of North Carolina
anavir_shermon@kenan-flagler.unc.edu

Mahka Moeen
University of North Carolina
mahka_moeen@kenan-flagler.unc.edu

Abstract: Faced with demand uncertainty in a nascent industry, entrants need to strategically consider which customer segments to serve, and what specialized product features can address customers' preferences. While high product usage breadth implies addressing preferences of a wide range of customers, low product usage breadth indicates inclusion of market-specific features that are specialized to particular customers. We suggest that when entrants have experience in contexts that are potential users of a new product, their products are likely to exhibit low usage breadth. The relationship is moderated by whether they are startups or diversifying entrants, and the cumulative number of customers that adopted the industry's product before the time of each entrant's product introduction. The empirical context is the U.S. commercial drone industry.

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INTRODUCTION

Entrants into a nascent industry often need to navigate pervasive technological and demand uncertainties that characterize early industry stages (Abernathy & Utterback, 1978; Mitchell, 1989; Rosenberg, 1982). In addition to advancing the technological landscape, entrants' commercial success often hinges on offering products that align with potential customers' preferences. However, early on, demand uncertainty implies that entrants lack complete knowledge about which customer groups will find the industry's products attractive, and which customers' functional and price preferences will prevail (Agarwal & Bayus, 2002). In part, this can arise from customers' lack of awareness about their own precise preferences, given that they have not had the chance to interact with a novel product (von Hippel, 1986). As various customer groups start engaging with a product, each customer segment may also exhibit diverging explicit and latent preferences (Adner & Levinthal, 2001). Faced with uncertainty and heterogeneity in demand, a crucial element of entry strategy pertains to what customer segments to serve, and what specialized product features can address customers' preferences.

This study seeks to unpack the pre-entry drivers of an entrant's product usage breadth, which is the extent to which a product can be used in different applications. On the one end of the spectrum, products with low usage breadth cater to the preferences of a particular segment of customers and include market-specific features that are chiefly valued by that segment. The other end of the spectrum represents products with high usage breadth that straddle across segments and offer acceptable features for multiple customer segments. Demand uncertainty makes assessing product usage breadth challenging, because entrants can neither always ascertain how the size and value of different segments will grow or shrink, nor foresee how potential customers will evaluate and react to product features.

In this study, we suggest that pre-entry experience is a key factor in explaining an entrant's product usage breadth. Prior to entry into a nascent industry, entrants may accumulate experience due to firm-level operations in other industries (Ganco & Agarwal, 2009; Benner & Tripsas, 2012; Helfat, 1997) or founder-level background (Campbell et al., 2012; Gambardella, Ganco & Honoré, 2014). When this experience comes from contexts in which the product of a nascent industry can fulfill potential customers' needs, entrants can draw on their pre-entry "use experience." Previous studies about user entrepreneurs (Adams, Fontana & Malerba, 2015; Shah & Tripsas, 2007) or user diversifying entrants (Roy & Sarkar, 2016) have documented the relevance of use experience for commercial activity.

Our central argument is that pre-entry use experience is negatively related to an entrant's product usage breadth. Two mechanisms underpin this relationship. First, pre-entry use experience situates an entrant in particular demand-oriented and user contexts that shape its interpretation of the nascent industry according to that particular segment (Baldwin, Hienerth & von Hippel, 2006; Shah & Tripsas, 2007). Second, pre-entry use experience privileges entrants with a deep market-specific knowledge of price and functional preferences in customer segments from which they come from (Chatterji & Fabrizio, 2012; Gambardella, Raasch & von Hippel, 2017). Thus, pre-entry use experience is associated with offering products that primarily target a limited customer segment and have low usage breadth. We also suggest that this relationship is moderated by the distinction between diversifying and startup entrants, and the cumulative number of customers that have adopted the industry's product.

The empirical context is the U.S. commercial unmanned aerial vehicle or drone manufacturing industry between 2014 and 2016. In its nascency, the industry has been characterized by considerable demand uncertainty. Although drones are being used in as many as 30 market applications such as aerial videography, agricultural surveying, infrastructure inspection, mapping, and parcel delivery (PwC, 2016), there is limited consensus about what uses will endure and to what extent drones can be applied within them. Indeed, many diversifying and entrepreneurial entrants come with experience in demand contexts that could potentially use drones such as commercial filming, agriculture, security and investigative services, land management, energy and utilities, and geo-surveying. The heterogeneity across applications and pre-entry experiences has resulted in entrants' strategic considerations about matching product features to the emerging and varying needs of these segments, thereby making the commercial drone manufacturing industry appropriate to study the pre-entry drivers of entrants' product usage breadth under demand uncertainty.

The theoretical contributions are at the intersection of entry strategies into nascent industries and pre-entry heterogeneity literatures. First, we examine product usage breadth as a key complementary aspect that entrants consider as part of their overall entry strategy. In particular, we highlight the complexities associated with product usage breadth under demand uncertainty and heterogeneity. Second, the study elaborates on how entrants with prior use experience can navigate an uncertain nascent industry, as they draw on the unique cognitive frames and capabilities gained in the user contexts from which they emerge. Third, we point to use experience as a source of demand knowledge within diversifying entrants. The study separates between the well-documented demand knowledge gained by producers interacting with customers versus the demand knowledge of user firms. The final contribution relates to how users' introduction of products with market-specific features can become a testing ground for revealing customers' preferences and reducing demand uncertainty.

THEORETICAL BACKGROUND

Review: Entry Strategies for Uncertain Nascent Industries

Regardless of whether nascent industries emerge from discontinuous technological changes or unmet user needs, technological and demand uncertainties abound in their early stages (Agarwal, Moeen & Shah, 2017). These uncertainties have made two aspects of entry strategy of interest to strategy and technology scholars: timing of entry and the choice between competing technical designs. First, confronted with uncertainty about the commercial and technological viability of an industry, timing of entry may turn consequential. Early entry may be driven by the possibility of shaping an industry's path and staking a strong position (Lieberman & Montgomery, 1988), conditional on access to the needed capabilities (Mitchell, 1991). Though, in the presence of exogenous uncertainties that may reduce over time, exercising the option to wait may be attractive (Folta & O'Brien, 2004).

Second, in industries that initially undergo an era of ferment with several variations of technical designs and then possibly converge into a dominant technical design (Anderson & Tushman, 1990), the choice between competing technical designs is consequential. Initially, the variation in designs arises from heterogeneity in entrants, as the technical design of products often reflect entrants' prior cognitive frames (Benner & Tripsas, 2012; Garud & Rappa, 1994) or capability portfolios (Kapoor & Furr, 2015; Martin & Mitchell, 1998). The emergence of a dominant design often brings about higher survival chances for entrants offering that particular design (Christensen, Suárez & Utterback, 1998; Schilling, 1998). Other entrants failing to switch to the dominant design often risk lower performance.

Although these streams have offered insights about a firm's entry strategy into a nascent industry, one understudied aspect relates to how entrants' products can address functional and price preferences of heterogenous customer segments evolving under demand uncertainty.

Demand Uncertainty and Product Usage Breadth

Attending to different customers' preferences as part of a firm's entry strategy is important in light of demand uncertainties, which are a hallmark of nascent industries. In general, the demand environment denotes potential customers' attributes, including: the needs that a product fulfils for them, the criteria that they use to evaluate a product, and the maximum price that they are willing to pay. Demand uncertainty in mature industries often relates to fluctuations in the size of each customer segment at each price point. However, in nascent industries, extreme incomplete demand knowledge gives rise to additional demand uncertainty about the customer segments that will find the product beneficial and the functional attributes that they favor.

At the center of this uncertainty is the stylized fact that customers' understanding of their needs and preferences is tied to their direct interactions with a product (von Hippel, 1986). Thus, even if novel products are described with analogies (Bingham & Kahl, 2013) or embedded in familiar forms (Rindova & Petkova, 2007), it is hard for customers to ex-ante articulate their precise expectations (Christensen & Bower, 1996). Further, the initial primitive nature of novel products and their system-wide interdependence typically make it difficult for inventors to foresee the full range of needs that a product may ultimately fulfill (Rosenberg, 1982). Over time, as new entrants offer products with varied functionalities, new customer segments may find them useful (Adner & Levinthal, 2001; Agarwal & Bayus, 2002). In parallel, as lead users engage with a product, they may identify new needs that it can satisfy (Gambardella et al., 2017). Although these processes and feedback loops between firms and customers gradually expand the customer segments served by a new product, it typically takes time before all segments, their size, and their differential performance criteria become known and stable.[1]

A few examples are illustrative of this environment. After the development of laser technology in the 1960s at Hughes Laboratories, the customer segments in which lasers could be used gradually expanded to industrial processes, telecommunications, medical imaging, dermatology, and optical disk reading (Conti, Gambardella & Novelli, 2019). Because each customer segment preferred lasers with different power and light emission wavelengths, manufacturers needed to customize features of laser systems for these different needs. However, initially, entrants and customers could not accurately forecast the direction of each segment (Klepper, 2016). Similar uncertain growth and shrinkage in customer segments are documented in other contexts, such as semiconductors with uses in consumer electronics, telecommunications, computation, and storage (Adams et al., 2015), or the Internet with uses in military communications, academia, and electronic commerce (Greenstein, 2015).

It is in this uncertain and heterogeneous demand environment that usage breadth, defined as the

[1] A prominent marketing typology assigns customers into groups of early adopters, majority adopters, and laggards (Rogers, 1995). The basis for this typology is the times at which customers adopt a product. Our definition of customer segments focuses on an orthogonal dimension that identifies heterogenous customers based on their different needs and preferences.

extent to which a product can be used across different usages and applications, becomes a meaningful aspect of a firm's entry strategy. In this definition, low usage breadth implies that by incorporating specialized components, design configurations, add-on features, or customer service, products are tailored to the preferences of specific customer segments. In contrast, high usage breadth corresponds to generic products that are acceptable to several customer segments.

In a mature industry, the assessment of economic costs and benefits for product usage breadth often considers the trade-off between the size of the customer segment versus profit margin per unit sold. While low usage breadth generates profit from a smaller number of customers, the associated product features may lead to higher profit per unit sold. However, high usage breadth can potentially gain a larger market share, though with smaller profit margin. The assumption is that despite generic products lacking market-specific features, there are customers who purchase them due to lower prices, preference to use their own add-on modifications, or to explore the product before a costlier purchase.

In a nascent industry, the assessment of these trade-offs may be more intricate. First, the size of each customer segment is subject to uncertain growth or shrinkage. On the one hand, an entrant's commitment to a specific segment may help offer products that attract and retain customers. On the other hand, a lack of assurance about market trends may warrant maintaining flexibility and spreading investments over multiple customer segments. Second, if achieving high profit margin entails offering highly valued features, firms may face difficulty in ascertaining those features under the conditions that even customers may not yet be fully aware of their precise preferences.

Then, what are the drivers of a firm's product usage breadth at the time of entry into a nascent industry? We next develop theoretical arguments that suggest how firms' pre-entry experiences can relate to the extent to which their products exhibit different usage breadth, and how the number of customers adopting an industry's product may condition the impact of pre-entry experiences.

HYPOTHESES

Entrants into a nascent industry often exhibit differences in their pre-entry experiences (Helfat & Lieberman, 2002). Studies in strategy and entrepreneurship have noted that pre-entry experiences of diversifying entrants come from firm-level capability endowments and cognitive frames (Benner & Tripsas, 2012; Klepper & Simons, 2000), whereas entrepreneurial startups often draw on founder-level experiences (Campbell et al., 2012; Gambardella et al., 2014). In addition to whether firms are diversifying entrants or startups, a key source of heterogeneity among entrants relates to pre-entry "use experience." Entrants can accrue use experience, when they come from contexts where a new product can fulfill customers' needs. These may be contexts that integrate a new product in their operations after its introduction, or contexts that are initiated by users due to their unfulfilled needs. For instance, electronic gadgets assemblers were among the users of CNC robots. If they engaged in CNC robot production, they could draw on their in-house use experience (Roy & Sarkar, 2016). Similarly, farmers have become users of drones to spray and monitor their fields. If a farmer founds a drone manufacturing startup, they could draw on their expertise in crop spraying and field assessment that was accumulated in the past. Generally, entrants diversifying from downstream user industries (de Figueiredo & Silverman, 2012; Roy & Sarkar, 2016) and user entrepreneurs (Adams et al., 2015; Baldwin et al., 2006; Shah & Tripsas, 2007) have pre-entry use experience to varying degrees.

We suggest that pre-entry use experience can influence an entrant's product usage breadth. The challenge in optimizing product usage breadth in a nascent industry arises from uncertain growth and shrinkage rates across different customer segments as well as the difficulty in ex-ante evaluation of customers' preferences. The crux of our argument is that a firm's pre-entry use experience can shift this trade-off. Due to the interrelation between pre-entry experience and a firm's interpretation of the industry, some entrants may target their attention toward particular segments without attempting to accurately forecast its size. Furthermore, because of the intertwined nature of pre-entry experience and a firm's capability portfolio, some entrants may find evaluation of particular customers' preferences less costly. We elaborate on these two mechanisms below.

First, how entrants differently interpret the demand environment has implications for their product's usage breadth. Absent complete and unambiguous information, entrants typically vary in their interpretations of the industry (Gavetti & Levinthal, 2000), which might alter entrants' locus of attention and shape their subsequent resource deployment (Eggers & Kaplan, 2009). For instance, firms that viewed digital cameras as a substitute for analog camera mobilized investments toward optical zoom features, whereas a PC peripheral conceptualization led to investments in dual webcams (Benner & Tripsas, 2012). Given that managerial attention may be partly situated by the context around decision makers (Ocasio, 1997), pre-entry experience can precede the link between interpretative processes and firm strategy. In particular, entrants are likely to target opportunities that relate to their prior experience (Shane, 2000; Gruber, MacMillan & Thompson, 2013).

Confronted by uncertain and conflicting signals about potential customers' preferences, pre-entry use experience may underpin a demand-oriented cognitive frame in sensemaking of the nascent industry. Pre-entry use experience implies immersion in a context where a new product may be used, thereby conditioning entrants' conceptualization of the industry in terms of market-specific aspects. For example, a photographer who uses drones may describe them as "flying cameras," compared to an engineer who views them as "flying robots." Such an attention to demand-side opportunities is documented for users innovating to address their own needs (Baldwin et al., 2006; Shah & Tripsas, 2007) or users sharing unfulfilled needs with innovators (Chatterji & Fabrizio, 2012; Jeppesen & Frederiksen, 2006). Thus, instead of engaging in a cost-benefit analysis of which customer segment may turn more sizeable or profitable, these entrants may exhibit a targeted attention to the market segment within which they are situated, and thus offer products with low usage breadth.

The second mechanism relates to how pre-entry experience may underpin differences in entrants' capability portfolios, which influence the market segments that they are able to target. Introduction of new products often entails recombining knowledge elements (Katila & Ahuja, 2002). An entrant's portfolio of resources and capabilities is a crucial source of not only the elements to be combined, but also the ability to develop innovative combinations (Helfat & Raubitschek, 2000). When firms have capabilities matching the industry profile, the reduced adjustment costs of capability development may increase the likelihood of entry (Silverman, 1999). Similarly, their capabilities can condition the specific solutions that they find at the technology-demand nexus (Nerkar & Robert, 2004). As capability accumulation is associated with past experience (Helfat & Peteraf, 2003), pre-entry experience is also often linked to various attributes of a firm's entry (Klepper & Simons, 2000; Mitchell, 1989).

Pre-entry use experience can create advantages in accruing demand knowledge. When entrants are involved in a context that has the potential to use the new product, they often benefit from "learning by using" (Rosenberg, 1982). Even when entrants have never used the new product, they probably have deep knowledge about the tasks that the product completes, criteria for their evaluation, and preferences of customers in that segment (Gambardella et al., 2017). For example, surgeons have knowledge of health issues solved by a device, surgical standards, and general expectations of the surgeon community, even if they have not yet adopted a robotic device (Katila et al., 2017). For user entrepreneurs, their own personal or professional needs can privilege them with demand knowledge (Adams et al., 2015; Baldwin et al., 2006), or they can easily gather it from user communities (Franke & Shah, 2003). For diversifying entrants, operations in downstream user industries can result in familiarity with internal needs or those of their competitors as users of the new product (Roy & Sarkar, 2016). Thus, despite difficulties in assessing customers' preferences, demand knowledge is less costly to access for entrants from those respective use contexts. This market-specific knowledge can enable product designs with specialized components and configurations, and thus low usage breadth.

Overall, we hypothesize that:

Hypothesis 1: There is a negative relationship between pre-entry use experience and product usage breadth.

Another important dimension of pre-entry experience is whether the firm is a diversifying entrant or a startup. To the extent that startup founders can leverage personal employment, scientific, or user experience to the nascent industry, their startups can reflect this pre-entry founder-level heterogeneity (Campbell et al., 2012; Shah & Tripsas, 2007). Diversifying entrants, however, often leverage more routinized and extensive experiences that reside at the firm-level (Ganco & Agarwal, 2009; Klepper & Simons, 2000). We suggest that the relationship between pre-entry use experience and product usage breadth can be conditioned by the distinction between diversifying entrants and startups.

When interpreting the demand environment, diversifying entrants are commonly more immersed in their past contexts relative to startups. For diversifying entrants, pre-entry experience is often not only tied to just past experience, but also to concurrent activities in adjacent domains. Pre-entry use experience may then imply presence of in-house units that use and integrate the product in their activities (Roy & Sarkar, 2016). To the extent that routinized information channels pre-exist in a diversifying entrant (Henderson & Clark, 1990; Joseph & Ocasio, 2012), the flow of customer-focused information from in-house user units may be prioritized. Further, commitments to in-house user units can make it a cognitive obstacle to deviate towards generic trajectories. Thus, diversifying entrants may be specially motivated and commanded to attend to product features that are specific to their in-house uses. By contrast, startups may exhibit a weaker interpretative frame. Although entrepreneurs with prior use experience view the nascent industry through the lens of demand-side aspects, they are often not formally affiliated and responsive to other in-house units. Thus, their market-specific orientations are not necessarily governed by cross-unit considerations. Further, startups often face pressure to build a novel identity that is tied to the nascent industry (Santos & Eisenhardt, 2009; Zuzul & Tripsas, 2019), which may slightly diminish their attention to past contexts from which they emerge.

A similar pattern holds regarding differential capabilities and demand knowledge of diversifying entrants and startups. In general, past studies have documented that diversifying entrants have access to capability portfolios that are often more sizable, compared to those of startups (Klepper & Simons, 2000). Larger demand knowledge of diversifying entrants can intensify the extent to which they draw on pre-entry use experience for product design. First, although user entrepreneurs and diversifying entrants have access to demand knowledge to some degree, diversifying entrants can gather emerging and credible demand trends from their past or concurrent in-house user units on a larger scale. The scale effect implies that this knowledge can be integrated more intensely into specialized components or design configurations of a new product. Second, a capability stock facilitates its accumulation along the same dimension, regardless of whether entrants pursue internal development or external sourcing (Capron & Mitchell, 2009). Thus, relative to startups, demand knowledge of diversifying entrants can provide an affordable and quick avenue for learning even more customer preferences. Third, besides demand knowledge, diversifying entrants may have technologies and complementary assets that are tied to a particular market and usage (Mitchell, 1991), whereas user entrepreneurs' capabilities are often limited to a single dimension (Bapna, Ganco & Qiu, 2019). Because diversifying entrants often design products that incorporate their existing capability portfolios (Kapoor & Furr, 2015; Wu, Wan & Levinthal, 2014), their market-specific technologies and complementary assets can tie their product features even more tightly to a particular market.

Overall, the juxtaposition of these mechanisms implies that the effect of pre-entry use experience on product usage breadth is more pronounced for diversifying entrants. Thus, we hypothesize that:

Hypothesis 2: The negative relationship between pre-entry use experience and product usage breadth is likely to be strengthened, if the firm is a diversifying entrant.

The relationship between prior use experience and product usage breadth concerns a nascent industry lacking clear interpretations and complete demand knowledge. Initially, entrants may resort to their pre-entry experience as a cognitive lens to interpret the industry and a capability base to reduce knowledge generation costs. We next suggest that as more customers adopt a new product, the impact of pre-entry experience on product usage breadth through both mechanisms diminishes.

In terms of cognitive processes, more product adoption by customers is often accompanied by public attention to the nascent industry, which can begin to eclipse an entrant's own interpretation. In the aftermath of a new product introduction, its limited adoption implies that the product is generally unfamiliar to the public and does not attract widespread attention from media, trade associations, and other stakeholders. Over time, an increase in the number of customers adopting a product can lead to more visibility for the industry. In turn, as stakeholders in media, trade associations, and others direct their attention to the industry and interact with an increasing number of customers, they may generate a web of diverse interpretations about an industry. For example, media can disseminate information about various customers and publish its own sensemaking of the industry (Kennedy, 2008). Trade associations and consumer activists that seek to bring collective awareness and recognition to the industry can bring their own interpretation to the spotlight (Rao, 2004; Wry, Lounsbury & Glynn, 2011). Market analysts often aggregate various customers' viewpoints and industry best practices in their reports (Benner & Ranganathan, 2013). Taken together, these diverse descriptions illuminate demand dimensions that supplant an entrant's unique views. Thus, entrants may consider customer segments that are not confined to their use experience, and instead reflected in public interpretations.

When considering demand knowledge and capabilities, as more customers adopt a product, knowledge about various customer segments and preferences within each segment accumulates in an industry. Initially, the first few customers have had too little interactions with the product to be able to articulate their precise preferences (von Hippel, 1986). Likewise, inventors may envision a few functionalities, but, are often restricted in predicting the entire range of demand attributes. As an industry advances, more product adoption by customers implies gradual accumulation of industry-wide knowledge through two processes. First, the increasing aggregate number of customers and the longer duration of product use provide more reliable avenues to learn about stated preferences in conventional market research (Clark, 1985) or revealed preferences in purchase behavior (Sorenson, 2000). Second, the information cascade from current customers implies that some potential customers who have not yet purchased the product become aware of it (Banerjee, 1992). These potential customers then share their preferences with manufacturers (Chatterji & Fabrizio, 2012) or in user communities (Franke & Shah, 2003). Because of this cumulative industry knowledge, each entrant's reliance on its pre-entry capabilities may no longer be the primary input for product usage breadth.

Overall, the contrast between entrants with and without use experience in impacting product usage breadth may become less noticeable.[2] Therefore, we hypothesize that:

Hypothesis 3: The negative relationship between pre-entry use experience and product usage breadth is likely to be weakened, as more customers adopt a new product.

DATA AND METHODS

Industry Description

The context is the U.S. commercial unmanned aerial vehicles or drones manufacturing industry. We follow the industry standard and define drones as heavier-than-air powered aerial vehicles that do not have a human operator on board and have a sufficient degree of autonomy for the intended functionality (Clarke, 2014). Primitive pilotless aircrafts have been around for decades, originally for military training. Following Tesla's 1898 patent for the first remote-controlled (RC) device, RC cars, boats, and planes became ubiquitous toys for adults and adolescents. Recently, a new form of advanced commercial drones has entered the civilian airspace that is neither toy nor a weapon.

[2] Our theorizing is agnostic about the direct effect of increasing adoption by customers on product usage breadth. The direct effect may be contingent on the type of adoption by customers that is revealed over time. Emerging knowledge about dominance of one segment may lead to an average low product usage breadth, whereas continued and robust presence of multiple segments may warrant high product usage breadth.

In these commercial cases, drones are used in activities that typically require time-intensive human effort or access to unreachable and hazardous locations. For example, instead of camera operators in helicopters capturing footage, photographers are able to launch drones mounted with high-definition cameras and image stabilizing technology on multiple-axis gimbals combined with motion-sensors to capture the same footage. For agriculture, an industry that requires extensive data collection related to crop health and harvest potential, farmers use drones with multispectral sensors and thermal imaging cameras to conduct remote sensing and automate spraying and planting crops.

Two factors have culminated in the recent takeoff of the drone industry. First, the past decade has experienced substantial technical advancements relevant to drone design and manufacturing. RC flight technology has benefitted from modern communication and navigation tools as well as military autonomous systems. Further, miniaturization of electronic components, which has been spurred by the rapid proliferation of smartphones and portable electronics, has offered new avenues for drone design. The increasing availability of off-the-shelf electronic components such as Arduino kits and the rise of open-source drone communities have also led to rapid knowledge diffusion.

Second, the sociopolitical aspects have become clearer. Although initially perceived as a flying weapon, the proposals to use drones for humanitarian purposes in the aftermath of Hurricane Katrina in 2005 or for Amazon Prime air delivery in 2013 and increasing acceptance by countries such as Canada, New Zealand, and Israel have impacted their social perception. Further, discussions over the safe integration of drones into national airspaces has prompted numerous interim regulations by the U.S. Congress. In particular, the FAA Modernization and Reform Act of 2012 allowed case-by-case authorization for commercial drone use, thereby leading to extensive commercial drone activity.

The industry provides an appropriate setting to examine how a firm's pre-entry experience relates to product usage breadth. First, there is considerable demand uncertainty and variation in drone use. Over 30 applications including agriculture, commercial filmography, construction, geo-surveying, search and rescue, inspection, and package delivery have been envisioned (McKinsey, 2017; PwC, 2016). While in retrospect these applications may appear obvious, the initial restricted operations implied that entrants lacked reliable knowledge of customers' preferences. For each application, the pace of product adoption, revenue-generation potential, the tasks performed by drones, their value-creating features, and their integration in the entire workflow of tasks were unknown. For example, a co-founder of Aeryon Labs, a drone startup, described the uncertainty as: "we saw that there were a lot of potential uses for UAVs, but we didn't know which ones would engage with the market" (Canadian Business, 2015). This uncertainty is reflected in diverging market forecasts across applications. Indeed, industry experts vary extensively in their predictions of the potential U.S. and global drone market size, often ranging between $12 billion to $127 billion by 2021-2025 with different sub-estimates for the specific market applications (BI Intelligence, 2016; McKinsey, 2017; PwC, 2016).

Second, because the contrasting nature of tasks performed in each application requires that the technical specifications of drones designed for each application vary, some entrants could create highly specialized drones that cater efficiently to a few functions in a subset of applications, while others may create generic drones that perform acceptable functions across a wide span of applications.

Third, entrants from user industries such as filmography, agriculture, utilities, and construction present appropriate variation to study pre-entry experience. In part, presence of user entrepreneurs and firms might have been enabled by free availability of technical knowledge about drones. Several patents on the basic architecture of drone airframes were granted in the 1950s and 60s. The rise of additive manufacturing, computer-automated design and manufacturing, and 3D printing, has made small-scale but rapid production of drones feasible. Further, drone enthusiasts, entrepreneurs, and firms can share ideas in large open source communities (Bremner & Eisenhardt, 2019).

Sample

The sample consists of drone models that received Section 333 exemptions from the U.S. Federal

Aviation Agency (FAA) to fly for commercial purposes. The FAA Modernization and Reform Act of 2012 mandated creation of guidelines for the safe and expedient integration of drones into the U.S. National Airspace System. Previously, drones required an airworthiness certificate or a certificate of authorization, which involved a time-intensive and costly review process similar to that of regular airplanes. Section 333 of the FAA Modernization and Reform Act allowed each commercial drone operator to petition the FAA for exemptions from airworthiness certificates on a case-by-case basis.[3] Instead of drone manufacturers applying for exemptions, firms and individuals who intended to use drones for commercial purposes, also known as petitioners, had to report the drone models they intended to use and the intended usages. Regardless of whether a previous exemption had been granted for a particular drone model, new petitioners had to file exemptions for that same model again. Petitioners could also file amendments to add models and/or other usages to initial petitions.

As part of the Section 333 process, the FAA authorized 5543 exemptions and 863 amendments. The first exemption petition was filed in January 2014 and exemptions were granted until August 2016. This regulatory requirement allows for comprehensive data collection of all drone manufacturers with products used in the U.S. between 2014 and 2016. In August 2016, the requirement was replaced with the "Part 107 Small UAS Rule", which served as a blanket exemption for the commercial operation of all drones that met certain physical criteria and were operated under certain limitations.

From the publicly released Section 333 exemption filings by FAA, we have extracted a list of drone models, and used various industry reports, firm websites, and technical manuals to identify the respective manufacturer of each model. Appendix A1 contains three annotated examples of Section 333 exemptions marking all the information extracted. Drones that were manufactured by universities, the U.S. Army, and other not-for-profit entities were not included in the sample.

[3] While Section 333 applied to commercial drones, FAA implementation of the regulation had another component for recreational drones. Section 336 established the "Special Rule for Model Unmanned Aircrafts," which permitted individuals to fly "recreational" drones within certain physical dimensions without a special exemption.

Dependent Variable

The dependent variable is product usage breadth. Theoretically, it is defined as the extent to which a new product can be used across different applications. Empirically, we measure it as the number of distinct categories in which a drone is authorized to be used by the FAA. To construct this measure, we follow three steps: (1) define usage categories for drones, (2) map drone exemptions to usage categories, and (3) aggregate exemption-level usage categorization to the drone-level.

In the first step, we identify five usage categories for drones: professional photography and videography, short-distance inspection, long-distance surveying, precision agriculture, and supply chain and aerial parcel delivery. Table 1 lists these usage categories, the common tasks performed, the respective industries, and the typical technical specifications valued by customers in those industries. The categories correspond to distinct tasks performed by drones, and how the underlying technical specifications required to effectively perform those tasks differ across each. As shown in the second column of Table 1, several industries have adopted and integrated drones into their activities. Two conditions allow for categorization of these diverse industries into broader usage categories.

--- Table 1 about here ---

First, there are often common tasks that drones perform across subsets of these industries. For example, photography and videography for media newsgathering, sport events, closed-set movies, and real estate promotions share common features. Further, tasks performed by drones in insurance damage assessment, wind turbine inspection, and powerplant monitoring involve short-distance or vertical elevated travel, whereas tasks performed by drones in mapping mining sites, exploring oil and gas sites, and monitoring railroads involve long-distance travel. In this example, task commonality in mining, oil and gas, and railroads allows for their categorization into long-distance surveying.

Second, there are often technical specifications that make drones suitable for a particular task. A drone's flying range, cruise speed, flight altitude, weight-carrying capacity, and autonomous capability may have implications for the types of tasks it can most effectively perform. These desirable attributes typically arise from design choices such as airframe structure (fixed wing, multirotor), motor type (electric, combustion engine), endurance (battery life, fuel capacity), or navigation (autopilot, radio-controlled, GPS). Further, some drones may have high definition cameras, image stabilization systems, thermal or specialized sensors. The third column of Table 1 provides details and examples. For example, drones utilized for photography and filmography typically move slower to capture more detail, incorporate more sensors for following targets, and include more powerful image stabilization technology. For short-distance inspection tasks, multirotor drones can better reach high altitudes and stay still in the air for steady observation. Short-distance flight within a pilot's line of sight is possible on shorter battery life and limited autonomous navigation capabilities. In contrast, for long-distance surveying tasks, fixed-wing drones with longer battery life and more autonomous navigation are better suited. Technically, a fixed-wing airframe structure allows for faster speed and surveying of larger areas, while autonomous navigation can help with flying beyond visual line of pilot's sight. While it is feasible to use either drone design to perform each task, one or more of these technical specifications provides a better and more efficient match for the task requirements.

The above two conditions underpin the rationale for our categorization. To create the categories, we start with a complete list of industries adopting drones. Based on contextual information available from the FAA, the Association for Unmanned Vehicle Systems International (AUVSI), and the Center for Study of Drones at Bard College, industry reports (BI Intelligence, 2016; McKinsey, 2017; PwC, 2016), and public drone manuals,[4] we identify common tasks and technical features across industries.

In the second step, we map the authorized uses listed in each Section 333 exemption document to our five usage categories. Each exemption document typically lists specific authorized uses such as

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[4] Petitioners often provided FAA a technical manual of the drones that they intended to use. However, technical manuals are classified as "confidential business information" and not systematically shared by the FAA. Thus, rather than having access to all technical manuals, we rely on a few manuals that are available on external websites.

"aerial videography for closed-set filming", "aerial data for precision agricultural surveys," or "conduct oil and gas platform inspections on land and over water." Some exemptions list multiple authorized uses such as "aerial videography for the insurance, utility, and telecommunications" or "aerial photography for real estate, agriculture, construction, insurance, utilities, and ecological preservation." A limited set of exemptions list general uses such as "aerial data collection" or "aerial imaging."

To link these authorized uses to our five usage categories, we create a dictionary of keywords and phrases that correspond to the particular categories. As an exploratory endeavor, we applied multiple text analysis tools such topic models, n-gram analyses, and other text mining indices to determine which words and phrases were more important in describing drone usages. We then manually examine a random subsample of exemptions to inspect and revise the dictionary. If an exemption has one of the keywords in the dictionary, it is marked as having a drone that is used within that category. Each exemption could have more than one of the keywords and is then marked as reporting more than one usage for its drone models. If petitioners filed amendments to add more drones or additional uses to their original exemption, we also include the updated list of drones or their updated uses. Appendix A2 lists all dictionary keywords used for classifying exemptions into usage categories.

As the third step, we aggregate the exemption-level usage categories to the drone-level. The categorization process in step 2 is at the exemption level, whereas our interest is in identifying usages across all exemptions for a particular drone model. 42% of drone models in the sample received one exemption, and their usage can be inferred from their only exemption. In a few cases where a drone model received one exemption and the usage description was not adequately specific, we manually inspected the primary business of its petitioner and the categories it belonged to. The remaining 57% of drone models received 50 exemptions on average. To infer drone-level usage categories in these cases, we compute the total frequency of each category across a drone model's exemptions. We eliminate exemptions that did not specify which authorized use related to a large number of drones.

For each drone model, this process generates a frequency count of the number of exemptions received in each of the five usage categories. To identify a particular drone model's usage breadth, we construct an aggregated count variable identifying the number of usages for which the drone has received exemptions. The larger the count, the greater the drone's model usage breadth.

Explanatory Variables

Pre-entry Use Experience. Our main explanatory variable captures whether a firm's pre-entry background aligns with use experience. We measure pre-entry use experience as a binary variable that is equal to one if a firm or its founders were previously active or employed in areas that could use drones in their operations, including photography, motion pictures, real estate, energy, utilities, mining, insurance, telecommunications, geological surveying, agriculture, and retail contexts. For example, ICR Service, a quality assurance energy firm, and Precision Drone, a startup founded by two farmers, have experiences in user industries of energy and agriculture, respectively. Detailed firm and founder data come from public sources including firm websites, CrunchBase, LinkedIn, AUVSI directory, industry reports, FAA documents, and other news sources. This variable is equal to zero if a firm or its founders were not active or employed in user industries. We additionally inspected industries from which these non-user entrants came from. Their experiences could be predominantly traced to aviation, electronics, robotics, and/or radio-controlled devices contexts.

Diversifying Entrant. We include a binary variable for a diversifying entrant that is equal to one if a firm was active in another industry prior to diversifying into drone manufacturing and is equal to zero if a firm was founded specifically to operate as a drone manufacturer.

Number of Industry Customers. We use the one-month lagged logged cumulative number of unique individuals or firms that petitioned for a Section 333 exemption for any drone prior to the month in which a drone model receives its first exemption petition. Results are robust to 2-, 3-, and 4-month lagged measures.

Control Variables

To separate the effect of a firm's pre-entry use experience from other possible explanations, we include control variables pertaining to firms, drone models, and industry trends.

We start with describing firm attributes. First, a firm's technical knowledge can condition its entry strategy. We account for technical knowledge by using the logged number of U.S. patents in aviation (Derwent class Q25: mechanical systems related to aircraft, aviation, cosmonautics) and computing (Derwent class T01: digital computing) that a firm applied for during the five-year window prior to the first filing of an exemption for each of its drones. The results are robust for three-, and four-year windows. Second, older and larger firms' may be associated with more financial resources. We measure firm age as the logged difference in years between its drone's first exemption petition and its founding year. We also include the logged number of employees. Third, before the commercial drone industry, drones were predominantly used in military. Given that military contractors might have had existing drones that could be repurposed for commercial use, we include a binary variable that equals one for firms or founders with prior military drone activity. We collect a complete list of pre-2014 military drone contractors from the U.S. Department of Defense Unmanned Systems Roadmap as well as the FAA certificates of authorization granted to the U.S. Army, Navy, Air Force research lab, and DARPA. Fourth, although commercial drones were restricted in the U.S. before 2014, other countries had different regulations. Thus, we include a binary variable that equals one if a firm headquarter is located outside the U.S. Fifth, under Section 336 of the FAA Modernization and Reform Act, individuals can fly drones within certain physical dimensions recreationally without applying for an exemption. Although these recreational drones often have limited functionalities, some petitioners may have considered them for commercial operations, experimentation, and/or pilot training. We measure recreational producer with a binary variable that equals one if a manufacturer's drone models were sold on either of three major recreational drone retailers, that is, Horizon Hobby, Hobby Tron and Hobby King. Finally, we include a binary variable identifying firms that introduced only one drone model to control for any differences between single-product and multi-product firms.

We also include two variables about drone models. The first one is the intensity of exemptions filed for a drone model. Popular drones with numerous exemptions might be associated with a wider range of usages, given that various petitioners could discover more uses for them. To account for this, we include the average number of exemptions that each drone model received per month between its first and last exemption petitions. Second, one concern about firms introducing multiple drones is that their subsequent drones might undergo post-entry learning, in addition to pre-entry experience. Thus, we include a binary variable that separates a firm's early drone models from the subsequent ones. This variable is equal to one for drone models that receive their first exemption petition within a 6-month window of a firm's first appearance in Section 333 exemption filings.

To account for industry-wide or economy-wide time trends, year fixed-effects corresponding to the year of a drone's first exemption petition are also included.

Summary Statistics

Our sample consists of 429 drone models manufactured by 228 unique manufacturers. These numbers are slightly lower than the population of drones and manufacturers in the FAA publicly-released Section 333 exemptions for two reasons: First, we dropped manufacturers without complete verifiable founder history. Second, we dropped drone models for which the Section 333 exemptions did not provide specific authorized usage.

Out of the 228 unique manufacturers, 26.3% of firms have pre-entry use experiences, and 36.4% of firms are diversifying entrants. Figure 1 presents the cumulative number of drone manufacturers with approved commercial petitions in each month, by the type of pre-entry experience. The industry has experienced a steady rise in the number of manufacturers from either type of pre-entry experience over this timeline. Figure 2 presents the percentage of applied exemptions or amendments for each usage category over time. While all usage categories experienced growth, their size and the timing of their sales takeoff diverged.

--- Figures 1 and 2 about here ---

Table 2 presents variable measurements and descriptive statistics and Table 3 reports the correlation matrix. Both are at the drone-level. Consistent with H1, the correlation between pre-entry use experience and the usage category count variables is negative. The correlation table does not reveal multicollinearity concerns between variables aside from the 0.73 correlation between the variables for diversifying firms and firm age. The results are robust to the exclusion of firm age, which mitigate concerns that the later reported results for H2 are Type I errors (Kalnins, 2018).

--- Tables 2 and 3 about here ---

Estimation Technique

The dependent variable is a count of usage categories for each drone model. Count data can be estimated with a Poisson or negative binomial model. A concern with a Poisson model is possible overdispersion (Cameron & Trivedi, 1990). To ensure that our data do not violate assumptions of the Poisson distribution, we use a goodness-of-fit post-estimation test with a null hypothesis of Poisson distributed data. The p-value is not significant (deviance stat = 217.50; p=1.00), suggesting the Poisson estimation is appropriate for our primary estimation method.[5] Further, because instances of drones with zero and six usage categories are impossible in our dataset, we apply left-truncation at zero and right-truncation at six. To account for possible correlation between repeated drone models by the same manufacturer, standard errors are clustered on the manufacturers' ids. The results are robust to estimations using a regular (non-truncated) Poisson model.

[5] In absence of overdispersion, a supplement analysis with a negative binomial model yields identical results to a Poisson estimation. A negative binomial estimation assumes a Poisson-like distribution that is adjusted for an overdispersion parameter. When the above goodness of fit reveals no violation of Poisson distribution assumption, statistical packages replace the overdispersion parameter to zero (Long & Freese, 2014).

RESULTS

Table 4 reports regression results. Models 1-5 are estimated using the truncated poisson model. Negative coefficients imply that a variable is likely to decrease usage breadth. Model 1 includes only control variables. The positive coefficients for foreign firms or firms that produce recreational drones implies that their products tend to have a broader usage breadth. Further, drones introduced earlier in a firm's life cycle seem to exhibit lower usage breadth.

--- Table 4 about here ---

Results for Hypothesis 1

On average, drone models span 2.35 usage categories. While the average product usage breadth for drones by firms with prior use experience is 1.76, it increases to an average of 2.53 for firms without use experience. Figure 3 shows the density distribution histogram of usage breadth based on whether entrants had prior use experience. For pre-entry use experience, it is skewed toward one usage category, whereas they are more symmetrically spread for other entrants. Regressions show similar patterns. Model 2 in Table 4 introduces the variable for pre-entry use experience. The coefficient for use experience is negative (β=-0.546; p=0.001). On average, having use experience decreases the expected product usage breadth by 1.07 usage categories. This evidence corroborates H1.

--- Figure 3 about here ---

In addition to regression results, preliminary descriptive evidence sheds light on the mechanisms behind H1. Our hypothesis development draws on the idea that pre-entry use experience allows for introduction of products with features specific to the user context from which firms emerge. To inspect this assumption, we manually verified the match between prior experience and the specific usage category of drones. Out of the 98 drones introduced by entrants with prior use experience, 91% were used in applications exactly consistent with the entrant's prior experience, that is, drones introduced by a photographer, farmer, or geo-surveyor corresponded to usage in photography, agriculture, and long-distance surveying, respectively. Among these, 58% of drones were used exclusively in the corresponding usage application, while the other 33% of the drones were used in usage applications consistent with entrant's experience but also an additional one or two applications.

The role of prior use experience in shaping cognitive frames and knowledge bases is also noted by founders. For example, Tony Carmean, co-founder of Aerial MOB and a former film producer, said, "the beauty (of drones) is low-altitude cinematography. Think of that space in-between jibs and full-sized aircrafts. There's a big area that's not covered. … In a lot of ways, we can replace dollies, jibs and cranes" (The Wrap, 2014). By interpreting drones as a tool to supplement existing aerial filming devices, Aerial MOB introduced professional-grade cinematography drones that emphasized stability with custom-made gimbals and supported dangerous camera angles previously captured by manned helicopters that could now be done far more safely by drones.

A similar case relates to Matthew Barnard, a lifelong farmer. Barnard said, "…I had a salesman stop while I was harvesting corn. He tried to sell me a hobby-grade unmanned aerial vehicle for about 10 times what it was worth. He didn't know anything about ag. He didn't know anything about my farm's needs or my concerns. … Our team is directly involved with production agriculture. We are our customers. It's also why our tagline is By Farmers, For Farmers." (Successful Farming, 2015). Later, Barnard founded Crop Copter and began producing durable, water-proof, and high-endurance drones for precision agriculture that were mounted with normalized difference vegetation index (NDVI) sensors, which are specialized sensors meant for assessing the quality of crop health.

Results for Hypothesis 2

Model 3 in Table 4 adds an interaction term between pre-entry use experience and whether the entrant is a diversifying firm. The interaction term is negative (β= -0.842; p=0.025). Following Long and Freese (2014)'s guidelines for interpreting interaction terms in non-linear models, the average marginal effect of prior use experience for diversifying entrants and startups is -1.80 (p=0.000) and -

0.64 (p=0.067), respectively. For diversifying entrants, pre-entry use experience decreases the expected usage breadth from 3.20 to 0.78 categories. However, for startups, it decreases the expected usage breadth from 2.24 to 1.55. The stronger negative effect on usage breadth for diversifying firms with prior use experience is consistent with H2.

Besides regression results, preliminary descriptive evidence helps us explore the mechanisms behind H2. In hypothesis development, we noted that pre-entry use experience within a diversifying entrant may imply the presence of in-house user unit for a particular product. To verify this, we examined the extent to which sample drone manufacturers also self-petitioned for operating their own drones. Self-petitioning for a 333 exemption is a possible indication that the firm intended to use the drone internally or to provide a service to customers. In the subsample of entrants with prior use experience, 76% of diversifying entrants self-petitioned for a 333 exemption, in contrast to 54% of startups. This statistic is consistent with our theorizing for H2.

Results for Hypothesis 3

Model 4 adds an interaction term between pre-entry use experience and the number of customers, which is positive (β=0.175; p=0.028). Following Long and Freese (2014)'s guidelines for interpreting interaction terms in non-linear models, Figure 4 shows the average marginal effect of the pre-entry experience variable for representative cumulative petitioner numbers. The figure shows that the marginal effect of prior use experience becomes less negative as more petitioners filed for exemptions. Thus, in support of H4, the negative relationship between prior use experience and product usage breadth is weakened as the number of customers increases.

--- Figure 4 about here ---

Model 5 includes all direct and interaction terms in a full model and exhibits similar coefficient signs and statistical significance in support of H1-H3.

Robustness Checks

Additional robustness checks examine the sensitivity of our findings to alternative model specifications. First, instead of using a count measure for usage breadth of each drone, we compute an alternative Herfindahl-type index (HHI) measure, summing the squared shares of frequency counts belonging to each usage category. This measure helps us rule out concerns about the distribution of petitions filed for each usage category. Let's contrast drone B with 10 petitions for photography and 10 for inspection with drone C with two petitions for photography and 18 for inspection. While the usage breadth count is two for either drone, an HHI-based measure captures the greater emphasis on inspection usage for drone C. This index variable has a range between zero and one, where a smaller number, and hence negative coefficient estimates imply higher usage breadth. Results in Models 6 and 7 in Table 4 report Tobit estimations, and are consistent with H1-H3.

Second, we aggregate a firm's drone models into a portfolio as the unit of analysis. 40% of entrants introduced more than one drone. One concern is that a multi-product firm may introduce multiple drones with low usage breadth that are each targeted towards different usage categories, and in doing so, maintain a portfolio of drones that exhibit high usage breadth. Our main regressions already include two control variables for whether an entrant in single-drone firm, and whether a drone is among early products of a multi-drone firm. To further mitigate this concern, we re-calculated the dependent variable from drone-level to portfolio-level, and adjusted control variables to reflect the time of a firm's first drone exemption. Models 8 and 9 in Table 4 provide support for H1-H2. We note that this specification does not allow estimating coefficients for H3, because the number of customers variable loses its variance at the firm-level. Nonetheless, it is still included as a control.

Finally, we broaden our drone usage categories to include satellite-type drones used for internet provision and mini-drones used for entertainment light shows such as those displayed at the 2017 Super Bowl LI halftime show and the 2018 Winter Olympics. These two usage categories were less established or frequent drone applications between 2014 and 2016 and apply to very few drone models (n = 3). Our findings remain unchanged in support of H1-H3 in a truncated Poisson estimation with a revised count dependent variable that includes these two additional categories.

Empirical Extension

The regulatory disclosure requirements used to construct the sample were in effect until mid-2016. Thus, our analyses are based on the first wave of commercial drone manufacturers. As a post-hoc exploration, we check their activity status in 2019. Notably, the exit of 3D Robotics in 2016 from manufacturing and its pivot toward software development has received considerable attention in the press (e.g., Mac, 2016), leading to speculations about the consolidation of the industry. As of August 2019, out of the 228 firms in the final sample, 68% remain active drone manufacturers, 14% were acquired with their knowledge and assets remaining in the industry, and 13% ceased operations. 5% had a fate similar to 3DR, that is, discontinued manufacturing and became software developers (1%), drone users (3%), or complement producers (1%). These patterns point to a vibrant industry with majority of previous manufacturers in existence plus new entrants. To illustrate, 219 producers showcased their drones in the 2019 AUVSI XPONENTIAL exhibition.[6] Further, the 2019 AUVSI Unmanned Systems and Robotics database lists 413 active U.S. commercial drone firms.

Given our interest in the role of pre-entry use experience, we also explore variations in activity status for these entrants. Out of 60 firms with prior use experience, 65% were still active in drone manufacturing, 8% were acquired, and 15% ceased operations. The statistics mirror that of the entire sample. The only difference arises for firms that discontinued manufacturing but became users. Five out six firms that continued operating as drone users had pre-entry use experience. Similar patterns hold in subsamples of startups and diversifying entrants with pre-entry use experience.

[6] Based on authors' data collection during the AUVSI XPONENTIAL event held in Chicago in April 2019.

Boundary Conditions

To the extent possible, the study incorporates statistical and descriptive evidence that help us rule out alternative mechanisms and corroborate our proposed mechanisms. Nonetheless, the empirical design shows statistical associations, and does not establish causality. Further, the generalizability of our results may be bound by the single-industry single-country design. Two features are noteworthy.

First, commercial drones face different regulatory frameworks and social legitimacy in other countries. Several countries still lack regulatory transparency, and regulated countries have adopted different approaches with frequent revisions (PwC, 2016). For instance, Canada and China allow flying beyond visual line of sight, while there are restrictions in the U.S. and Germany. Drone insurance is required in Canada, France, and Germany, though not in the U.S. Promoting commercial drones has been part of the Chinese government national plans, leading to institutional support and financial subsidies (Yu & Armanios, 2019). Further, privacy concerns, disruptions to airports, and weaponized drones have led to diverging social perceptions (Stanley & Crump, 2011). The implications of these regulatory and social factors for entry patterns in other countries are worthy of future examination.

The second feature is public availability of basic drone technology. Crucial expired patents, cheap off-the-shelf components, and open-source communities reduced barriers to technological entry. For example, patents US3053480 titled "omni-directional, vertical lift, helicopter drone," US3083934 titled "rotary wing aircraft," US2611344 titled "rotary wing aircraft," and US2954614 titled "flight training apparatus for hovering type aircrafts" are fundamental to airframe design, and were filed in the 1950s and 60s. Further, 61 of 145 startup founders in our sample were active members of DIY Drones, which is the first and largest drone online community with 90,000 members. Thus, entrants with and without use experience alike could design and produce drones. Future studies need to examine entry patterns from user contexts, absent access to this technical knowledge.

DISCUSSION AND CONCLUSIONS

Faced with demand uncertainty and heterogeneity that characterize most nascent industries, managers often have to contemplate about product usage breadth as a crucial element of a firm's entry strategy. These managers are often unable to forecast the accurate size and profit potential of different customer segments in order to engage in economic optimization about which segments to target. Further, they often lack complete knowledge of precise customer preferences within each segment in order to offer products that are highly valued by customers. By examining patterns of entry and product usage breadth in the commercial drone manufacturing industry, our study identifies pre-entry experience as one driver of product usage breadth. We propose theoretical mechanisms and find empirical support for the idea that entrants with use experience are likely to introduce products with market-specific features for particular customer segments, exhibiting low product usage breadth. Pre-entry use experience not only directs an entrant's attention toward particular segments, but also privileges it with demand knowledge about the context from they emerge.

The study contributes to the entry strategy, user innovation, pre-entry experiences, and industry emergence literatures. For entry strategy studies, we move beyond the predominant conceptualization of entry as a binary choice (Klepper & Simons, 2000; Mitchell, 1989). A firm's entry strategy often includes intertwined decisions about whether to enter, timing of entry, location choices, external partnerships, and capability reconfiguration (Eggers & Moeen, 2018). Although we recognize that a complete account of the endogenous nature of these simultaneous decisions may be outside the scope of a single study, our focus on product usage breadth helps illuminate one more element of a firm's entry strategy. In doing, we join existing studies that have linked pre-entry cognitive frames and founder experiences to product attributes (Adams et al., 2015; Benner & Tripsas, 2012).

By emphasizing the role of pre-entry use experience, we advance the user innovation literature (Baldwin & von Hippel, 2011; Gambardella et al., 2017). Existing studies have offered rich insights about how user entrepreneurs found startups (Shah & Tripsas, 2007), how user inventors collaborate with firms (Chatterji & Fabrizio, 2012), and how user communities facilitate exchange of innovative ideas (Franke & Shah, 2003). Consistent with the logic that users are often equipped with market-specific cognitive frames and capability stocks, our study sheds light on users' unique position in offering products with highly-valued features for a particular market, capitalizing on other entrants' inability to access similar demand knowledge of customers' preferences. Thus, regardless of whether they seek to fulfil their own needs or capitalize on their knowledge advantage, startups and diversifying entrants alike can leverage their prior use experience for economic activity in a nascent industry.

Our study also contributes to the pre-entry experiences literature by showing how diversifying entrants from user contexts can leverage their demand knowledge. Past studies often distinguished between diversifying entrants and startups (Ganco & Agarwal, 2009; Klepper & Simons, 2000), and linked it to the underlying technical capabilities and complementary assets (Helfat & Lieberman, 2002). In identifying entrants with access to market-specific knowledge of customer preferences, these studies largely assume that producers may have gained customer-focused knowledge as part of their overall downstream complementary assets (Eggers, Grajek & Kretschmer, 2019; Mitchell, 1989; Sosa, 2009). We highlight that deeper demand knowledge can reside in entrants coming from user industries.

To the industry emergence literature, rather than espousing a solely technological supply-side perspective, our study points to the demand-side drivers of industry trends (Adams, Fontana & Malerba, 2013; Adner & Levinthal, 2001). This literature has offered insights about an industry's technological path through the era of ferment and convergence around a dominant design (Suárez & Utterback, 1995) as well as an industry's quest for gaining legitimacy (Aldrich & Fiol, 1994). However, another key industry milestone is sales takeoff, which marks a sizable reduction in demand uncertainty and an acceleration in customers' adoption of a novel product (Agarwal & Bayus, 2002). Our study points to how reducing demand uncertainty can be tied to introducing products with varying market-specific features, thereby revealing customers' latent and unknown preferences.

Studying the drone industry also has implications for industry emergence in related sectors. Due to drones' integration in multiple industries, they resemble general-purpose technologies that have historically played a crucial role in the process of economic growth (Bresnahan & Trajtenberg, 1995; Rosenberg, 1963). Not only do general-purpose technologies create a new industry of focal producers, but also, their integration in other sectors have a multiplier effect on productivity gains. Our study notes how market-specific features that allow for incorporation of general-purpose technologies in other industries can come from engaging users in the innovation process.

A few avenues for future research that arise from the current study are noteworthy. First, what are the consequences of offering products with different usage breadth on different measures of performance? Is there a performance penalty for firms lacking use experience that offer market-specific products, or vice versa? Second, considering that entrants start with varying levels of product usage breadth, which entrants and with what pre-entry experiences pivot toward higher or lower usage breadth in their subsequent products? Third, if users engage in the innovation process to address their own needs or benefit from their unique demand knowledge, does their initial position turn into a sustained competitive advantage? Does entry of other firms force them to retreat downstream to user industries, or lead to their customization of existing products rather than self-provision of the entire product? Fourth, in light of ubiquity of diversifying entrants from user industries, how does their entry patterns compare to user entrepreneurs? Do they exhibit open knowledge sharing in communities similar to user entrepreneurs, or do their competitive motives prevail?

Overall, this study highlights a distinction in the pre-entry portfolios of firms that we hope can generate new insights about the antecedents of entry strategy under conditions of demand uncertainty.

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Table 1: Drone Usage Categories

Usage Category	Common Applications/ Industries	Common Features Valued by Relevant Customers	Sample Keywords in Dictionary
Professional photography and videography	Movie production Events and sport News and media Nature and landscapes Movie special effects Real estate	High resolution cameras Image stabilizing technology Motion-sensors	closed-set filming film production feature films photojournalism real-estate real property
Long-distance surveying	Pipeline inspection Railroad inspection Search and rescue Security surveillance Mining Mapping Oil and gas exploration Wildlife & ecological monitoring	Long battery life Fixed-wing architecture Faster max speed Requires runway for takeoff Beyond visual line of sight LiDAR sensors	pipeline railroad casualty site reconnaissance mining land survey forestry solar farms archaeological
Short-distance inspection	Utilities inspection Insurance assessment Bridge inspection Turbines Gas and electric Wind turbine Flare stack Petrochemical plants Inventory stock assessment	Shorter battery life Multi-rotor architecture Slower max speed Ability to stay still in the air Vertical take-off capability	turbine building inspection power plant landfill telecom tower construction property damage structure inspection flare stack
Precision agriculture	Field monitoring Crop health assessment Crop spraying	Long battery life Fixed-wing architecture Faster max speed Crop-spraying add-ons Soil sample collection Beyond visual line of sight Multispectral sensors	agriculture crop farm
Aerial delivery and supply chain management	Retail parcel delivery Inventory management	Heavier payload capacity Ability to lift and drop Beyond visual line of sight	delivery (e.g., Amazon Prime air) inventory management stockpile inventory
Less Established or Less Frequent Usage Categories between 2014-2016			
Satellites	Internet provision Defense and surveillance	Quasi-solar powered Heavier payload capacity Ability to be in continuous operation for months/years	internet service
Light shows	Entertainment	Micro-size (< 2 lbs) Shorter battery life Autonomous operation in formation with 100+ drones	light shows

Table 2: Variable Definitions and Summary Statistics

Variables	Measurement	Mean	Std. Dev	Min	Max
Usage Breadth	Count of usage categories for which a drone model received exemptions	2.35	1.22	1	5
Pre-Entry Use Experience	Binary variable = 1 if firm has pre-entry use experience; = 0 if no prior use experience	0.23	0.42	0	1
Diversifying Entrant	Binary variable = 1 if firm is a diversifying entrant; = 0 if startup	0.42	0.49	0	1
Number of Customers*	One-month lagged cumulative number of exemption petitioners for any drone prior to the month in which a model receives its first exemption petition	1105	1257	0	5225
Patents*	Count of aviation and computing patents applied for in 5 years prior to first exemption petition year for model	39.97	541.67	0	10508
Firm Age*	Number of years between first exemption petition year for model and founding year	11.85	17.24	0	121
Employee Count*	Number of employees in firm in year of first exemption petition for drone received	3885	29013	1	566000
Military Contractor	Binary variable =1 if firm or founder had military drone experience	0.04	0.19	0	1
Foreign Firm	Binary variable = 1 if firm is non-U.S. based	0.38	0.49	0	1
Recreational Product	Binary variable =1 if any of the firm's drones are listed on a hobbyist retail website	0.15	0.36	0	1
Exemption Intensity	Number of exemptions each model received per month of activity	2.13	7.66	0.07	112.05
Early Drone Model	Binary variable = 1 for drone models receiving an exemption petition within 6-months of a firm's appearance in the exemption filings	0.82	0.38	0	1
Single Product Firm	Binary variable = 1 for firm with only one drone model	0.32	0.47	0	1

Note: Variables indicated with * are log transformed in the correlation table and regressions. Summary statistics are reported untransformed.

Table 3: Correlation Table

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Usage Breadth	1.00												
2	Pre-Entry Use Experience	-0.27	1.00											
3	Diversifying Entrant	0.10	-0.06	1.00										
4	Number of Customers	-0.31	0.04	-0.04	1.00									
5	Patents	0.13	-0.15	0.34	-0.16	1.00								
6	Firm Age	0.13	-0.12	0.73	-0.03	0.39	1.00							
7	Employee Count	0.21	-0.22	0.57	-0.14	0.50	0.57	1.00						
8	Military Contractor	-0.07	-0.11	0.08	0.02	0.32	0.16	0.11	1.00					
9	Foreign Firm	0.24	-0.21	0.19	-0.14	0.03	0.18	0.40	-0.13	1.00				
10	Recreational Product	0.29	-0.21	0.28	-0.20	0.27	0.21	0.41	-0.08	0.25	1.00			
11	Exemption Intensity	0.21	-0.09	0.11	-0.20	0.21	0.03	0.20	-0.03	0.13	0.31	1.00		
12	Early Drone Model	-0.13	0.04	-0.12	-0.15	-0.13	-0.14	-0.21	0.03	-0.20	-0.26	-0.17	1.00	
13	Single Product Firm	-0.21	0.10	-0.09	0.08	-0.08	-0.20	-0.20	0.00	-0.16	-0.25	-0.10	0.32	1.00

Table 4: Estimations of Product Usage Breadth

	Controls	H1	H2	H3	Full Model	Alternative DV measure: HHI		Drones Portfolio Analysis	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Pre-Entry Use Experience = 1		-0.546	-0.300	-1.592	-1.294	0.216	0.690	-0.456	-0.110
		(0.001)	(0.097)	(0.002)	(0.010)	(0.004)	(0.004)	(0.006)	(0.544)
Diversifying Entrant **x** Pre-Entry Use Experience			-0.842		-0.788		0.259		-1.070
			(0.025)		(0.030)		(0.092)		(0.005)
Number of Customers **x** Pre-Entry Use Experience				0.175	0.164		-0.091		
				(0.028)	(0.039)		(0.016)		
Diversifying Entrant = 1	-0.106	-0.043	0.065	-0.004	0.094	-0.013	-0.087	0.052	0.264
	(0.526)	(0.776)	(0.664)	(0.981)	(0.533)	(0.864)	(0.246)	(0.778)	(0.156)
Number of Customers	-0.149	-0.166	-0.176	-0.206	-0.210	0.070	0.096	-0.095	-0.109
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.114)	(0.072)
Patents	0.010	0.005	-0.011	0.013	-0.006	0.007	0.013	-0.069	-0.095
	(0.854)	(0.915)	(0.805)	(0.793)	(0.894)	(0.785)	(0.602)	(0.241)	(0.107)
Firm Age	0.086	0.064	0.092	0.048	0.075	0.001	0.002	0.093	0.121
	(0.383)	(0.489)	(0.307)	(0.624)	(0.419)	(0.990)	(0.961)	(0.386)	(0.271)
Employee Count	0.007	-0.003	-0.001	-0.008	-0.005	0.010	0.012	-0.007	-0.005
	(0.835)	(0.923)	(0.965)	(0.794)	(0.871)	(0.478)	(0.397)	(0.827)	(0.882)
Military Contractor = 1	-0.285	-0.390	-0.445	-0.395	-0.443	0.001	0.008	-0.118	-0.180
	(0.272)	(0.113)	(0.082)	(0.126)	(0.096)	(0.991)	(0.951)	(0.698)	(0.568)
Foreign Firm = 1	0.231	0.172	0.117	0.191	0.134	-0.127	-0.113	0.277	0.207
	(0.047)	(0.122)	(0.271)	(0.092)	(0.217)	(0.020)	(0.035)	(0.026)	(0.099)
Recreational Producer = 1	0.289	0.201	0.168	0.198	0.168	-0.103	-0.080	0.249	0.161
	(0.018)	(0.094)	(0.156)	(0.117)	(0.173)	(0.100)	(0.198)	(0.244)	(0.443)
Exemption Intensity	0.013	0.011	0.011	0.009	0.010	-0.002	-0.001	-0.000	-0.000
	(0.277)	(0.234)	(0.247)	(0.258)	(0.264)	(0.193)	(0.321)	(0.931)	(0.996)
Early Drone Model = 1	-0.146	-0.192	-0.188	-0.188	-0.182	0.101	0.096		
	(0.262)	(0.131)	(0.141)	(0.140)	(0.156)	(0.147)	(0.166)		
Single Product Firm = 1	-0.204	-0.187	-0.150	-0.177	-0.148	0.050	0.033	-0.556	-0.521
	(0.089)	(0.111)	(0.193)	(0.132)	(0.202)	(0.408)	(0.579)	(0.000)	(0.000)
Constant	1.422	1.74	1.701	1.979	1.911	0.216	0.091	1.575	1.509
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.185)	(0.568)	(0.000)	(0.000)
First Exemption Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. Observations	429	429	429	429	429	429	429	228	228
Log pseudo-likelihood	-597.15	-586.95	-582.51	-583.55	-579.68	-281.80	-273.87	-304.91	-299.83

Notes: (1) *p*-values in parentheses; (2) Models 1-5: drone-level truncated Poisson estimation, robust standard errors, clustered on firm id; (3) Models 6-7: drone-level Tobit estimation, robust standard errors, clustered on firm id; (4) Models 8-9: firm-level truncated Poisson estimation, robust standard errors

Figure 1: Cumulative Count of Active Commercial Drone Manufacturers

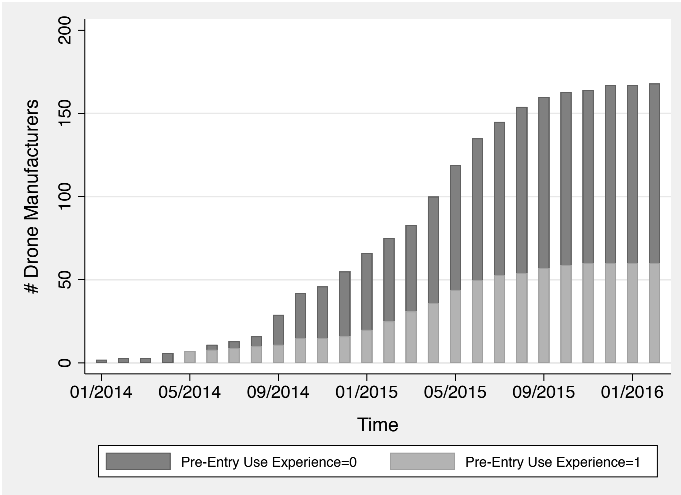


Figure 3: Histogram of Usage Breadth by Pre-Entry Use Experience

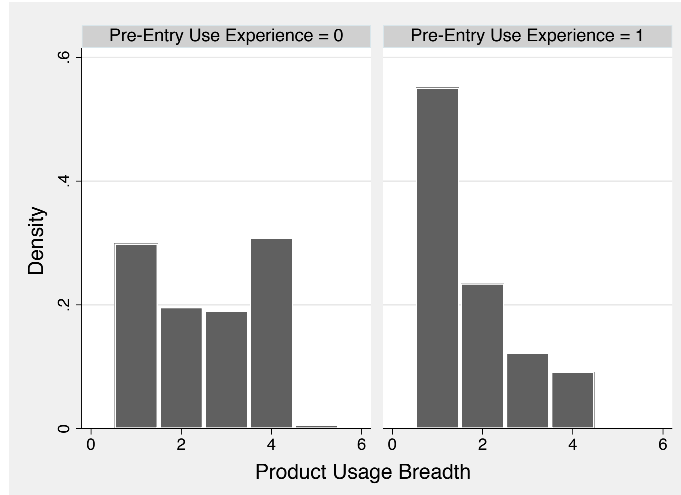


Figure 2: Customer Adoption Rates Across Usage Categories

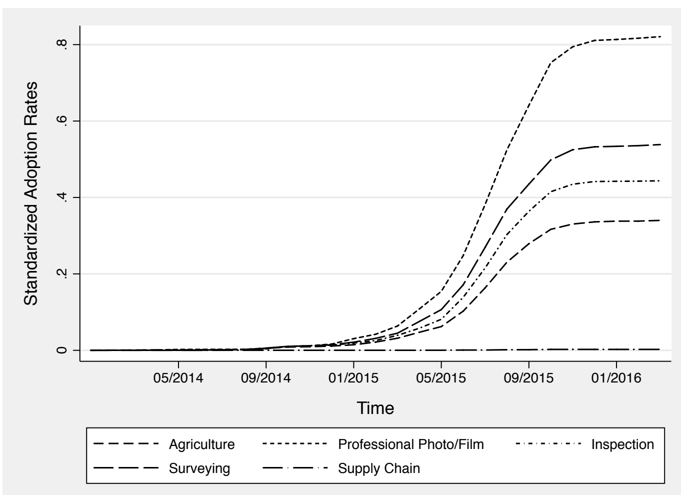
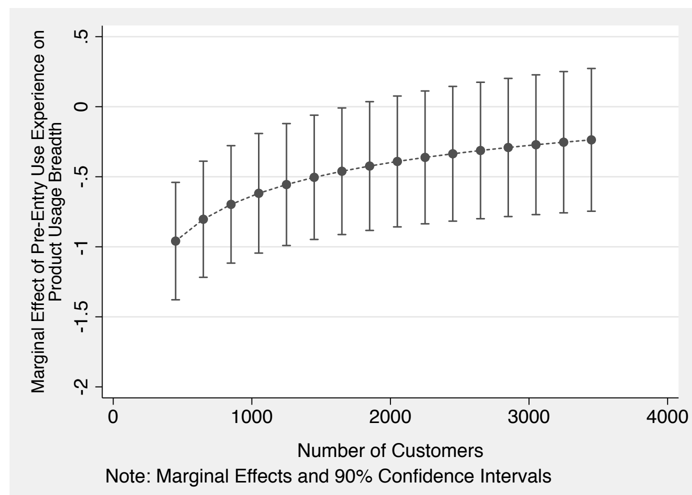


Figure 4: The Interaction between Pre-Entry Use Experience & Number of Customers



Appendix A1: Examples of Section 333 Exemptions

U.S. Department of Transportation
Federal Aviation Administration

800 Independence Ave., S.W.
Washington, D.C. 20591

December 11, 2015 **EXEMPTION GRANT DATE**

Exemption No. 13963
Regulatory Docket No. FAA–2015–3652

Mr. Charles A. Drouiland
Duncan-Parnell, Inc. **PETITIONER**
3150 West Montague Avenue
North Charleston, SC 29418

Dear Mr. Drouiland:

This letter is to inform you that we have granted your request for exemption. It transmits our decision, explains its basis, and gives you the conditions and limitations of the exemption, including the date it ends.

EXEMPTION APPLICATION DATE

By letter dated July 1, 2015, you petitioned the Federal Aviation Administration (FAA) on behalf of Duncan-Parnell, Inc. (hereinafter petitioner or operator) for an exemption. The petitioner requested to operate an unmanned aircraft system (UAS) to conduct aerial mapping, photogrammetry, inspection, volume calculation, and land surveying.

AUTHORIZED USES FOR THE BELOW DRONES

See the docket, at www.regulations.gov, for the petition submitted to the FAA describing the proposed operations and the regulations that the petitioner seeks an exemption.

The FAA has determined that good cause exists for not publishing a summary of the petition in the Federal Register because the requested exemption would not set a precedent, and any delay in acting on this petition would be detrimental to the petitioner.

Airworthiness Certification **DRONE MANUFACTURERS**

The UAS proposed by the petitioner are the Trimble UX5,SkyView Aerial Solutions MQ4, and SkyView Aerial Solutions MQ8.

In accordance with the statutory criteria provided in Section 333 of Public Law 112−95 in reference to 49 U.S.C. § 44704, and in consideration of the size, weight, speed, and limited

U.S. Department of Transportation
Federal Aviation Administration

800 Independence Ave., S.W.
Washington, D.C. 20591

November 19, 2015 **EXEMPTION GRANT DATE**

Exemption No. 13713
Regulatory Docket No. FAA–2015–3894

Mr. Walter J. Stachon **PETITIONER**
10345 Z Street
Omaha, NE 68127

Dear Mr. Stachon:

This letter is to inform you that we have granted your request for exemption. It transmits our decision, explains its basis, and gives you the conditions and limitations of the exemption, including the date it ends.

EXEMPTION APPLICATION DATE

By letter dated July 7, 2015, you petitioned the Federal Aviation Administration (FAA) for an exemption. You requested to operate an unmanned aircraft system (UAS) to conduct aerial imaging of agriculture crop improvement research and development experiments and monitoring farm production.

AUTHORIZED USES FOR THE BELOW DRONES

See the docket, at www.regulations.gov, for the petition submitted to the FAA describing the proposed operations and the regulations that the petitioner seeks an exemption.

The FAA has determined that good cause exists for not publishing a summary of the petition in the Federal Register because the requested exemption would not set a precedent, and any delay in acting on this petition would be detrimental to the petitioner.

Airworthiness Certification **DRONE MANUFACTURER**

The UAS proposed by the petitioner is a SenseFly eBee Ag.

In accordance with the statutory criteria provided in Section 333 of Public Law 112−95 in reference to 49 U.S.C. § 44704, and in consideration of the size, weight, speed, and limited operating area associated with the aircraft and its operation, the Secretary of Transportation has determined that this aircraft meets the conditions of Section 333. Therefore, the FAA

U.S. Department of Transportation
Federal Aviation Administration

800 Independence Ave., S.W.
Washington, D.C. 20591

February 5, 2016 **EXEMPTION GRANT DATE**

Exemption No. 14717
Regulatory Docket No. FAA–2015–5631

Mr. Larry Welk III **PETITIONER**
12653 Osborne Street, #6
Los Angeles, CA 91331

Dear Mr. Welk III:

This letter is to inform you that we have granted your request for exemption. It transmits our decision, explains its basis, and gives you the conditions and limitations of the exemption, including the date it ends.

EXEMPTION APPLICATION DATE

By letter dated August 19, 2015, you petitioned the Federal Aviation Administration (FAA) for an exemption. You requested to operate an unmanned aircraft system (UAS) to conduct aerial photography newsgathering and closed-set motion picture filming. **AUTHORIZED USES FOR THE BELOW DRONES**

See the docket, at www.regulations.gov, for the petition submitted to the FAA describing the proposed operations and the regulations that the petitioner seeks an exemption.

The FAA has determined that good cause exists for not publishing a summary of the petition in the Federal Register because the requested exemption would not set a precedent, and any delay in acting on this petition would be detrimental to the petitioner.

DRONE MANUFACTURERS

Airworthiness Certification

The UAS proposed by the petitioner are the DJI S1000 and Intuitive Aerial Aerigon.

In accordance with the statutory criteria provided in Section 333 of Public Law 112−95 in reference to 49 U.S.C. § 44704, and in consideration of the size, weight, speed, and limited operating area associated with the aircraft and its operation, the Secretary of Transportation has determined that this aircraft meets the conditions of Section 333. Therefore, the FAA finds that relief from 14 CFR part 21, *Certification procedures for products and parts,*

Appendix A2: Dictionary for Categorization of Exemptions into Usage Categories

Usage Category	Keywords in Dictionary	Example Sentences in Exemptions
Professional photography and videography	media; broadcas; closed set; film making; news; closed-set; photojournalism; feature films; televis; wedding; film and tv; film production; photography of nature scenes; movie; closed set filming; marketing campaign; high definition; sport; filmmaking; film-making; for use in films advertising; motion picture; special event; professional photo; video production; high-resolution; high resolution; high quality; cinematographic; for journalistic use; golf course marketing; local tourism; landscape; promotional video; outdoor events; hosted events; recording live events; for events and marketing; commercial video; commercial photo; commercial film realtor; real property; real-estate; real estate; homes for sale; homeowner properties; homes and properties; housing and business properties; of propert; private prop; property survey; property due dil; residential prop; properties for sale; properties and buildings; homes the team lists for sale; homes the petitioner list for sale; individual property	"scripted, closed-set filming for the motion picture and television industry" "capturing high definition feature film quality aerial cinematography" "videography and closed-set filming, aerial photography, mapping, surveying, inspection, and real estate photography" "wedding and real estate photography" "aerial data collection and closed-set tv/movie filming"
Long-distance surveying	disaster railroad; ocean; pipelin; catastrophe; security; tranmiss; land survey; oil; archaeological; land management; large acreage; public roadways; first responders; casualty site; water; rescu; maritim; bridg; solar farms; rural; power line; emergenc; nature monitoring; mining; coal; mineral; forensic; reconnaissance; patrol; ecological; large acerage; vegetation; forestr; wildlif; biological surveying; environmental; terrain photogrammetr; contour; geophysical; geospatial; orthomosaic; spatial analysis; geotechnical; digital cloud print; 3d; three-dimensional; orthorectif; topograph; lidar; gis; geographic information system; gps-based surveying instrument	"high definition aerial photography for search and rescue operations, law enforcement personnel, and other first responders" "aerial survey of oil and gas pipelines in rural areas" "for power line inspection and general mapping for utility companies" "documentation of archaeological sites" "conduct aerial land surveying and geospatial services"

Short-distance inspection	elevated; turbin; facility inspection; inspection of plant infrastructure; landfill; inspections of gas and electric utilities; communication; flare; architerctur; site inspections; building sites; building inspection; property damage; telecom; construction; equipment inspection; electric power; structure inspection; roof; power plant; powerplant; industrial structures; tower; visual inspection of industrial structures; safety inspection; electrical power; building projects; insurance; aec industry; stack; wind; industrial assets; petro; energy; inspection of power infrastructure; industrial facilit evaluation of infrastructure; infrastructure inspection; infrastructure evaluation; inspections of infrastructure; inspection of infrastructure; evaluations of infrastructure; property inspection; power generation; power distribution; project sites; vertical struct; traffic insured customer; risk assessment; rf signal	"infrastructure and construction inspection" "photography, surveying, and videography for real estate, construction, and utility inspections" "aerial imaging for insurance purposes" "aerial inspection of renewable wind power turbines" "utility infrastructure and equipment inspection" "aerial photography for inspections of turbine blades"
Precision agriculture	agriculture; crop; farm	"operations to map crop acres and assess crop damage" "precision photogrammetry and crop scouting for precision agriculture" "aerial data collection for agriculture, mining, and surveys"
Aerial delivery and supply chain management	delivery; prime air; inventory management; material stockpiles; stockpile inventor	"volumetric measurements for inventory management" "research and development for surveillance, conducting inventory, and package pickup and delivery" "conduct outdoor research and development testing for prime air." "aerial data collection to maintain accurate and precise measurements of its material stockpiles"