

Commercialization in LEO: Perceived Importance, Willingness to Pay, Willingness to Risk, Domain-Specific Knowledge, and Openness to Experience as Constructs

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Abstract

This quantitative study aims to measure the keys to the sustainability of space tourism by analyzing students' attitudes on willingness to pay, willingness to risk, domain-specific knowledge, openness to experience, and their relationship with the importance of a low Earth Orbit (LEO) ecosystem. On June 7, 2019, NASA announced it would allow commercial use of its portion of the International Space Station (ISS) with plans for development in LEO. NASA's long-term goal is to turn operations to the private sector, becoming a consumer of the human spaceflight enterprise and sparking a commercial demand in LEO. Using space tourism as the first step in LEO commercialization, this research aims at several individual factors that relate to the perceived importance of developing a sustainable LEO ecosystem. We designed a survey, dispersed it among students as potential future consumers, and analyzed 126 responses. Using a SAS regression analysis, we found that openness to experience strongly relates to an LEO ecosystem's importance. However, willingness to pay, willingness to risk, and domain-specific knowledge were not.

Keywords: willingness to pay, willingness to risk, openness to experience, space tourism, LEO ecosystem

The U.S. Congress passed the National Aeronautics and Space Administration Transition Authorization Act in 2017, calling for NASA to develop an ISS Transition Plan to expand human presence in Low Earth Orbit (LEO) through international, academic, and industry partners (Cruz, 2017). The ISS Transition Plan allows commercial use of its portion of the ISS with plans for development in LEO (nasa.gov, 2019). NASA's long-term goal is to turn over operations to the private sector, becoming a consumer of the human spaceflight enterprise and sparking a commercial demand in LEO. The transition is described as (moving) "from the current regime that relies heavily on NASA sponsorship to a regime where NASA could be one of many customers of a low-Earth orbit non-governmental human space flight enterprise." (Cruz, 2017, pg.131).

Were such a transition to successfully occur, it would represent a great example of Schumpeter's process of "Creative Destruction" (Schumpeter, 1961; Landgoodi, 2017). Such destruction is difficult to predict because it is challenging to predict consumer demand due to limited historic purchase patterns in something new like LEO commercialization. As we develop later, space tourism is a likely first step in LEO commercialization. Unlike previous studies of space tourism that used an information acceleration theory to predict growth (e.g., Crouch *et al.*, 2009), we adopt the more Schumpeterian approach of examining socio-psychological issues and

conduct a study more focused on what would *motivate* consumer demand for space tourism (Karadağ, 2016; Landegroodi, 2017; Prasetyo, 2019). As space tourism is asking consumers to risk their lives and considerable sums of money, this study focuses more on the perceived importance of developing a sustainable LEO ecosystem with space tourism as the starting point.

Creative Destruction in the Space Industry

Because of economic, political, and environmental factors, the U.S. Space Shuttle program officially ended on August 31, 2011, after paving the way for private shuttle companies (Houston, 2013). Earlier policies drawn from an era where NASA sponsored or led most of the work are considered “old space” policies and focused on clear and identifiable concrete challenges directed by centralized agencies. The “old space” markets were business-to-government or business-to-business services. The “new space” consists of companies that use decentralized innovation systems. The “new space” market is a key driver in the global space economy and focuses on business-to-consumer services (Robinson & Mazzucato, 2019).

Companies such as Blue Origin have a “vision of enabling a future where millions of people are living and working in space for the benefit of Earth,” SpaceX speaks of “making life multi-planetary.” One of the most accessible missions for creating a sustainable LEO ecosystem is transporting private individuals—who have paid a considerable sum of money—into space. While these space flights could pursue scientific outcomes, the more likely purpose for these private space flights is tourism. Indeed, while Blue Origin and SpaceX tout aims far beyond space tourism, Virgin Galactic’s current system is capable only of space tourism missions.

The costs associated with developing the sustainable LEO ecosystem as the first step to achieving grander space travel ambitions are still a substantial financial risk for private companies (Leigland, 2018). Some public funding is likely necessary to create an LEO ecosystem. Hence, these space companies require sufficient public support to make governmental investments into space popular or acceptable and the interest of wealthy individuals to purchase spaceflights and invest in the company.

From another aspect, NASA concentrates on “in-space manufacturing, regenerative medicine, bioengineering, and other fields that may lead to a scalable, financially self-sustaining demand for low-Earth orbit capabilities” (nasa.gov, 2019, pg. 24). However, this study aims to investigate the keys to attaining public support for a sustainable LEO ecosystem. Specifically, we seek to further the understanding of consumers’ motives and attitudes toward space tourism. We aim to answer: How do personal factors relate to how important a person feels that NASA is working with businesses to develop a sustainable ecosystem in LEO?

We briefly review prior research into consumer attitudes toward space tourism to achieve this aim. Drawing from these studies and the personality literature, we hypothesize four relationships between the importance of an LEO ecosystem and a person’s willingness to pay, willingness to risk, domain-specific knowledge, and openness to experience. We next describe the study methodology. The last section of our study discusses key findings from data analysis and implications for sustainable space tourism development.

The Growing Movement Toward an LEO Ecosystem

The FAA considers *commercial space transportation* as the movement of or means of moving objects, such as satellites and vehicles carrying cargo, scientific payloads, or passengers to and from or in space (Benjamin, 2018, pg. 87). Lockheed Martin, Raytheon, Boeing, and Orbital ATK manufacture 73.8% of the market share of space reusable vehicles (SRV). SpaceX, Virgin Galactic, and Blue Origin are creating more industry competition contributing to price competition from which consumers benefit (Benjamin, 2018). The years 2020 and 2021 were historical for NASA, SpaceX, Virgin Galactic, and Blue Origin. They launched their first-ever private space shuttles from U.S. soil and private astronauts and space tourists. The segmented consumer markets are commercial, military, and government. However, Lee and von Tunzelmann (2005) describe a model of a national innovation system that comprises five actors: government, industry (firms), research institutes (public and private), foreign companies, and universities. NASA created an emerging multi-actor space ecosystem approach that involved a more open-ended objective that does not have a unified or clearly defined end game (Mazzucato & Robinson, 2018).

New products and services from these emerging U.S. space ventures are flooding the marketplace. These include revolutionary, low-cost services now being offered by U.S. companies in the fields of Earth observation, space situational awareness, satellite tracking, space launch, and space manufacturing. After many years of promising advancements, “new space” companies bring revolutionary products to the marketplace, shifting space power leadership back toward the U.S. (Moltz, 2019).

However, legal, financial, and technical preparation costs can discourage potential private bidders from competing for projects (Leigland, 2018). De Schepper *et al.*, (2015) noted widespread agreement among practitioners and academics that private-public partnership (PPP) preparation costs are higher than preparation costs associated with traditional public procurement. In some cases, it undermines the primary cost-effectiveness rationale of PPPs and negatively impacts the economic and financial viability of the project.

To help with some of the high costs, the U.S. government created program initiatives to stimulate small U.S.-based high-tech firms by supporting high-risk research and development to provide technological innovations for public agencies to achieve their missions for the broader market (Wallsten, 2000). The initiative has become a significant funder of high-risk innovation in the U.S. instead of private venture capital investments (Audretsch, 2003; Block & Kellar, 2015; Lerner, 1999). Public support for NASA and the LEO ecosystem is essential to sustain funding for these initiatives. The notion of space tourism is a principal mechanism to build and sustain popular support for space programs.

Previous Examinations of Popular Attitudes Toward Space Tourism

Crouch (2001) describes the early generation of space tourism beginning on Earth as the movement of astronomical observers to different locations to observe better certain astronomical phenomena such as eclipses and planet movements. Studies also measured attributes of space tourism derived from the duration of the visit, market demand, willingness to pay, and most popular activities (Crouch, 2001). A Space Tourism market study completed in 2002 expected suborbital annual passengers of 15,000 and \$700 million in space tourism revenues by 2021 (Chang, 2015). Another study forecasted that suborbital space tourism would generate over 12,000 passengers, more than \$676 million in revenues, and ticket prices at \$50,000 by 2021 (Ziliotto, 2010). That has not happened.

While the development and adoption of the space tourism industry segment have been slow, commercial space tourism and transportation demand expectations will surge in the upcoming years (Benjamin, 2018). Furthermore, 2020 and 2021 were historical years for space tourism. SpaceX, Virgin Galactic, and Blue Origin launched their first historical private space shuttles from U.S. soil, with private astronauts as space tourists. Virgin Galactic is advertising a ticket price of \$450,000 for a 90-minute commercial flight into space (Kay, 2022).

Previous studies describe the transformation of the first powered airplane flight to the first shuttle missions. The qualifications for being awarded USAF Astronaut Wings profoundly affect travel and the tourism industry (Benjamin, 2018; Crouch, 2001; Crouch et al., 2009). These studies examined general consumer interest in space tourism and what tourism experiences would attract consumers.

Consumer interest appeared very high in these previous studies. Nevertheless, much has changed in 20 years. NASA grounded its space shuttle fleet in 2011 but not before a second catastrophic loss in 2003. On the positive side, the number of countries participating in space projects increased from 28 to 70 between 1996 and 2017 (Lee *et al.*, 2021). Space enthusiasts can support LEO development even if they can or do not desire to travel themselves. Therefore, we suggest that an investigation of attitudes toward a sustainable LEO with a starting point of space tourism is necessary for building a framework for market creation.

Importance

Studies show that the public sector focuses on the political environment while the private sector focuses on the market environment (Alford & Greve, 2017). Private sectors more specifically focus on a single organization strategy. Doing so can lead to quicker innovations. NASA is driving market creation using private-public partnerships to develop an innovation ecosystem. An *innovation ecosystem* consists of customers, subcontractors, infrastructure, suppliers, competencies, or functions and the links or relationships between them (Mazzucato & Robinson, 2018). The new commercial actors can drive costs down. The emerging multi-actor ecosystem approach has involved a more open-ended objective that does not have a unified or clearly defined end game (Mazzucato & Robinson, 2018).

Through these multi-actor ecosystems, funding opportunities in creating new marketplace technologies also emerge for investors. However, the difference between private and public financing institutions is time and risk. According to Mazzucato & Robinson (2018), public funding institutions often provide longer lead times and the willingness to engage with high uncertainty, thus making R&D expenditures attainable through mission-oriented public institutions such as the National Science Foundation and Advanced Research Projects Agency. These public funding institutions play a vital role in the innovation chain and market-making (Block & Keller, 2015). However, developing an LEO ecosystem also contains uncertainty, time lags, and failures in exploring new opportunities. Public understanding and support for the *importance* of an LEO ecosystem should sustain public funding for innovation, even if there are occasional setbacks and failures. For that reason, public awareness of PPPs' benefits in creating an LEO orbital econ reflects global and consumption-related values, and evaluations of brand attributes are related to the perceived importance of consumer preference for consumer products or services (Vinson et al., 1977). Therefore, understanding the importance of developing an LEO ecosystem is necessary based on the value perceived by consumers and evaluating attributes on consumers' expectations.

Willingness to Pay

According to the standard economic theory of consumer choice, it is essential to know consumers' *willingness to pay* (WTP) for current and new product and service prices (Jedidi & Zhang, 2002). WTP is defined as the maximum price at or below which a consumer will buy one unit of the product (Varian, 1992). Marketers gauge consumers' WTP to create pricing and promotion strategies, measure value and develop new products (Anderson et al., 1993; Jedidi & Zhang, 2002; Shaffer & Zhang, 1995, 2000).

Studies also show that a consumer's WTP is the most significant indicator of brand loyalty and equity (Aaker & Moorman, 2017; Netemeyer et al., 2004). Therefore, consumer brand purchasing behavior indicates their willingness to pay a premium price considering the perceived value cost and brand uniqueness (Netemeyer et al., 2004). We suggest that a higher WTP for a space tourism event would indicate the person has a higher estimation of the importance of a sustainable LEO ecosystem. Accordingly, we hypothesize the following:

H1a: Willingness to pay is positively related to the importance of a sustainable LEO ecosystem

Willingness to Risk

According to consumer research, Mandel (2003) states that *risk* is defined as either uncertainty or consequences (Campbell & Goodstein, 2001; Dowling, 1986). Consumers' risk perceptions determine their evaluations, choices, and behaviors (Dowling, 1999). The higher the perceived risk, the more negative consequences are associated with consumers becoming wary and risk-averse (Campbell & Goodstein, 2001; Oglethorpe & Monroe, 1994).

De Wulf *et al.*, (2001) define *trust* as a consumer's confidence in a brand's reliability and integrity. Trusting behaviors are related to consumers' willingness to engage in risk-taking behavior. Trust also encourages a person to take risks because of positive expectations (Walczuch & Lundgren, 2004). Delgado-Ballester & Munuera-Aleman (2005) study consumers' acknowledgment of risk according to trust as the experience of a recognized brand name. Within NASA's multi-actor ecosystem, many recognizable brands, such as Virgin Galactic, Blue Origin, and SpaceX, are beginning to fulfill consumer space tourism expectations.

Therefore, we suggest that an individual's *willingness to risk* (WTR) by engaging in space tourism, much as their WTP to engage in space tourism, indicates that the person values a sustainable LEO ecosystem more highly. Therefore, we hypothesize the following:

H1b: Willingness to risk is positively related to the importance of a sustainable LEO ecosystem

Domain-Specific Knowledge

Tied closely are consumers' knowledge and expectations. As previously stated in this study, the risk is directly related to consumers' evaluation of products and services. Consumers' WTR is central to their evaluations, choices, and behaviors (Dowling, 1999). Narrowing in from consumer expectations to consumer knowledge, we focus on *domain-specific knowledge* (DSK) held in long-term memory. DSK is defined as memorized information that can lead to action permitting specific task completion over indefinite periods (Tricot & Sweller, 2013). Values

developed from DSK are used in market analysis for greater precision and effectiveness in market segmentation. These values can act as a bridge between global, descriptive, and evaluation beliefs about product attributes.

The acquisition of DSK is costly, however. Engaging in memorization to accrue DSK requires extensive cognitive resources. We posit that individuals' level of investment in allocating the resources needed to develop DSK for the space program is also likely to suggest their weighted importance in developing a sustained LEO ecosystem. Therefore, we hypothesize:

H2: Domain-specific knowledge is positively associated with the importance of a sustainable LEO ecosystem

Openness to Experience

Openness to experience (OTE) is associated with the Five-Factor Personality Model (Costa & McCrae, 1992) and captures the extent to which individuals are broad-minded, curious, imaginative, and original (McCrae, 1987). People high in OTE are more willing to embrace new concepts and are highly motivated to actively seek new and varied experiences (Baer & Oldmahan, 2006; McCrae & Costa Jr, 1997). Also, those high in OTE appreciate new ways of doing things and the potential for improving and changing the status quo through observing novel and diverse information and knowledge (McCrae & Costa Jr, 1997). Lastly, previous studies show that people with OTE are more likely to trust and have knowledge-sharing behavior (Matzler et al., 2008; Walczuch & Lundgren, 2004).

Those rated high in OTE are revolutionary in nature and show an affinity for experimentation, indicating an openness to support private companies' opportunities to develop a sustainable LEO ecosystem (George & Zhou, 2001). Furthermore, OTE centers around novel ideas and experiences, suggesting that these individuals value unique "out of this world" experiences. Therefore, we hypothesize the following:

H3: Openness to experience is positively related to the level of importance of a sustainable LEO ecosystem

Methodology

This study used a sample of 125 college students enrolled in undergraduate business courses in a mid-sized public university in the southwestern United States. Thirty-six percent of the respondents hailed from outside the United States. The average and median ages of the respondents were 22 years old. The relative youth of the sample is helpful because they are more likely to represent the future beneficiaries of and participants in an LEO economy.

Measures

This study uses a five-point Likert-type scale (1 = not at all important, 5 = very important) to measure the dependent variable of importance: "How important is it that NASA is working with businesses to develop an orbit economy (Orbit Econ) in LEO?"

We measure WTP using direct and indirect questions for this study. Brown et al. (1996) argue that it is cognitively more effortless for a respondent to decide if a specific price for a product is acceptable than to assign a price directly. We asked respondents, "What is the highest price you would pay for a two-day trip on a rocket ship in LEO?" Consequently, we presented a

series of five price options and asked which the respondent was most likely to purchase. The respondent could also indicate they would not go to space under any condition. However, responses for the two measures of WTP correlated poorly ($r=.17$). We used the direct question of the highest price a person would pay for the analysis. We again used two items to measure willingness to risk for this study. The first question addressed the probability of a positive event (safe flight) in similar studies (Kozak *et al.*, 2007; Ritchie *et al.*, 2017). The second question asked about respondents' willingness to participate even though they could perish in spaceflight (Wolff & Larsen, 2017; Wolff & Larsen, 2016). We then averaged these scores for the analysis.

DSK measurement used five items: Is NASA private or publicly funded? Who was the first man to walk on the moon? Who built the engines for the Space Shuttle Program? When was the last year in which a space shuttle flew? Which of these shuttles was destroyed in catastrophic accidents? We summed the number of correct answers to measure the respondent's overall knowledge.

This study measures OTE using items derived from the NEO Five-Factor Inventory (Costa & McCrae, 1992). The scale has been used in numerous previous studies and is deemed highly credible (George & Zhou, 2001; Matzler & Grabner-Kräuter, 2006; Zhang *et al.*, 2019).

Analysis and Results

We used SAS 9.3 to conduct an ordinary least squares (OLS) regression analysis. Given all variables' continuous or interval nature, OLS is an appropriate evaluation technique (Montgomery *et al.*, 2012). Missing values in some observations reduced the sample size to 118 for the analysis. Table 1 holds the summary statistics for the sample. Table 2 holds the results of the regression analysis. The hypotheses regarding a positive relationship between willingness to pay, willingness to risk, and domain-specific knowledge received no support ($p>0.10$ in all cases). Hypothesis 3 concerning a positive relationship between the level of importance in building a sustainable LEO ecosystem and openness to experience is strongly supported ($p<0.001$). We also tested an alternate model using the indirect measure of willingness to pay and found the same results. The highest variance inflation factor was only 1.09, suggesting no significant issues with multicollinearity. An analysis of Cook's D indicated one highly influential observation. Removing that observation from the analysis did not significantly change the results.

Table 1: Means, Standard Deviations, and Coefficients for Key Variables

		<i>Importance of an LEO Ecosystem</i>					
Variable		Mean	SD	1	2	3	4
1	Importance	3.64	1.07				
2	High Price ^a	1.37	9.90	-0.01			
3	Risk	5.27	2.44	0.15	0.11		
4	Openness	35.51	6.52	0.42	-0.12	0.18	
5	Knowledge	2.65	1.05	0.05	-0.03	0.06	0.07

Note(s): \$ Million, coefficients 0.18 and greater are significant at $p < 0.05$ level. For this table $n = 118$

Table 2: Results of the Regression Analysis

High Price (1)	0.15
Willingness to Pay (2)	0.87
Willingness to Risk	0.87
Domain-Specific Knowledge	0.86
Openness to Experience	0.0001***
R^2	0.20
Adjusted R^2	0.16

Note(s): $n = 118$; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$; Standardized coefficients are shown

Discussion

Given the cost and complexity of creating an LEO ecosystem, understanding factors positively related to how important an individual views a sustainable ecosystem is essential to its development. Considering that space tourism is one of the early components of that sustainability, part of our research involved a person's willingness to pay and risk participating in space tourism. However, we found no significant evidence that a person's willingness related to how important they viewed an LEO ecosystem. While this outcome may have been because of methodical limitations, as we discuss later, it also may suggest a hopeful situation for the backers of a sustainable ecosystem. People may think an LEO ecosystem is important even if they do not wish to participate in that ecosystem directly. The same is true for the lack of a relationship between the space program's knowledge and the importance of the LEO ecosystem. People may think it is important even if they do not know the details.

The positive relationship between OTE and its importance is essential for promoting an LEO ecosystem. Individuals with higher OTE scores prefer and are loyal to brands that promote

a fun and playful experience (Matzler et al., 2006). Valuing creativity, individuals with high OTE favor complex tasks with multiple means and unclear ends (e.g., Campbell, 1988; Huber, 1985; George & Zhou, 2001). Therefore, those scoring high in OTE may value an LEO ecosystem for its challenge and complexity.

Previous studies show that OTE is useful in marketing segmentation and targeting because those scoring high on OTE respond stronger to stimuli (Matzler & Grabner-Kräuter, 2006). Studies have also shown that OTE positively affects brand evangelism (Doss & Carstens, 2014). OTE people also spread positive word-of-mouth messages (Anastasei & Dospinescu, 2018). OTE consumers look for conversation-worthy topics to post on social media, giving brands a constant free and credible advertising stream. Furthermore, marketers know how to connect with individuals high in OTE, allowing promoters of an LEO ecosystem to connect with these individuals more effectively (Caliskan, 2019).

Limitations and Future Study

While a sample of college students perhaps represents the future customers of a sustainable LEO ecosystem, they do not necessarily represent individuals who currently can invest funds and influence governmental policy. Therefore, additional studies with more middle-aged respondents would be necessary. Furthermore, we developed measurement items for three of the four dependent variables. We used established items for only OTE. It was also only OTE where we found a significant relationship, so the developed items may not be effective. Indeed, we discussed earlier the poor correlation between the two willingness to pay items. It may be that neither was effective. As for domain knowledge, respondents potentially looked up answers on the web while others relied only on their knowledge. Also, using only five items to measure domain knowledge may be too few to accurately assess the respondents' knowledge level. We recommend more work be done to develop validated measures for these key constructs.

Conclusion

One Bank of America analyst estimates the space economy will eclipse a trillion-dollar annual market within a decade (Sheetz, 2020). Based on the results of our study, supporters of a sustainable LEO ecosystem do not have to want to fly in space or even know the history of NASA. Those supporters are creative individuals who value tackling complicated tasks and enjoy fun and playfulness along the way. Suppose these lofty projections for the space industry are to come to fruition. In that case, it will require disciplined financial investments, sound technology, and an atmosphere that engages people who thrive on new experiences. Hence, perhaps people like Jeff Bezos and Elon Musk seem like ideal evangelists for an LEO ecosystem.

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