



**A Journal Of Perspectives**  
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**The Lens Journal**

*A journal of perspectives for young researchers*

Dear Readers,

I am delighted to introduce you to the inaugural issue of The Lens, an interdisciplinary journal committed to nurturing innovative ideas and fresh perspectives across diverse fields. As Editor-in-Chief, I am proud to present this first issue, encompassing cutting-edge articles in economics, business, environmental studies, and more. The Lens aspires to enhance academic understanding and knowledge through the publication of high-quality, peer-reviewed research and the cultivation of a community of young researchers.

We are excited to announce our partnership with Ascend Now Pte. Ltd., the premier provider of personalized education fostering academics and beyond in students from all over the world. This collaboration will help expand the reach of our research and further our mission to promote interdisciplinary understanding.

This issue delves into various urgent topics that embody our interdisciplinary approach. Our opening article offers strategies for Chinese companies aiming to integrate into foreign markets. We outline methods for firms to adapt products, marketing, and business models to appeal to Western consumers and establish a presence in developed economies, presenting examples of successful Chinese brands.

In the second article, we examine the impact of sneaker collaborations on the resale market. Using data from prominent resale platforms, we discover that shoes from sought-after collaborations can sell for up to 75 times their retail price. We discuss how brands can generate hype through such partnerships and how the secondary market has become an integral part of streetwear culture.

Our third article investigates the role of public-private partnerships in promoting sustainable development in least-developed countries. The author contends that, when appropriately structured, these partnerships can be effective tools for overcoming challenges, provided that risks are managed and local input is taken into account. Lastly, we appraise affordable aquaponics systems for education. We evaluate three options based on affordability, complexity, and scalability, and offer a step-by-step guide for the recommended system - realistic, adaptable, and efficient for teaching STEM.

At The Lens, interdisciplinary collaboration is crucial for addressing today's multifaceted challenges. We believe this issue will spark new ideas, foster deeper understanding, and contribute to the global exchange of knowledge among young researchers. Thank you for supporting The Lens and our partnership with Ascend Now. We eagerly anticipate your feedback and involvement as we explore these critical topics. The future is unwritten, and we aim to play a role in shaping it.

Best,

**Ruchi Steven**  
*Editor-in-Chief*



# How can a Chinese Company Successfully Integrate Itself in Foreign Markets?

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## Abstract

China's global influence has grown immensely in recent times. It has been propelled to the top, becoming a global superpower, much like the US. However while the latter has plenty of global household brands like Apple and Amazon, the former doesn't, highlighting the struggles most Chinese companies face on their path to global influence. While there are a few success stories, such as Lenovo, the majority of corporations have attempted and failed drastically due to lack of trust and chemistry between producer and consumer. Many Chinese firms fail to adhere to social standards in the West and struggle to adapt to and differentiate between new markets, instead thinking that each market works the same. This way of thinking is one of the main reasons why the outcome of a Chinese company going global is seldom positive.

*Keywords: Western Market, Global, Chinese Company, Expansion*

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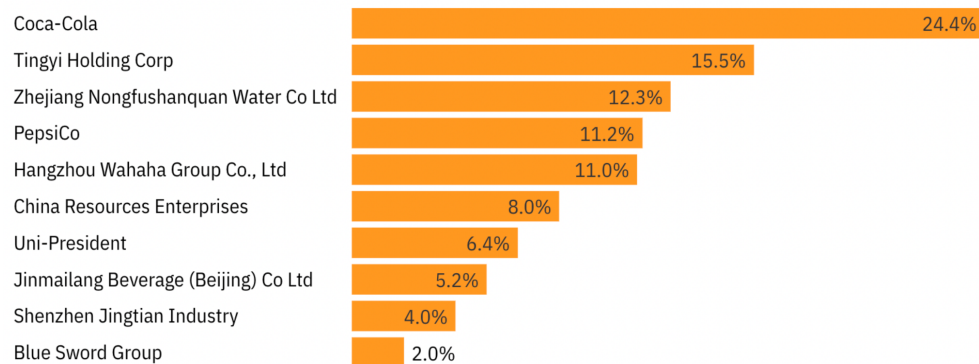
The last 30 years have seen a surge in China's global influence and prosperity, propelling itself to the top of command and becoming a global economic superpower. In fact, when assessing Purchasing Power Parity (PPP), China's economy is the largest worldwide. PPP is an index that compares the purchasing power of each currency, and according to a phenomenon known as the Penn effect, China's PPP is attributable to its low wages and labor costs combined with its incredibly productive and specialized industries (China didn't really pass the U.S economically.). Yet, this global superpower seems to lack household name brands such as Apple and Amazon; anyone can walk around the streets, supermarkets, malls of a western country and the chances of seeing any Chinese company is low. Even if someone is tasked to think of five different Chinese businesses, most people would likely struggle. Meanwhile, coming up with five American companies would be a rather simple task. So what are the determining factors for global success and how can China's biggest brands successfully integrate into foreign markets? Well, although there are a few exceptions, most Chinese companies that try to go global fail miserably due to the different strategies used between Occidental countries and China. Chinese business Jianlibao, is an example of a failed attempt to go global meanwhile Lenovo was one of few Chinese corporations that succeeded to go global.

Founded in 1984, Jianlibao Group emerged as a leading competitor in China's sports drink and beverage market, on par with Coca-Cola and Pepsi. Due to its national success, the company decided to expand outwards to more than a dozen international markets in the 1990s. Jianlibao, by now accustomed to its domestic success, was confident their product would be widely popular in Occidental countries as well. However the outcome was far from ideal, and Jianlibao's

expansion collapsed before it even started, for a number of reasons. Jianliboa failed to allocate its funds properly; although they spent a lot of money on grand parties and expensive real estate to get on good terms with American politicians, they lacked strategic spending on marketing and broader distribution networks (J. Backelar, February 25, 2014). The firm also miscalculated the importance of adapting its name and presence to conform with client needs in diverse demographics, and refrained from changing their mother name Jianlibao even in the international markets. This proved to be a fatal flaw, as Jack Shea -former vice president of marketing and sales of North America for Jianlibao- stated, “its brand name prevented it from being able to connect with the average American consumer” (J.Backelar, May 13, 2012). While Western consumers were familiar with long-time household names such as Coca-Cola, Fanta, and Sprite, Jianlibao lacked brand-building engagement and was like any other unfamiliar drink available: it failed to connect and create a long-lasting impression on consumers abroad.

As Jianlibao’s emergence as a globally renowned company seemed to become improbable, Coca-Cola quickly exploited this as an opportunity to implement itself in the Chinese markets and adapt to fill consumer’s unmet needs. Coca Cola’s Chinese brand name Kekou-Kele was a technique to connect more with their Chinese clients while keeping a similar name to their original counterpart. It proved effective and beneficial as it became an important player in the market and expanded its worldwide influence. As for Jianlibao, after failing internationally and also losing market shares in China from the likes of Coca Cola (as can be seen from Figure 1), it became clear that their market strategies, resource allocation, and lack of flexibility had cost them dearly.

#### Share of value of the soft drinks sector, 2020 (million USD)



Source: GlobalData

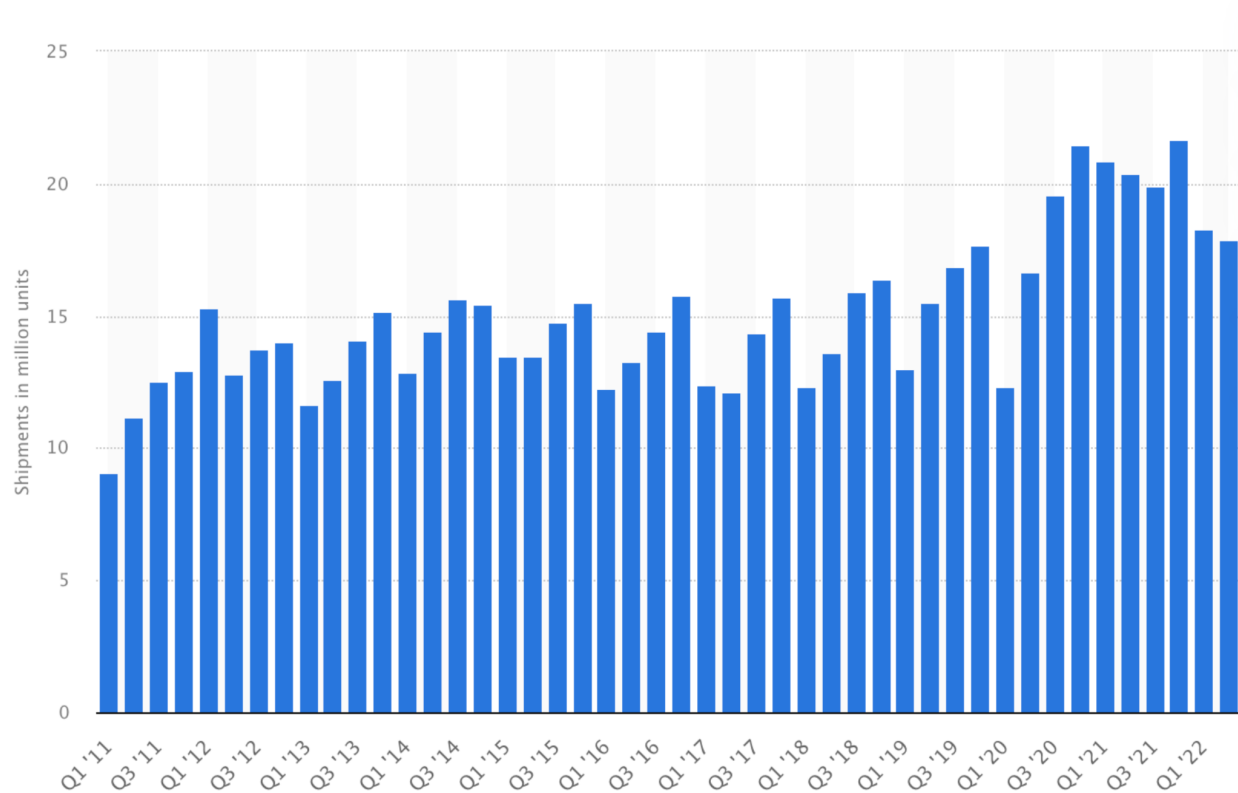
JUST DRINKS

**Figure 1.** Percentage shares of the soft drink sector in China as of 2020 (China's Soft Drinks Category, February 25, 2014)

Coca Cola went on to become the biggest soft drink company in China, having 24.4% of the soft drink sector in China as of 2020. Jianlibao ultimately abandoned the international markets in the late 1990s and was sold to a state owned enterprise called Zhejiang SDIC for 339 million Yuan. However their business continued deteriorating until Jianlibao was sold to the Unification Group for 100 million Yuan (Laitimes, October 26, 2021). Jianlibao's tragic downfall from a top beverage company to one that is a distant memory to the Chinese population marks a recurring pattern among many large Chinese companies, but not all.

Lenovo is one such example: it seems to have overcome barriers that their Chinese counterparts have stumbled upon, and its emergence as a globally recognised company is a case to understand. Also founded in 1984, this tech corporation

experienced a different reception to its product and has become incredibly popular around the globe, as its cameras, computers, and TVs are a staple of technology in many households. The company's revenue amounted to over \$71 billion in 2021, and has spurred the company's market cap to be listed at over \$66 billion. Lenovo's net profits in 2021 aggregated to over \$2.1 billion and have enabled the company to employ roughly 75000 employees. In the 4th Quarter of 2021 alone, Lenovo shipped more than 22 million computers worldwide, and is competing against tech giants like Microsoft and Apple (T. Alsop, August 8 2022).



**Figure 2.** *Lenovo PC Unit Shipments Worldwide 2011 to 2022 by Quarter (T. Alsop, August 8 2022)*

Lenovo's success story easily overshadows Jianlibao's failed global emergence, but why has the former's success far exceeded the latter's? Perhaps the most influential reason for Lenovo's emergence was its acquisition strategy: buying and partnering with competitors to grasp market demographics, gain useful insight on customer needs, and adapt to local consumers and customs (J. Fernando, July 18, 2022). Notably, Lenovo acquired IBM and its PC sector, which as Yang Yuanqing- the Chairman and CEO of Lenovo- mentions, "transformed Lenovo overnight into a truly global company, changing not only [the company] but [the] industry," (Lenovo Marks Decade of Success, May 24, 2019). However, it quickly became apparent that language barriers and cultural differences could impede the company from taking the next step and reaching the top of the industry. Specifically, miscommunications, misunderstandings, and different approaches were clashing and leading to less productivity and efficiency (W.J. Holstein, August 8, 2014).

Lenovo solved this by making English the official language at Lenovo and hiring western executives, transforming the original mother company from a Chinese-led corporation to a Chinese-bred corporation led by diversity but uniformity. The result: an executive board with multiple international members, and a diverse set of global perspectives that work in

symphony to decrease miscommunications and disagreements between the Chinese and western managers. As Yolanda Conners, the chief diversity officer states, “Both YY (Yang Yuanqing) and Gina (Qiao Jian) are global leaders. They have a genuine curiosity for learning about other cultures, new experiences, and getting out of their comfort zones.” (Goldkern et al). In turn, Lenovo benefits from its expansive array of cultures and values, and combines perspectives to address company challenges and exacerbate growth and expansion. In recent years Lenovo has used such perspectives to implement a key driver of success: the Protect and Attack Strategy. As a combination of both defensive and offensive business actions, this strategy employs a protective approach focused on defending the dominant market shares and supremacy held in China, and exercising a more aggressive approach to attack international markets and continue the upwards trend of influence in Western markets. In China alone, Lenovo controls roughly a third of shares of PC shipments, holding 37% of the 1st quarter of 2022 PC shares in China (Michail., May 26, 2022). They aim to reach a similar magnitude of influence outside their domestic sphere, currently claiming around 25% of global PC market shares, as per the 4th quarter of 2020 (J. Fernando, July 18, 2022).

### Why Companies Succeed in China and Fail Abroad

While many Chinese organizations struggle expanding their reach to Western Markets, the same does not apply to their domestic market; they seem to thrive in China. This can be attributed to their protectionist policies as China’s economic legislations protect domestic companies against their Western counterparts by taxing imports and incentivizing local consumers to purchase Chinese. These policies are not full-proof as can be seen by Coca-Cola’s expansion, yet the high tariffs -Chinese tariff rates are at 2.47% while U.K. tariff rates are 1.28% (China Tariff Rates)- increase barriers to entry and disincentive Western producers from penetrating the Chinese markets. The high tariff rates along with subsidies given to the Chinese companies has made it very difficult for western competitors to gain market shares in the Chinese market. While this helps Chinese organizations domestically, it lacks the foundational support and adaptability needed to succeed in foreign markets, and affects the reputation of Chinese brands leading to decreased levels of trust abroad. As can be seen in figure 3, the three smartphone brands with the least amount of trust are Huawei, Xiaomi, and Oneplus which are all Chinese companies. The margin of trust between the three Chinese smartphone brands and the other four brands is substantial, and heavily influences consumer choices: western consumers would most likely opt out of Chinese products if their Western counterparts provide a similar yet more trusted and established product (S.Reporters, October 24, 2019).

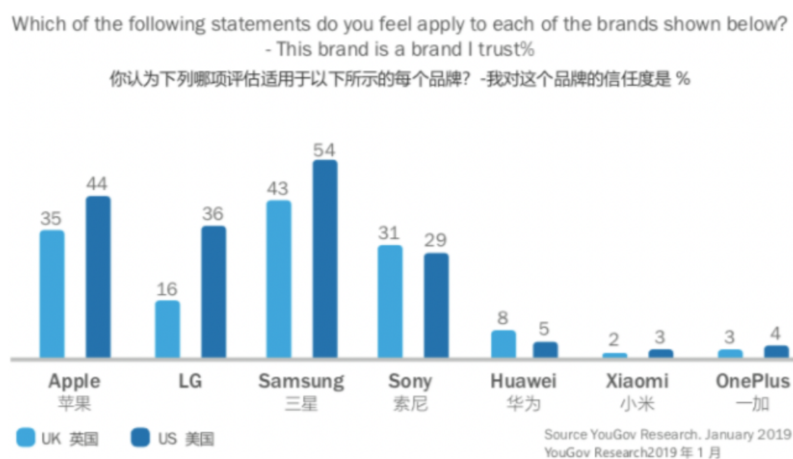


Figure 3. Trust in Smartphone brands in UK and US (S.Reporters, October 24, 2019)

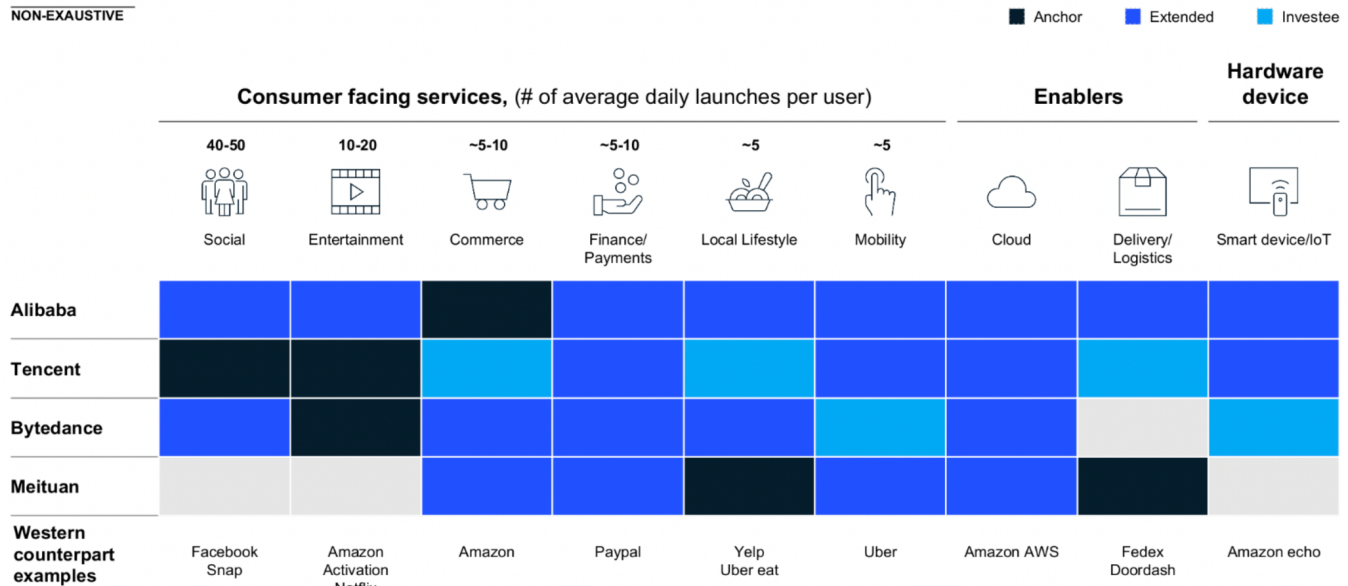
### How Chinese Companies Can Sustain Growth and Emerge as Global Leaders

Chinese companies have employed a myriad of strategies in the attempt to reach global recognition, many of which have resulted in unsuccessful efforts. However, when combining anecdotal evidence of Lenovo and Jianlibao, and distinguishing successful ventures' characteristics from failed ventures, much can be learnt from past errors and experiences.

As a basis, Chinese firms looking to expand their reach abroad must be sustainable and successful in their domestic market (Harvard Business Review [HBR], August 1, 2014) in order to make sure they don't lose their market shares back in China while risking going global. Such is the case of Jianlibao, which failed internationally while also losing in the Chinese market shares (British Broadcasting Corporation [BBC], May 13, 2012). Chinese companies must also learn to adapt to the change in markets. Western markets vary vastly from their Chinese counterparts due to differences in customs, culture, and mannerisms, thus hiring people with local expertise is crucial for success and diversity (D. Harris, June 19, 2021). Such is the case with Lenovo's successful business strategy of gaining knowledge through acquisition of global incorporations (J. Fernando, July 18, 2022). In addition, Chinese organizations must realize that they have to prioritize their western consumer, not the Chinese ones, as they need to meet their needs to grasp market share abroad. Chinese and western customers are widely different, from tastes and preferences to cultures and reactions; a marketing technique widely renowned in China may not adhere to Occidental customers, and a commercial in the US may offend or confuse Oriental customers (D. Harris, August 9, 2021). Failing to recognize the difference in customer needs based on the region and not adapting to client needs and wants, will segregate foreign companies and defeat any chance of grasping market power abroad, as was the case with Jianlibao.

Many Chinese companies try to branch out to western countries in an attempt to go global, failing to recognize or perhaps misinterpreting the extent to which foreign markets are different. For many such companies, going global may not be the best solution. So perhaps Chinese companies need to shift their thinking; India has a population of 1.38 billion people, second only to China, and presents an appealing opportunity for Chinese companies to explore untapped potential. Chinese smartphone manufacturers like Xiaomi, Vivo, Oppo, and Honor are currently all employing this strategy with huge success and collectively they have amassed more than a quarter of the Indian Smartphone market share (Management Study Guide [MSG]). This highlights that Chinese businesses in the horizon may not be dependent on Western markets to increase their global presence, and instead expanding their businesses to nearby regions can work as well if not better to cater to their wants.

A commonly employed business strategy, especially amongst aspiring Chinese companies, is branching out and offering a variety of services, as can be seen in figure 4 (McKinsey & Company, n.d.). For example Bytedance is the owner of the social media app TikTok. Tiktok has had a huge surge in popularity within the last few years. Having more than 1 billion users and being the sixth most popular social media platform in the world, behind Facebook, Youtube, Whatsapp, Instagram and WeChat, Tiktok has helped boost Bytedance's global influence and reach massively (D. Ruby, August 19, 2022).



**Figure 4.** Some of China’s biggest Companies and What they do (McKinsey & Company, n.d.)

After the failure of many Chinese companies to emerge as global superpowers, many of their counterparts may be skeptical to shift their attention and business strategy to pursue western markets. They may think the risks outweigh the benefits; going global is especially difficult for companies who need to adapt to western consumers and diversify company operations and management. However, this feat is far from unachievable, as Lenovo- the Chinese technology titan- has shown. Implementing smart business decisions that allowed their firm to adapt to the western customer and cater their needs, Lenovo was ahead of the curve and dominated its Chinese counterparts. Now a recognized name in many households around the world thanks to its adaptable approach, Lenovo’s rise to stardom has been cemented firmly in Western markets. Chinese companies seeking to emerge from their domestic market, must carefully consider their business prominence in China and look to maintain its Chinese dominance domestically, while shifting to a more diverse and western-focused approach abroad. If they can adapt to new markets and gain consumer confidence, then there is no reason why Chinese companies should fail to go global.

**Limitations**

A limitation that this research essay encountered was how the vast amount of research was on only two Chinese companies. In this research essay a form of extrapolation is used, as patterns from mostly two companies are assumed to be applicable in other Chinese companies that weren’t mentioned in this research essay.

**Acknowledgement**

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# ‘Sneakernomics’: Assessing The Successfulness Of Multifarious Sneaker Collaborations In The Sneaker Resale Market

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## **Abstract**

Scarce-supply in conjunction with the advent of social media has resulted in the conspicuous consumption of sneakers—creating a sneaker resale market with lucrative investment opportunities for both sneaker brands and consumers. As sneaker brands continue to branch, the practice of collaborating with famed endorsers (e.g. celebrities and athletes) on coveted sneakers has become an increasingly profitable endeavor. Although, with a myriad of endorsers to collaborate with, data and information on the success of multifarious sneaker collaborations remains meager due to the nascent nature of the market. As a result, this study compared three sneaker collaboration categories—celebrity signatures, athlete endorsements and brand-brand collaborations—aiming to determine the most successful collaboration category from 2017-2021 on the StockX marketplace for sneaker brands. A total sample of 90 sneakers were collected from StockX’s featured page, with 30 per category, and data on real transaction variables (12 month trading range, volatility, number of sales, price premium and average sale price) were noted for each sneaker. A two-part quantitative methodology was employed consisting of descriptive statistics on StockX sneaker data and inferential statistics on the mean price premium of a collaboration category. An ANOVA inference test with the null hypothesis that there is no difference in the mean price premiums and the alternative claiming there is, corroborated an insignificant p-value. Therefore, with no statistical significance in the mean price premiums, the study concluded that consumers on StockX were not extremely financially invested towards a particular sneaker collaboration, meaning each category was assumed to have equal resale market performance and therefore there wasn’t an ultimate winner in terms of a most successful category. The managerial implications of this study contend that while there was no statistical significance, brand-brand collaborations did produce the largest raw mean price premium (179.23%)—60% more compared to the other two categories. Consequently, although notable brands may already engage in brand-brand collaborations, the findings of this study are more applicable and relevant for smaller, local-level brands that are struggling to grow. By collaborating with other brands on supply-scarce sneakers, smaller brands may be able to generate positive resale market performance that helps them craft a successful image amid a competitive fashion industry in a digitally-influenced economy.

*Keywords:* Sneaker resale market, endorsements, brand-brand collaborations, stockX marketplace, digitally-influenced economy

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## Introduction

### *Scarcity In The Sneaker Resale Market*

In light of innovation in fashion over the past decade, companies in the sneaker industry have been pioneering new and unprecedented avenues by growing their branches through a variety of sneaker collaborations. A limited-supply of sneakers in conjunction with endorsements from celebrities, athletes, artists among other collaborators has fostered the burgeoning of the sneaker resale market and coveted sneaker lineups like the Jordans (BoPing, 2021). In essence, with the use of simple economics, brands have made a calculated manipulation of supply to fabricate a sense of artificial scarcity around sneakers—rendering them more and more exclusive. By employing supply-scarce production brands have induced a sense of excessive competition among enthusiastic consumers, arousing their desire for owning limited-edition sneakers (Cassidy et al., 2018). In fact, a study published by the Journal of the Academy of Marketing Science—investigating the effects of scarcity on consumers’ buying behavior—reasons that scarcity enhances consumers’ desirability by polarizing their subsequent preferences and judgments towards products (Hamilton et al., 2018). Referring this in the context of the sneaker resale market, sneakers’ scarcity essentially activates a mental shortcut in the human brain, formerly known as a type of ‘heuristic cue’, that subconsciously reduces consumers’ attention to the true value and quality of sneakers. In effect, consumers are left more prone to the product’s appeal, thus increasing their purchasing intentions (Nürnberg O., 2015). As a result, with a consumer base invested both financially and socially, retail and consumer brands research analyst Josh Kernan of the Cowen Equity Research firm predicts a lucrative future for the resale market—projecting a \$30 billion valuation by 2030 (Kenny et al., 2021). These market projections not only evidence an emerging market, but a market with growing capitalistic opportunities and untapped lucrative potential.

### *The Conspicuous Consumption Of Sneakers*

With the advent of social media nurturing a hyperconnected world, the sneaker resale market has been further promulgated within society as the importance placed on appearance and fashion sense continues to grow among people (Matthews et al., 2021). In this regard, scarce-production has also been instrumentalized by suppliers to promote the conspicuous consumption of sneakers given that consumers have become increasingly conscientious of appearance, status and fashion sense on social media outlets and in everyday life (Gierl and Huettl, 2010). In the sneaker resale market the concept of conspicuous consumption simply represents the purchase of sneakers to signify social status, ownership of a collector’s item or the desire to portray a contemporary, ultra-modern sense of fashion.

### *Sneaker Collaborations: A Valuable Growth Proponent For Brands*

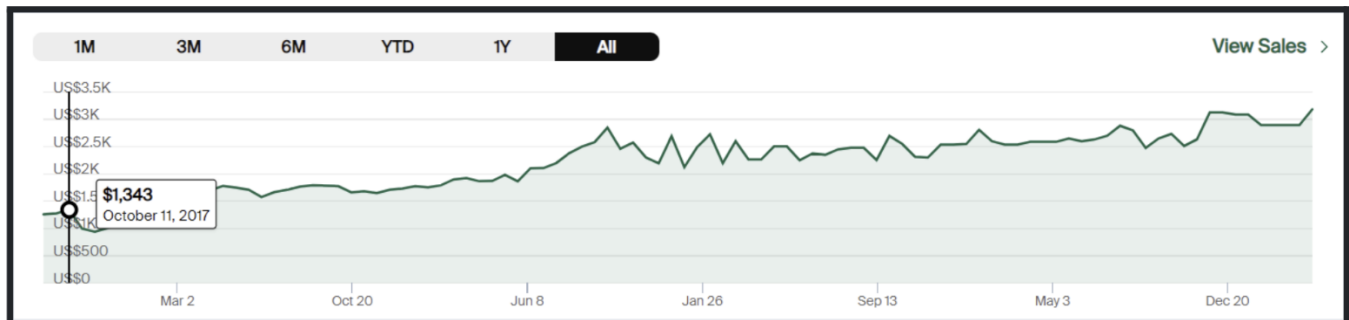
In regards to sneaker collaborations, the conspicuous consumption of sneakers—propagated by scarce-production—has incentivized several luxurious fashion brands like Dior and Louis Vuiton among others to endeavor fervently into the sneaker resale market by developing their coveted sneakers collections (Leeb et al., 2019). As more brands engage with the sneaker resale market, the emphasis placed on researching the economic trends, patterns, properties and models within such a dynamic market continues to garner interest among researchers. Specifically, exploring and understanding the sector of sneaker collaborations scrupulously has been emphasized given its more nascent emergence as a promising method to help brands succeed by branching their sneaker collections.

## Literature Review

### *The Business Model: Primary And Secondary Sneaker ‘Resale’ Market*

The business model of marketing supply-scarce sneakers in the primary market has led to creation of a secondary ‘resale’ market for sneakers. As limited supply instigates competition among consumers for ownership—enabling only a few to possess such sneakers—there is increasing demand to buy these sneakers through second-hand transactions (Newkirk, 2019). Bought in the primary market from retailers, limited-edition sneakers are instantly resold for upwards of two to

three times their original price depending on the situation (Burgess, 2020). An extreme example of this is the popular Nike Air and Off-White ‘Prestos’ collaboration, which sold on StockX, an online resale marketplace, for approximately \$1340 after release—indicating a 737% price premium<sup>1</sup> (StockX, 2022).



**Figure 1.** Nike Air ‘Prestos’ Off-White Price History

*Note.* After releasing in late September 2017 for a retail price of \$160, the Nike Air ‘Prestos’ Off-White resold for more than tenfold at a price of \$1,343 just a couple of weeks later on the StockX resale marketplace. Obtained from StockX.

With consumers continuing to pay exorbitant prices in a US sneaker resale market worth over \$6 billion, brands have tremendously benefited from a primary market standpoint (Kenny et al., 2021). While brands do not directly benefit from the profits of secondary market sales—as they do not engage in secondary market activity—factors such as consumer interest, financial performance and social media headlines resulting from the resale market have been promising in guiding brands’ success. Emeritus professor Peter Bug of Reutlingen University credits secondary market performance in terms of sales and consumer interest as critical growth components for brands in our modern economy (Lux & Bug, 2018). His explorative research claims that there is in fact a complementary relationship between sneaker brands and the resale market, where positive resale market performance is valuable to brands (Lux & Bug, 2018). Amid a booming sneaker resale market, the last several years have definitely maintained brands’ interest in continuing to practice supply-scrace production that creates demand for a secondary market in the first place.

### *StockX: A Global Resale Giant*

Famously known as the “Stock Market of Things”, StockX—an online fashion resale marketplace—has revolutionized the commerce of sneakers and high-end fashion items. Co-founded by Josh Luber, Greg Shwartz and Dan Gilbert in March of 2015, StockX enabled people to resell their sneakers through a unique bidding system (HBS Digital Innovation, 2020). Essentially, the seller is able to set an asking price while the buyer offers a bidding price, ultimately allowing the seller to either accept the first matching-bid price or wait for higher bids. These types of transactions, especially for fashion items like sneakers, were unprecedented and thus democratized the idea of the sneaker resale market on a mainstream level (Greenwood, 2021). In 2020, StockX reported a trading volume of \$1.8 billion in gross merchandise value as it closed 7.5 million trades throughout the fiscal year (StockX, 2021). In this regard, by facilitating a large volume of secondary market trading, StockX has cemented its reputation as the most popular and trusted online sneaker resale marketplace in the eyes of consumers. StockX regulating trades between sellers and buyers as an intermediary has contributed significantly to the aggregate growth and development of the sneaker resale market.

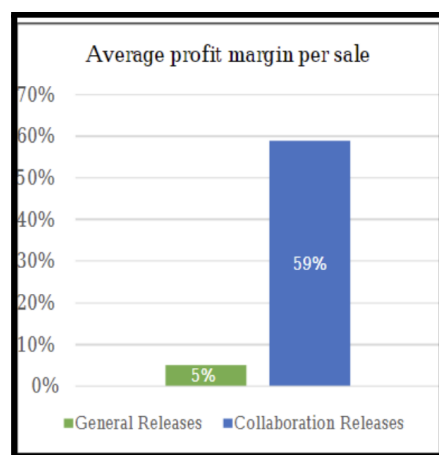
<sup>1</sup> The price premium of a sneaker refers to how much more it sells for compared to its original retail price as a percentage. A price premium of 100% denotes a consumer paid twice as much as the original price.

### *Coveted Sneakers: ‘Sneakerheads’ And Investment Opportunities*

With StockX creating mainstream trading channels for sneaker resale, consumers have utilized this opportunity to create new lucrative sources of income. People practicing the trade of coveted sneakers are now formally referred to as sneaker resellers. A case study from the Business Insider on Chris Holbrok, known as ‘Sneaker Jesus’, revealed that his reselling empire amassed \$1.5 million in gross revenue in 2019 (Ciment, 2020). Figures like these portray the business of sneaker reselling in a more promising light, rendering the practice comparable to professional full-time jobs. Over time, the business of sneaker reselling has propelled sneaker culture from “a type of underground subculture to a full-blown frenzy” (Ma & Treiber, 2020). Consumers immersed in sneaker culture have coined themselves as ‘sneakerheads’—fanatic sneaker collectors spearheading the development of the sneaker world. The evolution of sneaker culture to the forefront of mainstream media has elevated sneakers into a completely different type of asset class altogether. Among sneakerhead communities, sneakers are now perceived as iconic fashion staples, status pieces and investments (Ma & Treiber, 2020).

### *The Prominence Of Sneaker Collaborations*

The sneaker resale market has been largely successful and profitable due to the power and influence of popular endorsers (e.g. celebrities and athletes) collaborating with sneaker brands to induce high demand scarcity that provokes the conspicuous consumption of sneakers. Generally speaking, products are desirable if they hold value, offer unique features or are a necessity among consumers. In regards to sneakers, one would assume sneakers to be scarce and popular based on factors such as comfort, durability and style, however consumers’ scarcity preferences are rather driven by other motives. A 2018 study Nichollas Cassidy of Appalachian State University highlights these more appealing motives; the study surveyed 191 respondents on three sneaker scarcity types—demand scarce, not scarce and supply-scarce sneakers (Cassidy et al., 2018). The results of the study concluded that a majority of consumers prefer supply-scarce sneakers that are collaborations with hip-hop artists, celebrities and athletes (Cassidy et al., 2018). On the other hand, additional evidence from StockX co-founder Josh Luber corroborates this idea with a different setting in place, referencing celebrity Kanye West’s Adidas Ultra Boost sneaker selling out after he wore them for a performance (Luber, 2016). While the sneaker was widely available to the public, the high-demand among consumers was latent until the sneaker was affiliated with West. Both examples together emphasize the paramount role of endorsers and thus the sneaker collaborations of endorsers in creating high-demand in the sneaker resale market. Analyzing the role of sneaker collaborations in terms of resale market performance, evidence from Moritz Lux and Peter Bug further illustrated the dominance of collaborative releases compared to general sneaker releases. Their analysis on data collected from StockX confirmed that the collaboration releases significantly outperformed general releases in terms of average profit margin per sale by more than 50% (Lux & Bug, 2018).



**Figure 2.** *General and Collaboration Releases Average Profit Margin per Sale Comparison*

*Note. This bar chart highlights the disparity of average profit margin per sale between general releases and collaborative releases on the StockX resale marketplace, indicating collaborative releases generate 54% higher profit margins on average compared to general releases. From “Sole value – the sneaker resale market : an explorative analysis of the sneaker resale market,” by M. Lux and P. Bug, 2018, Reutlingen University, p.16.*

Exploring the dominance, influence among other patterns and trends pertaining to sneaker collaborations in the resale market has become increasingly valuable. Given the sheer amount of money, consumer interest and popularity, the opportunity to collaborate on sneakers with other entities is slowly becoming an inevitable option for sneaker brands. However, with several plausible endorsers to collaborate with, ranging from celebrities, athletes, musicians, social media influencers and other brands, there remains a gap within the body of knowledge that compares the successfulness of multifarious sneaker collaborations. In essence, with the current evidence and information available, brands continue to experiment with several different endorser-types on sneaker releases. While collaborating with a diverse array of endorsers is not unusual, brands’ marketing strategists and scholars like Kevin Ma and Matthew C. Treiber of Duke University advise comparing several types of sneaker collaborations with resale market data as a method of gleaning information on collaborative releases’ success. Thus, this paper’s research begs the question regarding which type of sneaker collaboration has been the most successful between 2017-2021 for sneaker brands on the StockX marketplace? The use of sneakers’ StockX resale market data to measure success is essential because, as mentioned previously, there exists a complementary relationship between brands and the sneaker resale market; brands succeed through positive resale market performance as consumers’ fascination and interest grows from the resale market. For the purpose of this study, the three sneaker collaboration categories of celebrity signatures, athlete endorsements and brand-brand collaborations were chosen for comparison. These categories were selected for comparison on the basis that they are the most relevant, underexplored and intriguing sneaker collaborations within the resale market. Further, the scope of the study has been limited to the last five years as a measure of gathering data that was a more current representation of this emerging resale market. While previous research by Moritz Lux and Peter Bug along with Kevin Ma and Matthew C. Treiber has analyzed the importance of sneaker collaborations and differences in sportswear collaborations respectively, research that comprehensively compares a variety of sneaker collaborations is yet to be done (Lux & Bug, 2018; Ma & Treiber, 2020). Sneaker collaborations that are across industry and include multifarious endorser types remain to be comprehensively compared and evaluated.

Examples of each type of sneaker collaborations are as follows:

1. **Celebrity:** In 2015, artist Kanye West’s collaboration with Adidas, valued between \$3.2 billion to \$4.7 billion today, led to the development of the renowned YEEZY brand—considered to be a driver of the modern day reselling market (Bhasin, 2021).
2. **Athlete:** In 1923, the first exhibit of an athlete endorsement occurred in a collaboration between basketball player Chuck Taylor, and Converse. 90 years later and Taylor’s endorsement still remains an iconic sneaker design (Schauer, 2012).
3. **Brand-Brand:** In 2017, footwear giant Nike and popular fashion label Off-White collaborated on the Nike x Off-White “The Ten” drop (Nike, 2017).

### *Research Purpose*

In aggregate, the purpose of the research is to support brands and investors of the sneaker resale market by providing useful data and information on sneaker collaborations. By determining the successfulness of different collaborations, brands can benefit by gaining a better understanding of the most lucrative types of endorsers. Consequently, brands can tailor their marketing strategies in accordance with success data. Similarly, sneaker resellers could also utilize the findings of this study to make data informed investments into the resale market. The research of this study helps promote the

growth and development of an emerging resale market by contributing data on an underexplored topic concerning sneaker collaborations.

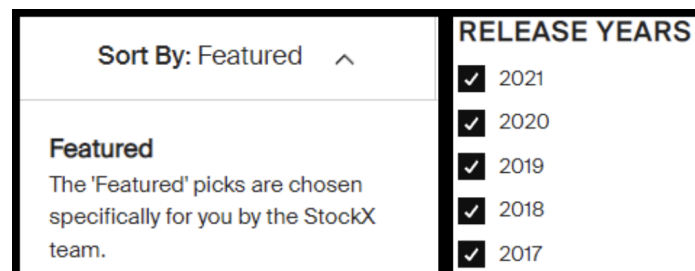
## METHODOLOGY

### *Method Overview*

This paper attempts to determine the most successful sneaker collaboration category between celebrity signatures, athlete endorsements and brand-brand collaborations from 2017-2021 on the StockX marketplace. The StockX resale marketplace was chosen as the subject of this study as it satisfies several requirements. Primarily StockX contains publicly available datasets that are accessible to analyze, a healthy level of trading activity with 7.5 million trades in 2020, and further was also accredited by other researchers in the body of knowledge (StockX, 2021; Raditya et al., 2021; Wu & Auerbach, 2020). In order to achieve the research objectives, a two part quantitative methodology was implemented. First, descriptive statistics on StockX sneaker data was collected, which was followed by statistical inference using the ANOVA test to analyze data significance at alpha level 0.05.

### *Extracting Data From StockX*

In order to minimize sampling variability, so that a variety of endorsers within each collaboration category are represented, this paper will use a method implemented by Northwestern's Roger Wu, where sneakers are selected from StockX's featured page (Wu & Auerbach, 2020). Although there are underlying reasons, unbeknownst to the researcher, as to how StockX sorts their featured page, this method will hopefully prevent similar collaborations and induce an element of randomness that eliminates variability. The sample size for each of the three collaboration categories will be 30 sneakers, thereby totalling the study's sneaker count to 90 sneakers. When surfing StockX's featured page, the relevant years between 2017 and 2021 will be selected (StockX, 2022).



**Figure 3.** Display of Random Sampling Methods

*Note.* Filters on the StockX marketplace in the forms of the “featured” option and “release years” were toggled to generate a random selection of sneakers for the study sample. Obtained from StockX.

Sneakers from these pages will be selected for all three categories until each sneaker collaboration category has a total of 30 sneakers. The classification of a category to celebrity, athlete or brand-brand collaboration was implicitly determined by the researcher. Although, in most cases the type of collaboration was obvious due to the sneaker name, title or was stated in StockX's description of the sneaker.

### *Measuring Success With StockX Sneaker Data*

In order to measure the success of a sneaker collaboration, StockX data that highlights resale marketplace performance will be collected on the 30 sneakers selected from each collaboration category. Resale marketplace performance is a credible measure of success as it takes into account consumers' vested financial interest in sneakers and accounts for the



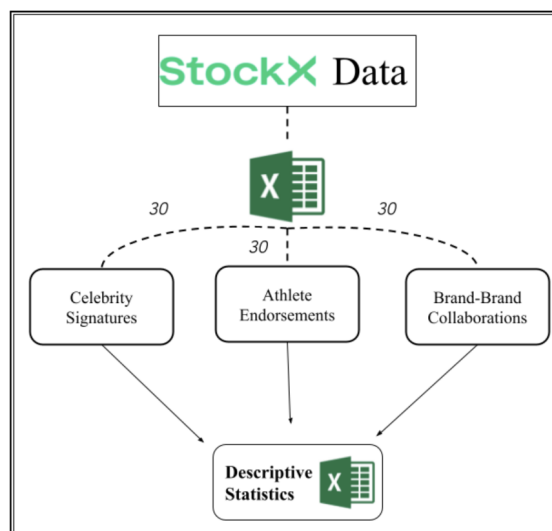
harmonious relationship between sneaker brands’ success and positive resale performance on secondary markets. The specific StockX variables that will be analyzed for the descriptive statistics include the 12 month trading range, volatility, number of sales, price premium and average sale price. Below is an example of the aforementioned variables on StockX for a sample sneaker (StockX, 2022).

12-Month Historical		
<b>\$217 - \$450</b> 12-Month Trade Range	<b>\$356 - \$400</b> All-Time Trade Range	<b>6%</b> Volatility
<b>749</b> Number of Sales	<b>191%</b> Price Premium	<b>\$292</b> Average Sale Price

**Figure 4.** Converse Chuck Taylor All-Star 70 Hi Off-White Sample StockX Data Variables

*Note.* This is a sample of the relevant study variables that were collected as a part of sneakers’ StockX data. Obtained from StockX.

The “All-Time Trade Range” variable was not collected as a part of the study for each sneaker as it is more subject to skewness and variability due to the fact that it measures a trading range over the entire life-period of the sneaker. This range could have included data that was unrepresentative of the more current resale activity for the sneaker, thereby eliminating the reason to collect data on sneakers’ all time trading range. To clarify, while sneakers released from 2017 to 2021 were collected as a part of the sample to narrow the focus of the study and contain a variety of sneakers, performance for sneakers was measured using their last 12 months historical data to represent more current resale activity. Once all the above variables were manually inputted into Excel spreadsheets by collaboration category, descriptive statistics were computed using the five summary statistics feature.



**Figure 5.** Visual Diagram of Study Design

*Note.* StockX data for 30 sneakers was collected and manually noted in Excel for each of the three collaboration categories, after which descriptive statistics were computed using Excel software features.

### *Statistical Inference: Analysis Of Variance (ANOVA) Test Using Price Premiums*

To determine whether the data was statistically significant the single factor Analysis of Variance (ANOVA) test was chosen as the statistical inference procedure. The single factor ANOVA test enables you to measure statistical differences in the means of a parameter between and within two or more independent data groups which fit the requirements of study's three independent collaboration types. In the case of this study, the mean variable utilized for statistical inference was the mean price premium of the 30 sneakers collected in a sneaker collaborations category. The price premium variable was chosen for inference as it was the strongest measure of resale market performance and hence the success of a sneaker in the resale market. Moreover, the price premium is a relative measure of performance as it compares the selling price to the original retail price for a particular sneaker, which is beneficial when comparing a multitude of sneakers with varying retail prices. Furthermore, by detailing how much above the retail price a consumer is willing to invest, the price premium also emphasizes a consumers' vested financial interest in the sneaker, which is a good measure of resale market performance in regards to consumers' perception of the sneaker. For context, a price premium value of 100% signifies that a consumer paid twice as much as the original retail price. Greater price premium values for sneakers imply strong levels of resale market performance and are indicative of convincing success. The null hypothesis for the ANOVA test assumes that there is no difference in the mean price premiums between the three sneaker collaboration categories, while the alternative hypothesis claims that there is a difference in the mean price premiums between categories.

These hypotheses align with the research goal of determining whether there is a most successful sneaker collaboration type as a difference in the mean price premiums—rejecting the null hypothesis—would signal that the mean price premium of a category was statistically greater or significant enough compared to the other two categories. Such a result would suggest that consumers paid significantly higher above the retail price on average for a particular sneaker collaboration category. If the null hypothesis is rejected, meaning there is a difference in mean price premiums, a post-hoc ANOVA analysis will be conducted to determine which collaboration category contained the extreme mean price premium as the single factor ANOVA test is unable to indicate which group provoked the difference in the parameter.

### **Results**

The scraping obtained links to 90 pairs of sneakers from StockX—30 per collaboration category—and these links provided more than 48,000 data entries of sneaker transactions. A preliminary examination of the dataset for the three sneaker collaboration categories revealed that brand-brand sneaker collaborations have the highest mean price premium of 179.23% compared to the other two categories. Thus, highlighting that on average a consumer is willing to pay upwards of three times the original retail price for brand-brand sneaker collaborations. The datasets below report descriptive statistics on the collected numeric variables from StockX for 30 sneakers in each collaboration category.

Variable	Mean	St.Dev	Min	Max	Count
<i>52 Week Low Price</i>	251.7	190.18	25	850	30
<i>52 Week High Price</i>	533.6	358.82	142	1,541.00	30
<i>Volatility</i>	0.15	0.07	0.01	0.36	30
<i>Number of Transactions</i>	206.57	499.07	2	2,665.00	30
<i>Price Premium</i>	1.16	1.2	0.27	4.79	30
<i>Average Sale Price</i>	361.9	251.15	96	1,101.00	30
<i>Retail Price</i>	180.4	47.98	80	250	25

**Table 1.** *Celebrity Signature Collaborations*

Variable	Mean	St.Dev	Min	Max	Count
52 Week Low Price	589.24	1,188.70	26	6,045.00	29
52 Week High Price	1,830.52	3,206.30	95	16,000.00	29
Volatility	0.24	0.11	0.07	0.57	30
Number of Transactions	1,141.77	2,879.12	2	13,880.00	30
Price Premium	1.79	2.05	0.08	9.29	30
Average Sale Price	964.2	1,799.52	88	8,232.00	30
Retail Price	307	429.08	70	2,000.00	30

**Table 2. Brand-Brand Collaborations**

Variable	Mean	St.Dev	Min	Max	Count
52 Week Low Price	151.77	123.23	46	632	30
52 Week High Price	485.23	386.38	130	2000	30
Volatility	0.25	0.2	0.01	0.95	30
Number of Transactions	267.43	952.13	2	5247	30
Price Premium	1.2	1.81	-0.35	9.56	30
Average Sale Price	276.57	222.67	83	997	30
Retail Price	151.67	51.82	70	260	30

**Table 3. Athlete Endorsement Collaborations**

However, comparing the raw mean price premiums, the resulting P-value of 0.288 from the single factor Anova test corroborated that the mean price premium data was not statistically significant at the 0.05 level. As a conclusion, the categories’ mean price premium are assumed to be equal.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	75,181.67	2	37,590.83	1.2605	0.2886	3.1013
Within Groups	2,594,435.93	87	29,821.10			
Total	2,669,617.60	89				

**Table 4. ANOVA: Single Factor**

Note.  $p > 0.05$  alpha significance level, therefore ANOVA test was not statistically significant.

Given that the Anova test was statistically insignificant, leading the researcher to reject the alternative hypothesis, a post-hoc ANOVA analysis was not conducted. After obtaining the results from the descriptive statistics data, it became apparent that there was a strong presence of outliers for the price premium parameter that could have potentially skewed the data and thus the outcome drawn from the ANOVA test. By graphing the price premiums from each collaboration category on Microsoft Excel with a 3D line chart, outliers in the forms of price premium peaks and negative price premium values were identified.

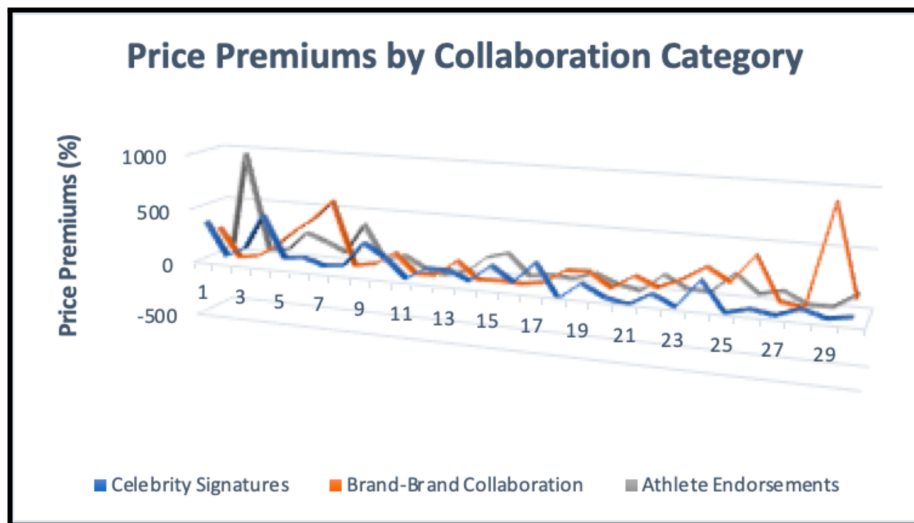


Figure 6. Price Premiums by Collaboration Category

As a result, a subsequent single factor Anova test excluding outliers was conducted with the same hypotheses. A resulting P-value of 0.3 and F-statistic within the 95% confidence level assured that data was not statistically significant at the 0.05 level without outliers.

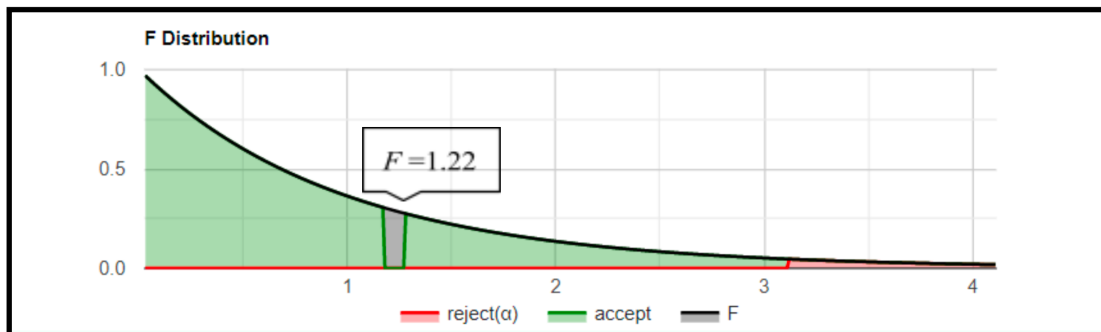
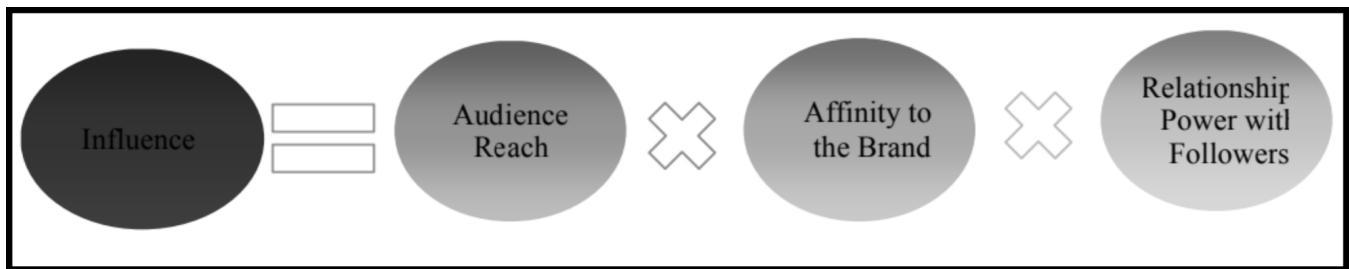


Figure 7. ANOVA: Single Factor Excluding Outliers

**Discussion**

*Implications*

In the context of this study, both ANOVA tests implicated statistically insignificant results that support the null hypothesis and suggest there is no difference in the mean price premiums between the sneaker collaboration categories. Therefore, consumers do not pay more above the original retail price on average for any of the studied sneaker collaborations even though, numerically from the raw data, brand-brand collaborations had the highest raw mean price premium by far—more than 60% above the other two categories. Observing the results from a logical standpoint, the brand-brand mean price premium appeared to be unexpected and in some sense counterintuitive. Typically, one would speculate celebrity signatures or athlete endorsements to draw more attention, secondary market revenue and thus higher price premiums per transaction. This hypothesis of celebrities and athletes outperforming brand-brand collaborations is further substantiated by the modern influencer-follower relation model described by Dr.Kadekova and Dr.Holienčinová, both professors in the Department of Marketing and Trade at Slovak University (Kadekova & Holienčinová, 2018).



**Figure 8.** *Mathematical Expression of the Influencer Follower Relation*

*Note.* This influencer-follower relationship expression was produced by professors at Slovak University, modeling the components—audience reach, affinity to brand and relationship with followers—that impact endorsers’ influence. From “Influencer marketing as a modern phenomenon creating a new frontier of virtual opportunities,” by Z. Kádeková and M. Holienčinová, 2018, *Communication Today*, 9, p.96.

According to their model, endorsers’ influence is generated through three integral components: audience reach, affinity to the brand and relationship power with followers. By these criteria, celebrity and athlete collaborations are most probable to have a greater influence compared to brand-brand collaborations due to their more prominent relationship with fan bases coupled with a generally larger audience reach. In this regard, assuming that greater endorser influence generally provokes more conspicuous consumption among consumers, celebrity signatures and athlete endorsements should have dominated the brand-brand category in terms of the mean price premium variable.

Although, with raw data extremely contradictory of the expected results, the results of this study reason that brand-brand collaborations may in fact have greater influence through the brand affinity component, as this is the most logical ingredient that could enable brand-brand collaborations to achieve a larger presence of influence on consumers’ purchasing behavior of sneakers.

### *Managerial Implications*

Generalizing the implications of this study to the larger population, the results are relevant and applicable for brands specializing or branching in the sneaker industry. At the current state of the market, brands should continue to practice supply-scarce production that disseminates conspicuous consumption among consumers and creates high-demand in resale markets. However, with the newly obtained data described in this study, brands’ marketing strategists could also decide to experiment branching through co-branding efforts with other brand entities. On a macroscopic level, although, it’s important to note most brands already engage in some form of brand-brand collaboration, therefore centralizing marketing efforts towards collaborative brand-brand releases may result in unproductive or perhaps even counterproductive results with regards to generating success in the primary market.

Disregarding bigger brands or known brands, the results of the study may be more relevant for smaller brands struggling to grow or brands looking to enter the sneaker resale market. Keeping in mind 179.23% mean price premium for sneaker collaborations, from their perspective, collaborating with a local brand while simultaneously maintaining an element of scarce-production could potentially spur growth by generating secondary market success. Success as a general principle can help these smaller, local-level brands in cultivating brand-image, values and long-term customer affinity. Though, overall, with insignificant results on the mean price premium variable along with a myriad of uncontrollable factors in the

sneaker resale market, the results do not produce conclusive managerial implications for brands of the sneaker industry but rather raw data that can be instrumentalized for experimental purposes, especially for smaller brands.

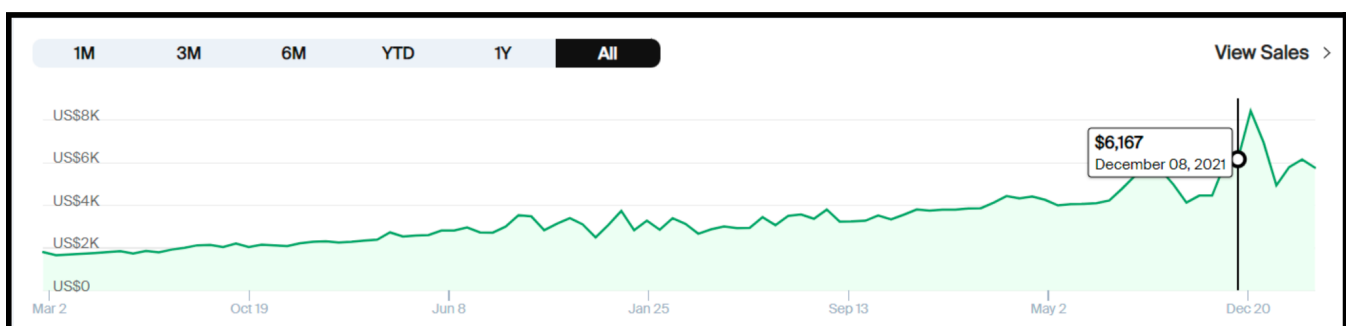
### *Sneaker Reselling Implications*

Contrary to the managerial implications proposed for brands, the study evidences more applicable conclusions for sneaker resellers and investors of the market. Resellers and investors may view strong brand-brand mean price premiums as an opportunity to increase average profit margins on their brand-brand sneaker holdings as consumers are willing to pay exorbitantly for the category. In the event of this, the initially shown 50% gap difference in average profit margin per sale between general releases and collaborative releases may widen due to the higher margins achieved on brand-brand collaborations.

### **Limitations**

Apart from the rejection of the alternative hypothesis, there were several limitations in the study worth noting. Primarily, the sizing of the sneakers is a vital factor that could have impacted the resale value of sneakers, given that different brands release sneakers in varying quantities for a particular size group. However, given that StockX does not openly provide complete data on sneaker transactions and thus the collected variables by size group, the study did not account for sneakers' different sizes, which may have affected the results. An important drawback in this case would be the fact that the availability of sneaker sizes limits the amount of resale activity for said sneaker in the first place. Limited resale activity may therefore correspond to increased variation in the price premium of a sneaker, as scarcity provokes increased demand leading to higher prices and thus higher price premiums.

Next, time as a contextual variable in measure and influence was another uncontrollable factor. Sneaker collaborations are often carefully planned and released during “hyped periods” meaning that certain sneakers may produce more attention and hype during their release period—leading to hype-driven sales on StockX that incites variability in the price premium variable. Therefore, the researcher operated under the assumption that all resales and StockX activity resulting from media attention among other external influencers (e.g. events like a concert) are directly produced from the initial marketing. To put the power of external influences into context, StockX data evidences that the death of popular fashion designer Virgil Abloh<sup>2</sup> in late 2021 provoked massive increases in his sneakers' resale value, not only inflating the price premium but general hype around his sneakers as shown in the price history graph Below (StockX, 2022).



**Figure 9.** *Off White's Jordan 1 Retro High White Price History*

<sup>2</sup> Virgil Abloh is the founder and designer behind the notable luxury fashion label Off-White

*Note. After the passing of designer Virgil Abloh, founder of Off-White, in late November of 2021, the price of his Off-White Jordan 1 Retro High White sneaker—in collaboration with the Jordan brand—skyrocketed to approximately \$6100 from its previous standing of around \$4000. Obtained from StockX.*

The price history graph above from StockX explicitly illustrates the ability of external factors directly influencing the resale value of sneakers. In this case, the spike in the price of the Off-White Jordan 1 Retro High White sneaker was not motivated by consumers' vested financial interest but rather emotional sentiment acting as an external influence on consumers' purchasing behavior and decisions. Given that the resale value of a sneaker is directly related to its price premium, if any of the endorsers for the 90 collected sneakers passed away between 2017-2021 or other external events indirectly influenced sneakers' resale value, it may have caused variability in mean price premium parameter used for statistical inference.

### Future Considerations

As the sneaker resale market continues to emerge and develop, additional research is crucial in order to continue to provide relevant data for brands and investors of the market. In regards to the study's investigation of determining the most successful sneaker collaborations, similar studies could be conducted where each time the secondary market success indicator—in this study the mean price premium of a sneaker—is altered to measure success in different ways. Measuring success with different indicators is vital because complex factors such as social media play an integral role in influencing consumers' purchasing behavior. Therefore, measuring an endorser's capacity to influence purchasing through social media can also be an indicator of success. In recent times, complex and moderately efficient algorithms have been developed to gauge and analyze public sentiment on social media platforms like Twitter and Instagram. Consequently, they can be utilized in conjunction with resale market performance data to perform linear regressions tracking correlations between public sentiment and the price premium of a sneaker. This type of analysis can help provide further insight into the motivational power of endorsers to persuade consumers' mood concerning sneaker interest. Overall, measuring the success of a collaboration category with several indicators will allow researchers to comprehend through what success is generated—allowing brands in the future to adapt and inform their marketing strategies based on success data along with investors who can make data-informed investments.

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# **Sustainable Developments in Least Developed Countries: Are Public-Private Partnerships the Most Efficient Financial Arrangement to Spur Sustainable Developments in Least Developed Countries?**

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## **Abstract**

The escalating foreign indebtedness of less-developed countries (LDCs) and their vulnerability to economic and environmental shocks pose significant challenges to their sustainable development. This paper examines the financial arrangements that can address LDCs' sustainability crisis by comparing full public sector involvement, full private sector involvement, and public-private partnerships (PPPs). Dependency theory is used as a framework to understand the structural conditioning of LDCs within the global economy and their vulnerability to international market instabilities. The analysis of the financial arrangements reveals that PPPs, particularly in the form of blended finance, are the most efficient means of allocating funds and resources to developmental projects, maximizing net benefit, and promoting sustainable growth in LDCs. This paper emphasizes the importance of pursuing long-term oriented and environmentally conscious development projects, which can be best achieved through public-private partnerships.

*Keywords: foreign indebtedness, least-developed countries (LDCs), dependency theory, public-private partnerships, sustainable growth*

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## **Section I: Introduction and Debate**

One of the most prevalent weaknesses in our contemporary global economy is the mounting foreign indebtedness of the less-developed countries (LDCs). Especially prevalent in this current era of emphasis on development, debts have become an integral aspect of LDCs funding. Since around 1970, sovereign borrowing has replaced concessional aid and foreign direct investment as the principal means for capital inflows to developing countries. In fact, data compiled by the World Bank Group (2022) reveal that medium-term and long-term indebtedness of LDCs increased by 20% annually from 1970 to 1982. Debt servicing, the scheduled payments of principal and interest, has become extremely difficult for a growing number of countries. As LDCs continue to battle the growing climate crises imposed upon them by developed nations, they face the consequences of poverty, hunger, and disease. Consisting of nations across Africa, the Asia-Pacific and the Caribbean, LDCs form over one billion people yet contribute to less than 1% of global emissions (Knowles & Garcés-Ozanne, 2003). However, these same members are most vulnerable to environmental and economic shocks,

disproportionately affected by the actions of developed countries (World Bank Group, 2022). Yet this same vulnerability brings into question the types of developmental projects that LDCs should undertake, and raises the question: Are PPP an efficient arrangement in the financial sector of Least Developed Countries?

One of the major theoretical explanations and hypotheses concerning LDCs vulnerability, is dependency theory. Central to most dependency approaches to the political economy of development and underdevelopment is the notion that LDCs are inordinately vulnerable to events, processes, and forces that originate in the capitalist world economy. Among a wide array of alleged vulnerabilities, it is frequently asserted that instabilities in international markets are transmitted into and exert destabilizing effects upon the national economies of LDCs. Their economies are characterized by openness to international markets, and they must respond to the volatilities and external shocks generated by those markets (Avery, 1990). LDCs are inherently structurally conditioned by the nature of their linkage to the international political economy. Typically, LDCs export raw materials at relatively cheap prices to the countries of industrial core, which convert these materials into finished goods, and sell them to LDCs at comparatively high prices. Such unequal terms of trade exploit LDCs natural resources and produce balance of payments issues. This then imposes two unpleasant decisions upon LDCs: (i) reduce imports and risk unrest arising from “frustrated consumer demand” and (ii) seek external finance capital through direct foreign investment, relying on foreign government aid, external private sector funds, or public private partnerships. The first option typically exerts political unrest, leaving LDCs victims to foreign aid, and thus dependent on loans and credits. It becomes clear that considering the vulnerability of LDCs growing indebtedness and their negative repercussions following climate crises, developmental projects must be sustainable: long-term oriented and environmentally cognizant. In what follows, I will cover the financial arrangements which can approach the LDCs’ sustainable crises. I will begin by analyzing full public sector involvement, followed by full private sector involvement, and lastly delve into public-private partnerships. This paper aims to uncover the best means to ensure efficient allocation of funds and resources into developmental projects, to maximize net benefit and spur sustainable growth. I will examine the function and purpose of the aforementioned arrangements, and outline their pros and cons from a financial aspect to reach the conclusion that public private partnerships, especially in the form of blended finance, outshine the full private and full public sector interventions.

## **Section II: Assessing Efficiency of Public Sector Intervention**

This section will focus on the overarching topic of full public intervention in LDCs, specifically defining what this intervention entails, and providing reasoning regarding the efficiency of this arrangement to spur developments and growth.

Government intervention is the term for purposeful acts taken by the government to affect how resources are allocated and how markets operate. It can take a variety of shapes, including laws, levies, subsidies, and monetary and fiscal policies. The government occasionally imposes upper and lower price caps on the market. Government, or public sector intervention, serves to increase nominal wealth in least developed nations by primarily supplying public goods, boosting the domestic economy, and protecting the environment. In addition to producing collective goods and services like infrastructure, public sanitization, and defense spending, the State is also in charge of preserving and enhancing the economy by enforcing trade restrictions and tariffs to safeguard domestic industries and prevent overexploitation of natural resources. More precisely, in emerging nations, governments extend their influence into industry, agriculture, power, and transport in addition to the creation of communal goods and services. By allocating public funds and forming organizations with official backing, they support and invest in the production of private goods. Governments address the lack of private enterprise, oppose the private sector's failure to pool resources for investment, and maintain control over the dominant sectors of the economy in LDCs as a result.

In fact, proponents of public intervention claim that laws imposed by the government actually promote economic growth in several ways. Governments implement a variety of policies, from supply-side to demand-side actions, affecting total supply and total demand in accordance with the demands of the economy. These policies typically concentrate on raising monetary or fiscal policies and improving production efficiency in product markets or factor markets (such as the labor market). The engagement of the public sector offers a range of rules designed to handle concerns including employment, competitiveness, and consumer protection. For instance, by supporting the automatic transfer of tax returns to bank accounts and simultaneously making it easier to register bank accounts, governments in LDCs may emulate established systems and play a significant role. On this front, some data from the Chicago First Account program offers cautious optimism. For people who qualify for an EITC refund, the Center for Economic Progress has offered free tax preparation services for many years. The center has been attempting to integrate this tax preparation service with the First Account program for the past few years. In particular, the center has been identifying people who are entitled to a refund but do not have bank accounts and making it possible for them to receive their return much sooner after opening a bank account. According to data gathered from the bank managing the First Account program, people who opened accounts in this "rapid refund carrot" context weren't any less likely to be using them now than people who got accounts after attending a financial education course (Marr et al., 2015). Government engagement in this situation expands financial access to new parties, further defining the intricate web of wealth distribution. Greater innovation in the field will raise average wealth as more people become financially literate. In other cases, governmental control in the form of foreign aid gives LDCs the rights they need to encourage fair trade and economic development prospects.

Examples of this include the Generalized System of Preferences (GSP), which accords equal treatment to all allied countries, and the General Agreement on Tariffs and Trade, which offers legal protection (GATT). In addition to non-LDC nations like Bolivia, Colombia, Ecuador, and Peru, the United States provides foreign aid to LDCs that participate in preferential programs like the Caribbean Basin Economic Recovery Act (CBERA) and the Andean Trade Preferences Act (ATPA) (Marr et al., 2015). The Africa Growth and Opportunity Act eliminates the competitive needs restrictions that apply to nations other than LDCs in the GSP program and locks in preferences for beneficiary countries for 8-year periods rather than annually, in contrast to GSP (Haveman & Shatz, 2004). These foreign aid programs, which are one facet of the power of government intervention, have been utilized to increase domestic rivalry and production in LDCs, with a particular focus on export textiles and apparel.

A more critical viewpoint reveals that governmental intervention in LDCs has fallen short of expectations. Although political authorities have given it a lot of attention and support, its unchecked growth has led to unexpected consequences. For instance, costly supply delays, reduced marginal benefits, and economic inefficiency have been brought on by capital misallocation, excessive expenses, and a lack of innovation. Particularly, inadequate provision of goods and services, failure to achieve desired goals, and strain on finances have served to deteriorate diplomatic relations as a result of political meddling and bureaucratic growth (Poynter, 1982). The decision takers do not have skin in the game: they are not profit seekers risking their own money. To understand the faulty system of public sector intervention, one must ask themselves, what do they seek?

A naive response would be to assume the government simply wants to provide collective good, to generate sustainable growth and guarantee a more promising future for all its citizens. Reality sways from this optimistic assumption. Government officials seek to get re-elected, to monopolize their power as much as society blindly allows, and to gain campaign donations. Thus public sector decisions take the form of strategic political consideration rather than commercial growth. Whereas commercially-oriented investments honor agreements and are disciplined by nature, political decisions are skewed towards political gain and reputation. For instance, during an election campaign, the government may set off on a new developmental endeavor, appealing to its voters and promoting community welfare. Yet at a deeper glance,

location is fundamental in understanding the intentions of this endeavor. The project undertaken may be developed in a marginal area, designed to captivate voters whose vote can be shifted, even if this means that areas in more need do not get the necessary attention they necessitate. Strategy thus often plays a more important part than impact. Misaligned incentives and deliberate political moves lower productivity and lead to inefficient LDC development.

Such flaws have not gone unnoticed by critics. They contend that ineffective government policies disincentivize creative producers, harm a large majority who rely on successful government intervention, and fail to effectively allocate human capital and LDCs' limited domestic resources. Concerns about government authority are also present, mostly because of the restricted production and distribution that results from government control (particularly in command economies). Domestic corporations experience decreased marginal profit and are worse off than previously as a result of being compelled to comply with greater costs and more sophisticated safety procedures. Intervention may be advantageous for one party but harmful for another due to discrimination policies. For instance, the competition policy promotes state-owned businesses over private ones. Similar to a bailout, the government supports large banks financially rather than all banks by using tax money. (Nasrudin, 2022).

Perhaps even more detrimental to LDC economies is the form of long-run inflation. The process of income redistribution driven by inflation is typically brought to light since it benefits the government, business owners, and debtors while harming creditors and those who receive incomes that do not, only partially, or tardily follow the inflationary trend. The fast expanding urban population in LDCs typically bears the brunt of this process, commonly specified as "forced economy," and is obliged to reduce their consumption spending (Walter, 1973). Growing earnings and a propensity to encourage the expansion of the production potential are the results of rising prices that are not accompanied by an equal rise in costs. Yet "it would be all too short-sighted to break off the train of thought at this point" and to arrive at the fallacious conclusion that inflation was indeed a one-way street of welfare (Walter, 1973). Long-term Inflationary pressure poison the economy and capture stakeholder perception, compelling the government to resort to acts of intervention that, at best, will put the desired goal in jeopardy and, more than likely, will fail (Walter, 1973).

As a result of slow rates of economic growth, inflation, and a greater concern of public sector inefficiencies, there has been a shift in mindset. Governments have changed their roles to allow the private sector to carry out a number of tasks, and this has led to an increased focus on privatization (Paul, 1985). It has two objectives: first, it aims to reduce the size of the public sector; second, it aims to move the production of public goods and services to a more economically viable and effective method. Perhaps the socioeconomic makeup of some LDCs, like Haiti, Honduras, and Uganda, restricts the growth of the public sector by blinding the government and deflecting attention away from the reality that its own intervention falls short of meeting the countries' developmental needs (Paul, 1985). Despite the mounting evidence of poor financial returns, ideology has driven some political leaders to make significant investments in the public sector. In other cases, such as Bhutan and Cambodia, public sector expansion has been subject to a quest for patronage among politicians and a form of defense mechanism against expatriates, rather than the compulsions of ideology. The aforementioned instances provide insight into the nature of public sector involvement in LDCs and perhaps why developments have been hindered and largely unsuccessful (Behrman, 1972). History, politics, and economics thus present unmistakable evidence. It is apparent that full public sector involvement lacks the efficiency to spur sustainable growth in LDCs, and requires supplemental efforts by the private sector. Yet, there is reason to be optimistic. Empirical evidence shows important complementarity between public and private sector investment: public sector presence increases productivity through the provision of infrastructure and services, which attracts private sector investment (Cardoso, 1993).

Government intervention may thus not be the most efficient means to drive financial sector growth: its selfish gains, and inefficient means to spur growth are faulty and detrimental to LDCs desperate for aid. But it can be a medium and a tool

to retain necessary private funds for development. The question that then arises, and that will be answered in the next section, is whether the private sector intervention can carry the financial sector of LDCs by itself, and if it is the most efficient mechanism to bolster the financial sector.

### **Section III: Assessing the Efficiency of Private Sector Intervention**

After analyzing the lack of efficiency in which the public sector spurs sustainable developments in LDCs, this section will uncover whether full private sector arrangements can create the necessary changes to shift their financial sector. The private sector, unlike its public counterpart, is commonly held to have no incentive in producing the optimal amount of such goods and services, employing a strictly analytical approach rather than prioritizing public satisfaction. The private sector argues that by doing this, it avoids market imperfections brought on by the non-exclusionary nature of public goods and the simultaneous and concurrent usage of such services. By nature of their uncertain make-up, LDCs are more volatile: inflation, real interest rates, and other macroeconomic variables shake their economies and fluctuate the strength of the financial sector. Highly dependent on public external support, mainly Official Development Assistance (ODA), LDCs progressively move towards private financing at early stages of their development. Private financing itself evolves, with a progressive substitution of ODA with Other Official Flows (OOF), corresponding to a decline in concessionality as countries transition. By filling the gap between ODA and private finance, OOF are essential to help countries gradually transition towards the mobilization of private resources. Since LDCs are characterized by structural handicaps, such as low productivity, low economic base and high exposure to economic shocks and disasters (e.g. commodity price fluctuations, climate change, epidemics and natural disasters), private development finance institutions bear risk. This can at times lead to LDCs' struggle to diversify their financing resources, making it difficult to mobilize domestic resources and attracting private sector investment (Cattaneo et al., 2021).

For the private sector, risk aversion, adjustment costs to investments, and turbulent returns on investment affect their investment methods and allocation of capital in LDCs (Abel & Eberly, 1994). Participation of private capital in low-income countries is limited due to their perceived elevated risk environment and low profitability for commercial profit-seeking investors, placing developing countries at a disadvantage. Thus, private development finance is more commonly associated with LDCs. As institutions geared for developmental purposes, Multilateral Development Banks (MDBs) are subsidized to implement SDGs in the Agenda for 2030 and lend mainly to LDC governments or other key shareholders in long-term loans (OECD, 2018). They are encouraged to increase long-term lending in domestic currencies to developing countries given the potential for serious dysfunctions generated by external indebtedness and foreign currency based financing for developing country public sectors (Abalkina & Zaytsev, 2021).

The success of private enterprises follows a simple scheme: demand and supply for financial services depends upon the growth of real output and monetization of the developments and substance achieved. The more rapid the growth, the greater the demand for and supply of such enterprises, and the greater the funding and profits. Under this criteria, it would seem inherently efficient to entrust the profit-seeking private sector to undertake developmental projects and surge the economy in LDCs. The more success they achieve, the more demand for their service, and the more sustainable and profitable the income. A constant cycle embodying the essence of capitalism. Combined with the supply-leading funds, "favorable expectational and psychological effects" incentivize the private sector to invest in its human capital and "expand to new horizons" (Patrick, 1966). Such innovation is necessary for ingenious solutions that can exacerbate growth in developing countries, and efficiently lead developmental projects in LDCs. The disciplined and profit-oriented mindset of the private sector is especially important for LDCs' mission of sustainability. Private finance can be mobilized for sustainable developments, particularly the UN's Sustainable Development Goals (SDGs), and can fill the gap between development co-operation and private investment through private sector development (PSD) (Cattaneo et al., 2021).

Proponents of private finance are optimistic for the future. They envision LDCs who can achieve an improved resilience of development co-operation efforts by building an ecosystem for private sector-led development. In particular, development partners could promote foreign investment and trade, with greater emphasis on their qualities or development footprint. This would require investing in private sector development, investment climate, the business environment; improving access to credit; creating markets and building local capacities to attract the “right” foreign investors (i.e. renouncing the race to the bottom to attract investors, and raising local standards to join higher value-added supply chains). The Aid for Trade initiative could also be leveraged to create conditions conducive to trade, including by building local capacity and increasing the efficiency of global value chains (GVCs), ensuring that significant value-added is left behind (Morrissey & Udomkerdmongkol, 2012)

Critics on the other hand, offer another aspect to this nuanced debate, arguing instead that the private sector is not fit to be the sole engine in LDCs financial sector development. Firstly, from a solely economic perspective, they claim that LDCs volatility and inherent corruption may lead to crowding out. Due to limited funds and shaky money supplies, there is a small amount of savings available to be borrowed, and this causes real interest rates to increase. The private sector as a result undertakes a cost-benefit analysis, and is left unincentivized to begin development projects, or even continue them, as the payout may not compensate for the additional risk. This form of investment proves to be heavily inefficient and problematic, and can leave LDCs in turmoil, even worse than before. Can the private sector truly transform the financial sector if it cannot withstand the economic pressures present in LDCs and becomes inefficient? Paul E. Roberts Jr. adds to this thought, analyzing why the private sector seems to earn a higher level of profit on loans than the public sector even when proven more inefficient at times. He holds that the answer lies in the form of loans and equity investments that the private sector obtains from international institutions, often made in foreign exchange (Roberts, 1971). These same loans however, may not be as strong in developing countries with shaky currencies and volatile foreign exchanges. Although transactions may be made by entities in the developed world, third parties in LDCs would still have access to the transaction and magnify the risks involved, thereby shifting loans as well. In turn, it would render the private sector near to obsolete, killing its higher level of profit on loans, disincentivizing production and developments, and inefficiently undertaking projects.

When further combined with extraneous and unpredictable events such as COVID19 outbreak, there is a further sense of incertitude. In fact, private finance commitments still lag 12% lower than the previous five-year average, an indicator that recovery from the deep recession triggered by COVID-19 is still underway (World Bank, 2022). Yet, we must look at the full picture to truly assess the impact of private finance. Investments have been unequal across regions: while Europe and Central Asia have seen the largest increases in private investment (400% since 2020), private investment commitments have decreased in Sub-Saharan Africa by 17%, in South Asia by 16%, and by 90% in Middle East and North Africa (World Bank Group, 2022). Considering this paper analyzes the impact on LDCs, we must assess the impact of private finance in LDCs. While it is clear that mobilizing private finance in developed countries is beneficial, the same cannot be said for developing countries. This can be attributed to developed nations’ typically lower risk and interest rate loans, secure profit, stable politics, and strong currencies, while LDCs on the other hand, are politically unstable, heavily exposed to viruses, riddled with high loan interest rate and risks, and economically volatile. The sharp distinctions highlight that private finance alone cannot handle the myriad of difficulties that intervening institutions need to face and reinforce previous points on the weakness of private finance in the presence of risk and uncertainty.

Accordingly, private finance is not the efficient arrangement to shift the economies of LDCs and transform their financial sector. High risks, political and economic instability, and uncertain extraneous situations, are inevitable. They are part of the difficulty of transforming LDCs and the reason circumstances are slow to improve. It thus becomes clear at this point in the paper, that only full public or full private sector intervention, are not the most efficient means of achieving financial

sector growth in LDCs. The next section examines a partnership between the private and the public forces, and will further look into a specific type of PPP, blended finance, in hopes of finding a more efficient solution for LDCs.

#### **Section IV: Public Private Partnership**

After analyzing the shortcomings of full public and full private arrangements in the financial sectors of LDCs, this section aims to uncover the truth behind the efficiency of a combination of both sectors, in the form of public-private partnerships (PPPs). More specifically, this section will discuss the stakeholders of PPPs and uncover the efficiency of PPP involvement in LDCs and then offer blended finance as a possible solution to spur developments and sustainable growth in the regions this paper focuses on.

PPPs appear on the spectrum of financial arrangements as a contractual arrangement that primarily involves a partnership between a public entity and a private institution to primarily finance, build, and operate developmental projects. PPPs vary in terms of configurations, presenting differing degrees of involvement and risk management, especially by the private party (Investopedia Team, 2022). Public-private partnerships frequently involve concessions of tax or other operating funds, liability protection, or an element of ownership rights over assets that are ostensibly public. They can be classified into two categories, namely those with a purely contractual basis and those with an institutional nature (Marques, 2010). While a PPP of an institutional nature involves cooperation between the public and private sectors within a specific body, a PPP of a strictly contractual type, on the other hand, is based only on contractual relations (Marques, 2010). Both arrangements grant delegated management of conventional public sector activities to the private sector and follow contractual regulation. Institutional PPPs act in accordance with administrative contracts, which govern the rights and obligations of the present parties. Contractual PPPs are slightly different, as the rights and obligations are supported by the shareholders' agreements and the company's statutes.

As the influence of PPPs' binding contractual agreements has proliferated, so too has global support for public-private partnerships (PPPs), especially prevalent in the field of infrastructure development. Discussions in G20 meetings over the last several years have increasingly focused on the need for a huge scale-up in infrastructure investment in developing countries, particularly low-income countries. G20 pronouncements talk about the advantages of realizing this scale-up via large, "transformational" projects involving private sector participation (Heathcote & Rowden, 2022). By this they mean large, regional, or cross-border infrastructure projects involving private investment and management, which potentially have positive, transformational impacts on entire countries or regions. From time to time over this period, the G20 has considered efforts to help modify the mandates of national and international development banks so that these institutions will take the lead on such PPPs and crowd in the private sector.

As a result, several development banks have been considering adjustments to their business models to give more attention to regional infrastructure PPPs. During the negotiations in 2013 for the 17th replenishment of the International Development Association (IDA17), the World Bank proposed using IDA funding to help develop transformational PPP projects. Those proposals have now evolved into the Bank's design of the Global Infrastructure Facility (GIF), an entity meant to coordinate the efforts of MDBs, private investors, and governments to prepare and structure PPPs. The BRICS countries, at their summit in Durban in March 2013, announced plans to create a new development bank (now known as the New Development Bank) that would focus on infrastructure, and do so in a way that would make up for the deficiencies of the existing international financial architecture and help catalyze the private sector investment needed in rapidly-growing BRICS economies (Republic of South Africa 2014). Perhaps the most ambitious and concrete commitment of this kind to date is the decision, announced by the African Development Bank (AfDB) in July 2013, to create a billion-dollar preparation and financing facility for large infrastructure projects in Africa, referred to as Africa. The institution's purpose "is to unlock private financing sources... and to accelerate the speed of infrastructure delivery in Africa," (Akintomide,



2013). This could prove especially beneficial in LDCs desperate for immediate infrastructure development. Besides the increased speed of developments, in their paper, Engel, Fischer, and Galetovic (2014) noted that in some countries PPPs are attractive to the government not necessarily because they are expected to be less expensive, but simply because accounting rules allow project costs to be moved off government books in order to give the appearance of lower debt levels.

Yet, as this enthusiasm for PPPs is growing, so is a less widely-recognized body of research that takes a much more measured approach; it still represents a kind of advocacy, but one that incorporates a greater degree of critical analysis of PPP successes and failures. The view among PPP advocates generally has been that these criticisms are mostly ideological polemics that mix opinion with selected but often misinterpreted facts. But over the last two decades, as the experience with PPPs has increased in both developed and developing countries, a different kind of critique has emerged, one that is based on non-ideological empirical research, and is sometimes expressed by PPP advocates. These studies often focus on individual aspects of PPPs, and usually do not claim to be “PPP evaluations” or express opinions on the overall value of PPPs. Taken together, a powerful, evidence-based critique of PPPs is emerging, but one that is more measured than much of the criticism of the last two decades. This new critique recognizes many cases in which

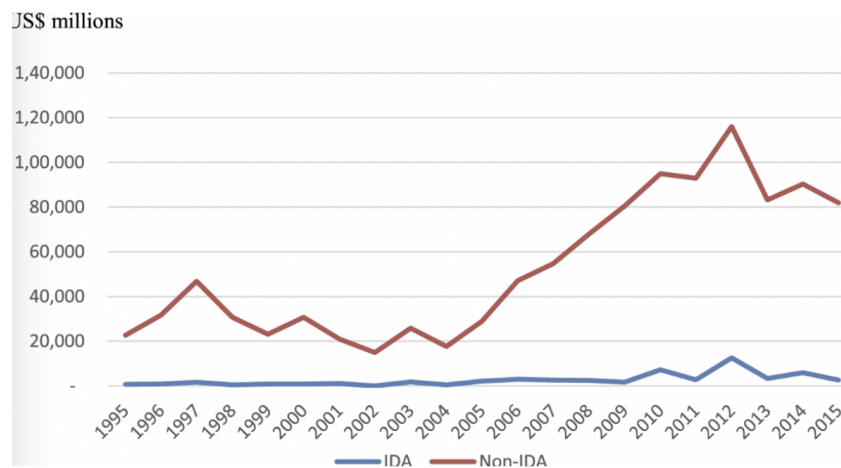
PPPs have not been successful, but also some situations in which PPPs can generate value for money. Because of its critical tone, some of this research is now regularly cited by the civil society critics of PPPs, giving their arguments more weight than was the case a decade ago. A recent example of this is evident in a World Bank working paper by Michael Klein (2015), an influential PPP advocate during the 1990s and early 2000s. Klein notes that despite more than two decades of use and refinement of the PPP mechanism, there are still no consistent geographical patterns of usage: “The general picture is one of waves of enthusiasm for PPPs followed by some disenchantment and consolidation. Different countries were caught up in the waves at different times.” What accounts for this lack of sustained enthusiasm? Klein says that evaluations show that PPPs can outperform public sector firms, and “are useful tools for reform of service delivery” (Klein 2015). But it is no longer clear that PPPs are consistently better run than public firms. “The evidence suggests that well-run public firms tend to match the performance of private firms in regulated sectors” (Klein 2015).

Klein's comments are a reminder that a significant amount of evidence-based research on PPPs has accumulated since the late 1990s. But a good deal of it, particularly over the last decade, has not been uniformly positive about PPPs, at least not in the fashion of the largely promotional literature published by MDBs and donors in the 1990s and early 2000s. One such notable example lies in the findings of economist Antonio Estache, an outspoken critic whose work has bolstered PPP criticisms amongst civil society groups (Alexander, 2013). Such groups have produced a broad collection of critical PPP studies: International Rivers (Bosshard, 2012); Public Services International (Hall, 2015); Heinrich Boell Foundation (Alexander, 2013); CEE Bankwatch Network (2008); Oxfam (Marriott, 2014); the Bretton Woods Project (2016). As a united front, these groups have long been critical of PPPs, but in the past their arguments against private participation have often seemed more ideological than evidence-based, and therefore not very compelling. But the growing use of evidence-based research reported on by respected social scientists like Estache, Klein, and others has added weight to their arguments, warranting more careful consideration by PPP advocates.

Coasian economics offers further useful insight into criticism of PPP. According to Ronald Coase's ‘Theory of the Firm’, it is frequently less expensive to command tasks by decree than to negotiate and uphold individual contracts for each transaction (The Economist, 2017). Transaction costs, after all, are mainly contract difficulties, ranging from errors, to problematic clauses and unsatisfied parties, and render PPPs inefficient before they even take off (Leigland, 2018). Government projects are notorious for overrunning and overspending, and thus need the discipline of the private sector to combat misallocation of capital. Yet, the minute the private sector is lured in, they get a guaranteed revenue stream

extended over a certain period of time, disincentivizing them from providing the sharpness and efficiency which balances the government's lack of productivity. The question then arises, how can PPPs formulate a contract that reduces risks to get the private sector involved, but doesn't guarantee them profit which disincentivizes efficient developments? Formulating contracts entails long negotiations, costly services, and numerous errors. By nature they are tricky, presenting unclear risks to the cost-bearer, and usually providing negative externalities to taxpayers. During a contract negotiation, the government will not be willing to jeopardize the project. The public sector will protect its reputation and government officials will seek optimal chances at re-election. To avoid running into issues, they thus compromise with the private sector, even at the expense of taxpayers. The government ensures the private sector is satisfied with its compensation, but by doing so sacrifices taxpayer money, at times even discreetly. A further issue arises with the presence of corruption, exchanging shady deals between parties and benefitting the primary stakeholders of the contract, rather than providing common good for society.

Having considered the proponents and critics of PPPs, the next portion of this section will focus on PPPs impact on developments in LDCs. According to the Independent Evaluation Group of the World Bank, PPPs play a relatively small role in infrastructure investment across the developing world, averaging between 15 to 20 percent (Independent Evaluation Group 2014). In least developed countries, the use of PPPs has been even more negligible. The figure below demonstrates this, using data from the World Bank's PPI Project Database to show investments related to "private participation in infrastructure" (PPI) in countries eligible for support from the International Development Association (countries whose Gross Net Income per capita is below \$1,215), and contrasts these against data from non-IDA developing countries (World Bank, 2014).



**Figure 1. PPP impact, IDA vs Non-IDA**

In the developing world, a share of infrastructure investment in the range of 15 to 20 percent does not mean that PPPs have failed to play a significant role in infrastructure. But it is far less than what was expected of PPPs in the 1990s when Klein and his colleagues at the World Bank were considering sharp reductions in infrastructure lending because they expected the private sector to eventually play a more dominant role in bridging the gap and financing and managing infrastructure services in that region of the world.

What does this information about PPP prevalence tell us about the conditions under which PPPs are likely to provide value for money? The message is simple: PPPs work much better in middle-income economies than they do in low-income countries. This means that in most cases a complex, long-term, brownfield concession for retail water distribution, for example, requiring significant capital investment, should not be the first choice as the service delivery

solution in a least-developed country (as such contracts often were in the early 1990s). The poorest countries can usually benefit more from traditional technical assistance and capacity building, or from hybrid projects that mix elements of PPP contracts with those of consulting or engineering, procurement, and construction (EPC) contracts to reduce risks for the private partners. Reforms to legal and regulatory frameworks within which PPPs eventually would be structured are also critical in these countries, along with help in improving government procedures for things like procurement and construction management.

From a financial aspect, considering costs and profits is perhaps one of the clearest indicators signaling the efficiency (maximizing net benefit and minimizing costs) of PPPs in LDCs. As they involve multiple stakeholders, the conventional view of PPPs, compared to typical public projects, provides better services at lower costs. This can be attributed to the private partner's desire to make a profit, combined with a reasonable return and government pressure: projects that do not fulfill expectations can be subject to public criticism and civil society. Yet, traditional means of PPP suggest that its common positive perception is misguided. PPPs have typically cost more than conventional public procurement methods. (Jomo et al. 2016). A 2006 report by the European Investment Bank (EIB) reviewed the costs of 227 road projects in 15 European countries and concluded that projects done as PPPs (65 of the total), were 24 percent more expensive than those done via traditional public procurement (Blanc-Brude, Goldsmith, and Väililä 2006). In a 2015 review of effective interest rates on private finance projects, the U.K.'s National Audit Office found that these rates, at 7 to 8 percent, were double the rates on normal government borrowing, at 3 to 4 percent (U.K. National Audit Office 2015). It seems illogical to devote PPP arrangements in vulnerable nations with limited funds, when developed countries already face substantial roadblocks and ineffective spending. So what can be done?

One way to avoid this issue is by anticipating project benefits and costs, requiring a metric called "value for money" (VFM) to conduct a PPP project cost-benefit analysis. VFM analysis involves estimating project costs, including profits for the private partners, and measuring them against project benefits, including service quality, quantity, and prices for governments or end-users (Leigland, 2018). Quantitative VFM assessment typically involves comparing the chosen PPP option against a "public sector comparator" (PSC). The PSC allows a comparison of the risk-adjusted cost to the government of procuring the project through traditional procurement (the PSC), with the expected cost to the government of the PPP (pre-procurement) or the actual PPP bids (post-procurement) (European PPP Expertise Center, 2018). But ever since the technique was first refined and pioneered as part of the UK's PFI program in the 1990s, it has been criticized for being inaccurate and subject to manipulation, leading some observers to conclude that it is often an expensive way of endorsing the pre-selected choice of private participation.

Thus traditional PPPs' attraction seem to have faded, revealing instead the systemic failures and volatile costs that render it an inefficient means to spur developments and growth in LDCs. Specifically, The OECD (2008) attributes the high cost of PPP projects, especially when compared with the costs of traditional public procurement, to preparation costs. Preparation costs include the legal, financial, and technical costs incurred by both public and private sector actors in developing a PPP for commercial operation, and so include "transaction costs" associated with PPP procurement processes and contract negotiation, as well as (especially in some developing countries) "upstream" legal, regulatory, and policy preparation tasks that go well beyond normal transaction costs (De Schepper, Haeqendonck, & Dooms, 2015).

How are governments and their development partners coping with the fact that PPPs are costlier and less profitable than assumed in the 1990s? One way is to rely more heavily on "blended finance" approaches to PPPs. Since the launch in the early 2000s of the multi-donor trust fund for output-based aid (the Global Partnership on Output-Based Aid), "blended finance" has become increasingly popular as a way of using concessional finance to catalyze private sector investment, particularly in infrastructure PPPs. The International Finance Corporation's (IFC) Blended Finance Unit, launched in

2007, and the EU's regional blending finance facilities, such as the EU-Africa Infrastructure Trust Fund, have all used subsidies to bring down the costs of various kinds of infrastructure PPPs (IFC 2012). The use of blended finance in this way creates a hybrid approach that combines PPP elements with those of more traditional public projects. Blended finance acknowledges private partners' limitations to fully prepare PPP projects in a way that optimizes economic benefits. It provides substantial effort by donors and MDBs to pay for and supervise preparation before private partners become involved, resulting in more effective, sustainable, and pro-poor projects. The stronger role for governments and their development partners in identifying problems and designing solutions for private partners to implement is a characteristic of hybrid management contracts being developed or implemented in countries like Benin, Liberia, and Sierra Leone (Republic of Sierra Leone 2015). These contracts shift risks away from private partners, toward governments, donors, and MDBs, who are, theoretically, better able to mitigate those risks. Ultimately, this should make the contracts more productive and sustainable.

Yet critics argue that blended finance involves the use of subsidies, requiring justification to ensure that it is really crowding in private finance rather than crowding it out. Economists typically recommend the use of cost-benefit analyses for such justifications to clearly identify any obstacles that reflect market failure and help determine whether subsidized finance can solve the problem. Theoretically, cost-benefit analyses can confirm that the likely development impacts of using subsidized finance far outweigh the distortions that may result. When this kind of analysis can be done, it almost certainly leads to more developmental projects, and ensures quantifiable metrics to maximize the benefits of undertaken projects. Evidence then points to blended finance, as a means to combine the public and private sector, while avoiding the risks and shortcomings of classical PPP arrangements. Blended finance may very well be complemented with other forms of intervention in the future, but it seems to be an effective means to spur growth in the financial sector of LDCs, and since it is focused on sustainable development, its longer-term orientation may lead to more future success.

## Section V: Conclusion

The conclusion we can ultimately reach is complex. Full public sector intervention is typically more oriented on spurring developments for LDCs, but corruption, misallocation of capital, and at times misaligned incentives, highlight that it is not the most efficient arrangement in LDCs' financial sector. We move on to full private sector intervention, where the profit-seeking mentality by nature should incentivize efficient growth and mechanisms to ensure more financial stability. In reality however, the private sector fails to handle risks and high interest rates, political and economic instability, and extraneous circumstances such as COVID19 virus. It proves weak against challenges that are very common in LDCs, and seem to not have the tools to survive in tougher financial environments. Lastly, we shift our attention to public-private partnerships. Considered traditionally to combine the legislative power, influence, and urgency of the government, with the organized, structured, and rich structure of the private sector, PPPs seem to be the most efficient means to spur growth in the financial sector of LDCs. Yet, as we unmask the whole truth, it becomes clear that certain forms of PPPs are problematic, and especially in LDCs may be obsolete. It is however, not always the case, as can be seen with blended finance. Focused on sustainable development and philanthropic funds to cushion private sector risks, blended finance offers a more risk-averse and navigable path towards long-term growth. We thus reach the conclusion that LDCs should look to adopt PPPs in the form of blended finance. This is necessary to mobilize needed funds, focus on a sustainable future, and provide the tools and strength against risk that is needed to combat the adverse situation of LDCs and ensure efficient financial sector developments.

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# Mixed Methods Analysis of Two Inexpensive and Simple Aquaponics Systems for School Use

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## Abstract

Aquaponics is the conjoined farming of fish and plants in the same system. Researchers have found that aquaponics can provide many educational and nutritional benefits to schools such as educational opportunities and access to fresh food, but many schools lack the funds to build them (School Systems, n.d.). This finding from previous studies sparked this study's question: how can a High School student with little to no building experience, construct an inexpensive and reliable aquaponics system for school usage?

To answer this question a convergent parallel mixed study was conducted, comparing the fish and plant growth, ease of maintenance, and construction of 2 different aquaponics systems, one of a raft design and another based on a pipe design. It was concluded that a pipe system would be better for schools, as it resulted in a better growth rate of both plants and fish, along with lower costs, easier maintenance and simpler construction.

*Keywords: aquaponics, building, school, inexpensive, education*

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## Introduction

Aquaponics is a subset of the larger farming method of hydroponics, growing plants without soil. Aquaponics uses fish to provide fertilizer in the form of excrement (i.e. feces) as well as a food source for humans. Aquaponics is an ever-growing market and is gaining traction around the world as a way to effectively farm in small spaces (Shahbandeh, 2021).

This farming method has been around for most of human history in South East Asia, Africa and South America. They did this by building floating rafts on lakes where the roots of the plants would float in the water (Keeper, 2016). However, it is only in recent years that this method of cultivation is coming back into common use (Keeper, 2016). The idea behind aquaponics is to grow fish and plants together in a single system, with fish creating fertilizer for the plants (i.e. feces). This type of farming often uses fast-growing and hardy fish that also serve as food. In this way, two food sources can be created in one system.

Schools have been known to use aquaponics for food production, as a community project and learning piece (Rains, 2018). Unfortunately, not all schools have access to aquaponics due to the price and complexity that can come with maintaining such a system. Therefore, this study seeks a solution to address both the price and complexity issues schools



face with aquaponics. The ultimate goal of this study is to provide schools with a sustainable, replicable, and cost-effective method for agriculture, food production, and education.

## Literature Review

### *General Aquaponics Uses and Benefits*

A study conducted by marine scientists in 2016 (Mamat et al., 2016) found that catfish aquaponics production is an effective and timely manner to cultivate plants and fish for consumption. Another study of carp and watercress growth in an aquaponics farm, found that all carp grew rapidly in just a few weeks and suffered no mortalities (even in the limited space of the tank), leading to the conclusion that aquaponics is an effective form of farming (Irhayyim et al., 2020). Additionally, in a study of low-income Hawaii residents, easy access to fish and vegetables from a low-cost aquaponics system was found to reduce rates of diabetes and other diseases, as well as obesity (Beebe et al., 2020).

### *School Uses for Aquaponics*

A look at another source shows that aquaponics can be useful in classrooms and schools as a tool for educating students (Stroud, 2018). Schools should be teaching students about future technologies and emerging markets like aquaponics. Aquaponics is becoming an increasingly popular agricultural option around the world, as evidenced by the continued rise and projected growth of this market. This market is projected to increase from a value of \$523 million in 2017 to over \$870 million in 2022. (Shahbandeh, 2021)

Therefore, it is beneficial to teach students about this different form of agriculture as it is seen by many as the solution to food shortages and the future of agriculture. Not only that, if you look at a school in Chattanooga, Tennessee, the students were very excited to talk about their farm. As such, teachers taking students to the farm would be a good way to teach students about future forms of agriculture and how nutrients move around an ecosystem, instead of using a video or a model (WDEF CBS Chattanooga, 2015). But while this is all useful, it won't matter if they can't procure a system due to the costs and complexity involved in purchasing one (School Systems, n.d.).

### *Literature Gap*

When schools build an aquaponics system, they often bring in professionals from a company like Nelson and Pade (an aquaponics construction company that sells to schools) to build a large-scale system. This can be a complicated process because of the required technology, large temperature controlled space, water access and the overall assembly and upkeep. A limiting factor in large scale aquaponics is price (Chattanooga, 2015). A large-scale, piped system built at Chattanooga School, cost according to Nelson and Pade Aquaponics between \$84,000 and \$114,000. This puts such a system out of reach for the vast majority of schools as they cannot afford such a complicated and advanced system. No study currently places a focus on the implementation of aquaponics, rather than its effectiveness.

This study determines whether a student can build and later maintain an aquaponics system. And whether it can be done reliably and with little monetary investment but great yield of fish and plants. This can be determined by comparing the weight gain of the fish and plants with the weight gain of other types of cultivation. The aquaponics design should be compact, inexpensive, but simple enough that an average high school student can build it with as little difficulty as possible. The people this would affect the most would be those who work and learn at a school, as the owners and principals can decide what to do with their system, whether it be to reduce food production costs or to introduce their futuristic system to others.

The goal of this study is to construct a system on a smaller scale that is far less costly, so that any school that builds such a system would not have spent a lot of money if it failed. In this way, even schools with fewer resources can use aquaponics.

Some may argue that there is no need for this study because other studies have already been done on the low-cost production of aquaponics, such as studies on the production of systems in Hawaii where aquaponics was used to feed native Hawaiians living in poverty (Beeb et al., 2020). The topic of this academic study is to construct and maintain inexpensive aquaponics systems for each school with the research question, "How can a high school student with little to no construction experience construct an inexpensive and reliable aquaponics system for school usage? The results of this study determined which aquaponics system would be easier for a high school student with little construction skills to build and maintain in order to construct a system for a school to reap all the benefits of aquaponics.

### *Design and Prototype*

There are many limitations to a project like this, but the most important are those of price, space and skill. The average school may not be willing to buy a \$50,000 Aquaponics System, and it is even less likely to provide large sums of money to a student attempting to build such a facility. But most schools have two hundred dollars that can be used to build an aquaponics farm. The solution to this problem was using inexpensive materials such as plastic containers and PVC (Nelson, 2019). Space was taken into consideration. Therefore, the study was limited to a small space, a small part of an empty balcony in the school. This was to simulate the small space a school might have for such a project. The skills of the students were also taken into consideration. Not everyone can handle power tools, so as few power tools or complex building techniques as possible were used in these designs.

### **Project**

To gather information on the topic and search for designs, a focus was placed on scholarly sources from online databases such as Gale. This study was a convergent parallel mixed study, using a true experimental design. The growth of tilapia and watercress were measured in 2 separate systems and recorded on a spreadsheet over two weeks.

### **Methods**

#### *Research Methods*

After consideration, a 2-system convergent-parallel mixed study was chosen. In this study, plant growth and fish growth were measured in 2 systems, along with notes on how the systems performed and any errors that occurred (Appendix D). The quantitative portion of this study was inspired by previous aquaponic growth studies (Irhayyim et al., 2020). The fish and plant measurements make up the quantitative part of the mixed methods, while the notes and history make up the qualitative part of the study.

#### *Study Subjects*

The fish chosen for this study was the Red Tilapia (*Oreochromis Niloticus*) because it is very hardy and thrives in hazardous conditions as well as having a rapid growth rate. Six specimens were taken from a school pond. The plant chosen was watercress (*Nasturtium Officinale*), due to its history of aquaponics growth and cultivation. It was also chosen because of its rapid growth rate, which would enable a short growth study, such as this, to show much clearer results. The size of the watercress when they entered the aquaponics system varied from 0.2 cm to 1.6 cm. This can perhaps be attributed to uneven exposure to sunlight as they were covered with an umbrella during germination to protect them from heavy rain.

#### *Ethical Considerations*

This study used live organisms, as such, measures were put in place to ensure their health and comfort. The fish chosen were from a local pond at the Singapore American School, as there was a very large population of tilapia and removing six fish would not injure the ecosystem. They were placed in bins with adequate water supply, fed conventional aquarium

food, and given cover to keep them safe throughout the study. The fish were measured only twice throughout the study's duration so that they would not experience stress. In the event of a fish casualty, however, they would not be replaced, as that would be altering the qualitative data from the study. Once the study was over, the fish were released to their native pond.

### *Instruments*

A ruler was used to measure plant height and an electric scale was used to measure the weight of the fish. In the construction of the systems, a focus was placed on economical and simple materials. Rather than using PVC in the pipe system, a rain gutter was chosen (Figure 1). The choice was made after consulting with an experienced builder, who had worked with PVC pipe before, who said that PVC pipe is difficult to work with, even with access to power tools, while rain gutters have an open-top already, eliminating the need to cut holes. For the ponds, plastic bins were used, as they are inexpensive and common (Figure 2). Aquarium filters were chosen due to their low price, easy repair, and large availability. It should be noted that the price of the fish, feed, and seeds are not included in the overall budget as worldwide prices and availability vary. The pipe system cost \$136.8 Singapore dollars (Appendix B) and the raft system cost \$75 Singapore dollars (Appendix B).



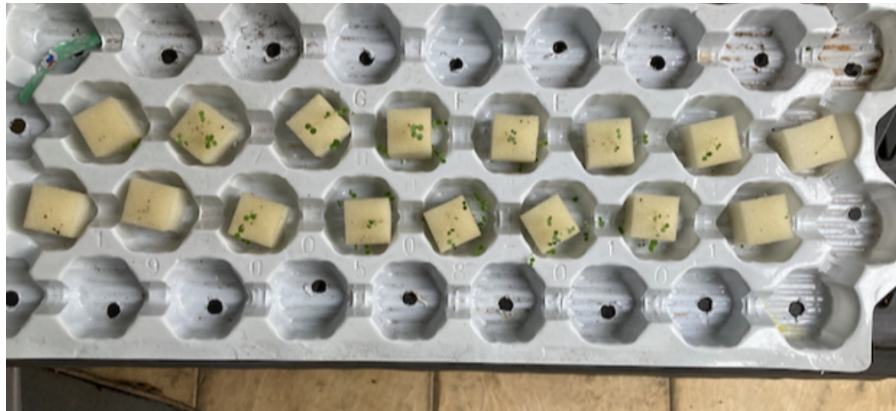
**Figure 1.** Pipes used in the construction of the pipe system



**Figure 2.** The Raft System materials before assembly

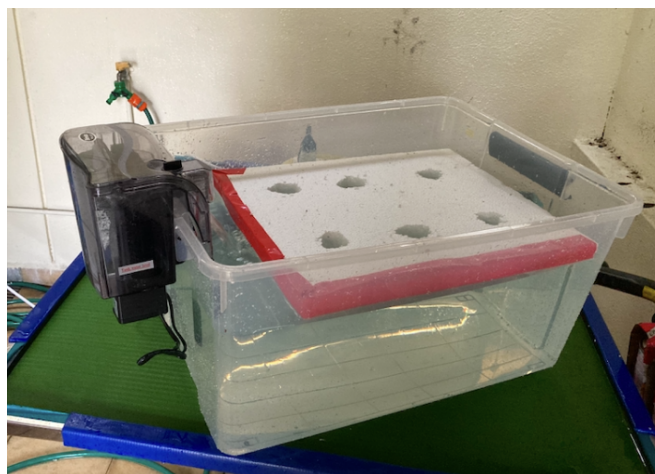
### *Procedures*

Two aquaponics systems were constructed differing in design and prices. One being of the floating raft (Appendix A: Figure 1) variety and the other being of pipe design (Appendix A: Figure 2). These designs were chosen as they were shown to be mechanically simple systems. Approximately five days before the study began the watercress was 'started'. This process involved soaking a sponge with water, making a small cut, then placing the seed inside. This allowed the plant to germinate and grow to a seedling (see Figure 3). The sponge was periodically checked for signs of mold, which could damage the seedlings. While the plants were germinating the two systems were constructed.

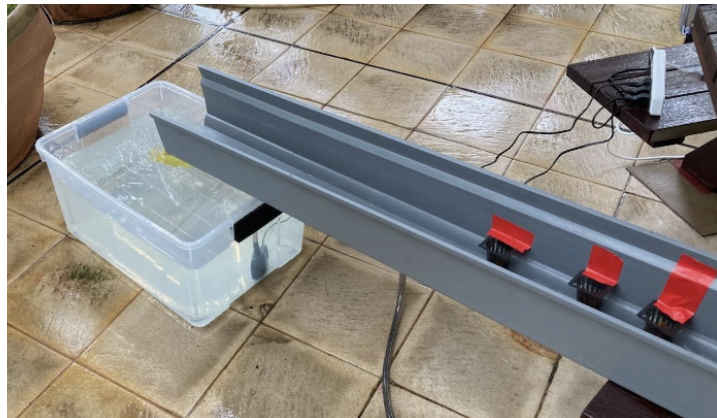


**Figure 3.** *Watercress seeds being started in damp sponges before the study*

The first system built was the raft system. It was built by first pouring water into the tub, fitting the filter, letting it cycle to clean the water, and test that it was working properly. The system was then left to run for four days to let the chlorine dissolve. While the water was filtered and cleaned, the styrofoam was cut into a rectangle that covered about half of the water's surface (see Figure 4). The plant holding baskets were measured and holes were cut for them in the styrofoam, being careful that the holes were smaller in diameter than the basket's lip. For this study, the ratio used was two plants per fish as suggested by other researchers (Brooke, n.d.); once the baskets had been placed, the leca balls were deposited, so that bacteria could start growing and prepare the water for the Watercress. Figure E shows the fully assembled pipe system during the several days in which water was filtered in order to get rid of any chlorine or chemicals.



**Figure 4.** *The Raft System fully assembled during building process*

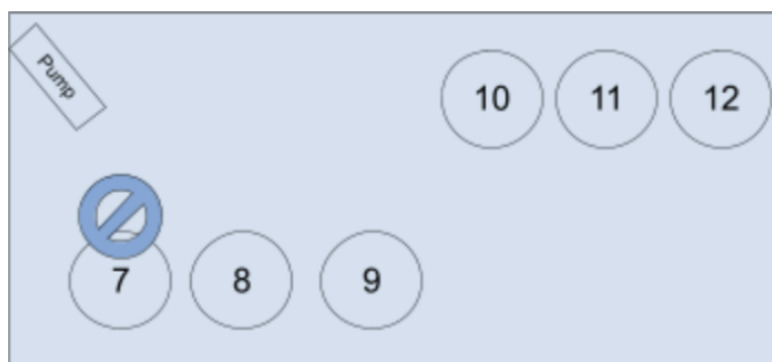


**Figure 5.** The Raft System fully assembled during building process

Next, the water was allowed to cycle for two days, before the fish were introduced and measured. The fish were given two days to acclimate before the plants were measured and added to the system. Figure F and Figure G showcase the layout of the plants on both the pipe and raft system. The plants in the diagrams have been numbered, in order to better understand the results discussed later.



**Figure 6.** Raft System plant Layout. Note that plant 5 has a cross over it, illustrating that it died during the study.



**Figure 7.** Pipe System plant Layout. Note that plant 7 has a cross over it, illustrating that it died during the study.

### *Variables*

This experiment had one dependent variable, the subject growth. Their growth was dependent on the effectiveness of the system and the ability of the researcher to maintain it. The independent variable was the system, as that was the variable that was changed to see the differences in the growth. The dependent variable could be altered or tampered with by a change in weather conditions (rain, excessive heat, etc.) but the comparative portion of the study would be unaffected by this as both systems are in the same location and environment, and suffer the same conditions.

A variable that had not initially been taken into consideration was pests such as ants. After the loss of several crops to ants, a nontoxic solution was devised by using a two-inch tall barrier of Vaseline and baby powder. (Appendix A, Figure 3) The ants were stopped as they would slip off the barrier. Using pesticides ran the risk of water contamination and possibly killing the fish or harming the plants.

### *Assumptions*

In the study, it was likely that the raft system would overall be slightly more effective in plant growth and fish growth. The pipe system pump had the possibility of being jammed by a leaf that falls into the pond or a leftover piece of fish feed. This would be easy to fix but would take time to do so. The filters could fill with waste, causing them to become near useless in terms of cleaning the water. In the event of nitrification, the fish could run out of oxygen in the water and possibly suffocate. Regarding the results, it was determined that some of the plants would not have grown. Mr. Andrew Grant, a project consultant who has a background in agriculture, said that some plants are ‘fussy’ in the sense that they simply will not grow, which is a factor that was carefully observed and included in the qualitative notes.

### *Threats to validity*

In the study, larger fish were selected for the systems. The rationale behind this choice was the presence of large cats and birds at the school. A cat would be more able to eat and kill a smaller fish, while a larger fish has a better chance of survival. If a fish or plant were to die, and the researcher replaced it then another threat to validity will have been created, as the study would have been compromised due to tampering of the dependent variable. But, if a piece of technology fails such as the filter or pump and a repair is unable to be done, then a new one shall be procured, and the price be included in the 200 dollar budget of the design. In the event of an animal or external threat, the necessary precautions will be taken, and the price for such be added to the overall budget. There was also a threat in the form of other humans tampering with the systems. This could ruin the data collection of the whole study.

## **Planned Analysis**

### *Quantitative*

A T-test was conducted on the quantitative data collected to determine the average growth of both plants and fish in each of the systems and determine any outliers or strange results in the data. Graphs were generated in R, a coding program that is used specifically for data and statistical analysis.

### *Qualitative*

The notes taken daily, which included observations on the functionality of the system and subject condition, were analyzed together with the research mentor, Mr. Andrew Grant, and presented in the final conclusions. These results could change the outcome of the study, as a system may grow both plants and fish incredibly effectively. But if the system requires constant maintenance and parts replacement then it would not be an effective system.

## Data Gathered

### Plants

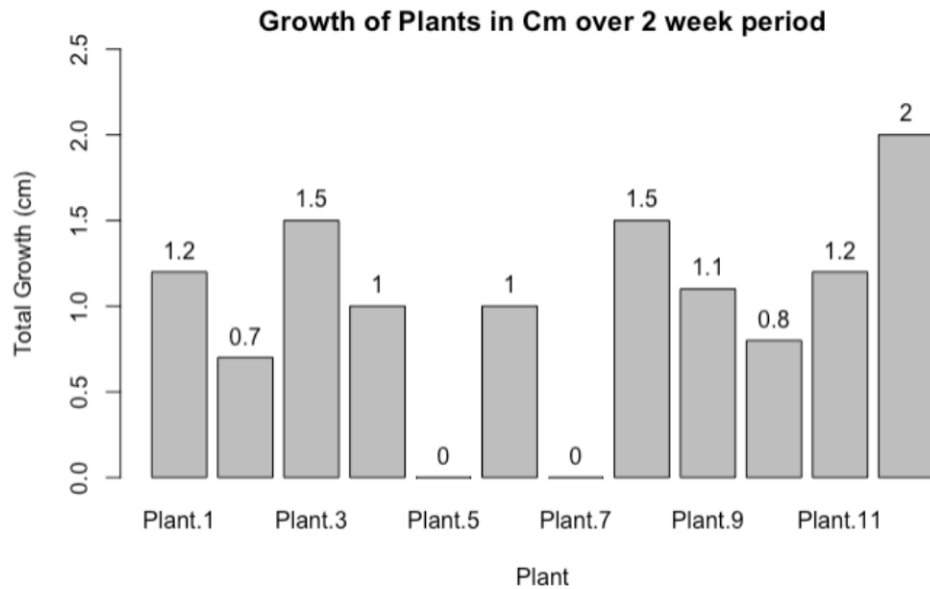
Plant growth averaged 1.08 cm for the Raft System and 1.32 cm for the Pipe System, therefore the Pipe System plants grew more, on average, than the plants in the Raft System. However, both systems lost plants. Plant five died on day 11, while Plant seven died on day six (Figure 8, Figure 9 and Figure 10).

Day	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1	0.2	1.4	1	0.3	1.2	1.5
2	0.2	1.4	1	0.5	1.2	1.5
3	0.3	1.5	1	0.7	1.3	1.7
4	0.4	1.6	1.1	0.7	1.3	1.7
5	0.5	1.6	1.1	0.7	1.3	1.7
6	0.5	1.6	1.1	0.7	1.3	1.7
7	0.5	1.7	1.2	0.7	1	1.8
8	0.5	1.8	1.2	0.8	1	1.9
9	0.6	1.8	1.2	0.7	1	1.8
10	0.7	1.9	1.4	0.8	1	1.9
11	1	2.1	1.7	0.9	0	2
12	1.2	2.4	2.1	1	0	2.1
13	1.3	2.9	2.4	1.2	0	2.4
14	1.4	2.1	2.5	1.3	0	2.5

**Figure 8.** Chart of Raft System Plant growth, all values are in CM. The day the value becomes 0 is the day a Plant dies.

Day	Plant 7	Plant 8	Plant 9	Plant 10	Plant 11	Plant 12
1	1.1	1.4	1.5	0.5	1.6	1
2	1.1	1.4	1.5	0.5	1.6	1.2
3	1.4	1.6	1.8	0.7	1.8	1.5
4	1.5	1.9	1.9	0.9	2.3	1.7
5	1.6	2.2	2	1.1	2.4	2.1
6	0	2.2	2	1.1	2.4	2.1
7	0	2.4	2.1	1.2	2.6	2.2
8	0	2.6	2.1	1.2	2.8	2.5
9	0	2.7	2.3	1.3	2.9	2.7
10	0	2.7	2.4	1.3	2.9	2.7
11	0	2.7	2.5	1.3	2.7	2.9
12	0	2.7	2.5	1.3	2.7	2.9
13	0	2.8	2.6	1.3	2.7	3
14	0	2.9	2.6	1.3	2.8	3

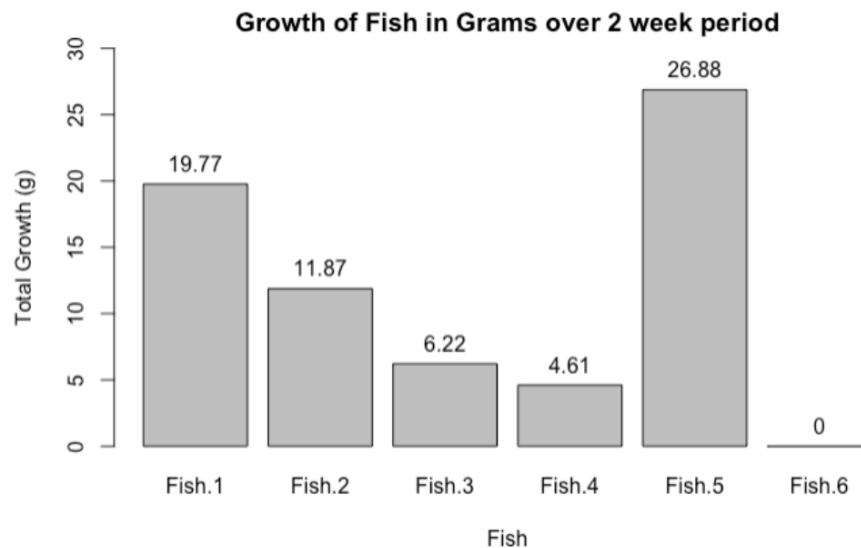
**Figure 9.** Chart of Pipe System Plant growth, all measurements are in CM. The day the value becomes 0 is the day a Plant dies.



**Figure 10.** Growth of Plants in Cm over a 2-week period. The plant value of 0 indicates that the plant died.

*Fish*

Figure 11 shows that fish 4-6 in the Raft system grew an average of 15.74 grams over two weeks, and the fish 1-3 in the pipe system grew an average of 12.62 grams over that same period. In the raft system, it should be noted that fish six died due to nitrification (when an algal bloom consumes oxygen in the water), while fish four grew 4.61 grams and fish 5 grew 26.88 grams, causing the high average growth. Whereas in the Pipe system all three fish survived, fish one with a weight increase of 19.77 grams, fish two with 11.87 grams, and fish three with 6.22 grams (Figure 11).



**Figure 11.** Growth of Fish in Grams over a 2-week period. Fish 1 through 3 were in the Pipe System, Fish 4 through 6 were in the Raft System. The value of 0 indicates that the fish died.

*Casualties*



It was noted that both systems had one plant casualty, plant five in the raft system and Plant seven in the pipe system. Plant seven died due to biological material (i.e. feces, fish food, plant matter, bacteria) getting carried up by the pump, and blocking water from reaching the watercress roots (Figure 13 and 14). The raft system had a larger issue in the form of nitrification. An algal bloom occurred and began to consume much of the oxygen out of the water, causing fish six to suffocate to death. This was determined to be the cause as previous attempts at the test had had similar results happen, and they happened during an algal bloom. Along with fish six’s death in the raft system plant five died, but its death has been determined to be caused by ‘fussiness’ or an unwillingness to grow. This was determined as parasites or chemical imbalances would have affected the plants around it, rather than just affecting plant five.

## Quantitative Analysis

### Fish growth

The variable measured for the tilapia was their weight increase. The growth rate of the fish in the pipe system (.9 grams a day) was fast for tilapia, which can range from .1 grams a day to 1.9 grams a day in a professional aquaponics farm. (Santos, 2018) This makes this system (if scaled up) a feasible form of small-scale food production for schools. But after conducting a t-test in R, the p-value was found to be 0.06213 meaning that there is a ~6% chance that the differences between fish weight could be attributed to a random variable (genetics, age). The most likely candidate for a random growth would be fish five, as it gained 26.88 grams in the study, above the average.

Day	Fish 1	Fish 2	Fish 3	Fish 4	Fish 5	Fish 6
1	112.94 g	98.6 g	86.73 g	89.52 g	74.83 g	42.62 g
14	132.71 g	110.47 g	92.95 g	94.13 g	101.71 g	Dead (day 5)

**Figure 12.** Chart of Fish Growth. Fish 1 through 3 were in the Pipe System, Fish 4 through 6 were in the Raft System. The day the value becomes 0 is the day a Fish died.

### Plant Growth

The growth of the pipe system plants was an average of .09 cm per day, although it should be noted that plant ten reached its height of 1.3 cm on day eight, then proceeded to stop growing. Whereas plant 12 grew consistently over the two weeks with one centimeter gained per week. This does show that not all plants are the same, and some will inherently grow better than others. This is interesting as, due to the plant layout (Figure 7), plant 10 would get more water than plant 12, despite this plant 12 grew incredibly quickly.

### Failures Analysis

The pipe system had several issues with its maintenance as the pump in the system would pick up solid matter (i.e. feces, fish food, plant matter, bacteria) and pump it directly into the pipe (Figure 13). This resulted in a large amount of solid waste entering the pipe causing blockage and overall issues for the pump's ability to operate, as some of the matter was stuck in the pump, decreasing the water flow through it (Figure 14). This could harm the longevity of the system but can be fixed by placing filter sponges on the outside of the pump. In the case of the raft system, the nitrification that occurred would cause problems for the long-term use of the system. The nitrification caused the fish to suffocate. This could damage the farming ability and upkeep of the system as one mistake could kill every fish in the pond.



**Figure 13.** Biomatter in the Pipe System carried by pump. A mix of fish feces, algae and leaves that had fallen in.



**Figure 14.** The large biomatter buildup that suffocated Plant 7 in the Pipe System. Note how the biomatter is clogging the basket.

## Qualitative Analysis

### Cost Analysis

In an effort to produce low-cost aquaponics for schools, some trade-offs had to be made to keep it cost-effective, one of those trade-offs being the price and quality of the material (see Figure 1 and 2). This resulted in unexpectedly inferior materials being used. Specifically, the filters had to be changed every five days because they were clogged with algae. In addition, the plastic tanks had problems with flexing from the volume of water inside pushing on the walls. The first problem could be solved by using larger filters, while the second problem could be solved by placing one tank inside another to increase the structural integrity of the entire system.

### *Unexpected Results*

Interestingly, in the pipe system, the fish spawned. This fact has large implications, as this can lead to a replicating farm and serve as a teaching opportunity to possible students about the spawning of fish, their life cycle, and the conditions required for it. This can also help with system longevity, as the young fish can be moved to another new system if the school ever decided to expand their systems.

### *Building and Maintenance Process*

The building process for both systems was quite simple. (Refer to the methods section for building process). Once all materials had been collected the building was simple, it took two hours to fully build both systems. Importantly, no power tools were used as they require a level of skill to use effectively and are expensive. The only tools used for building were scissors, duct tape, and box cutters. The only time the box cutter was used was when cutting out holes in the Styrofoam for the plant baskets to hang from. With these common tools, a simple design, and adaptable materials the ability to easily build and maintain aquaponics can become far more open to schools.

### *Limitations*

There have been limits to what this study accomplished. The largest of those is the materials list and their pricing. The materials used were purchased in Singapore, and while chosen due to their nature as common materials, students at schools in less developed regions may have trouble replicating these designs precisely. As such these designs should serve as a general guideline, with materials being very general and subject to differentiation based upon the location of the school building these systems. The price is subject to the same implications. In this study, pH and Nitrate levels were not measured, as it had not initially been planned to measure them.

### *Conclusion*

Overall, the better system was the pipe system, as it grew plants faster, had better survivability, and created a good habitat for the fish to spawn in. While it is true that the pipe system had more pieces that could fail, these could be solved with ease. For example, a filter sponge on the pump intake would solve matter being carried to the pipe. As such the death of plant seven could have been avoided as the water's flow would not decrease due to clogging. Additionally, the flowing water would prevent nitrification in the tub, keeping the fish more comfortable and alive.

In contrast with the raft system, where the repairs required were minimal, but the algal bloom was a large failure, which can destroy a system. Further research can be done on these systems involving a longer study with more controlled conditions (weather, temperature). If schools use this study to begin the building of aquaponics, high school students will begin to build and encounter obstacles similar to the ones encountered here. This research allows them to innovate over what has been experimented on, expanding the knowledge base of how to build a cost-efficient and functional Aquaponics system for schools around the world.

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## Appendices

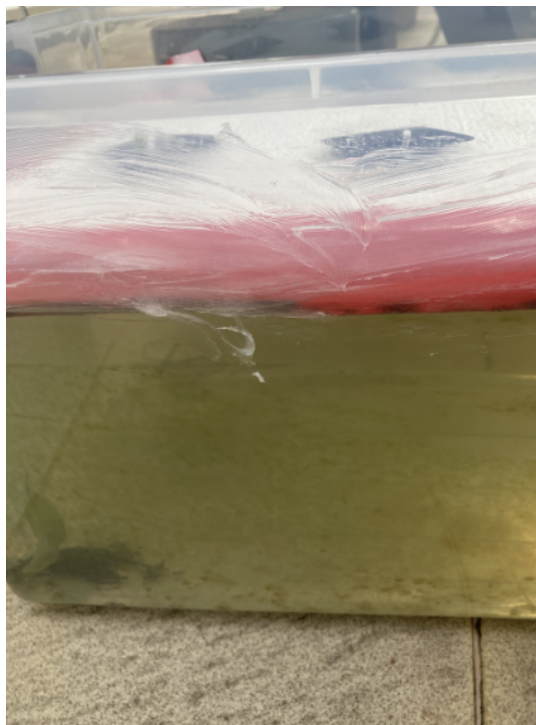
### Appendix A



**Figure 1.** Raft system during study. Note the green water indicating a high amount of nutrients and algae in the water.



**Figure 2.** Pipe System during study, fish 2 can be seen in the bottom left of the bin beneath the filter.



**Figure 3.** The Vaseline and Baby Powder layer applied to the outside of both systems

### Appendix B

List of Materials (All in 2020 Singapore Dollars)

Pipe System Materials:

- Rain gutter \$17.5
- Leca balls \$8.9
- Syncra silent pump \$47
- Filter: \$30
- Plant baskets 40 cents each
- Germination foam \$6
- Tub \$25
- Total: \$136.8

Raft System Materials:

- Foam float \$3.6
- Filter \$30
- Plant basket 40 cents each
- Germination foam \$6
- Tub \$25
- Leca balls \$8.
- Total: \$75

## Appendix C

```

library(dplyr)
library(ggplot2)

Quest <- read.csv("~/Desktop/Fish Quest Study/Quest (1).csv")
#Create a zero vector for size difference for plants and fishes
Size_Difference = rep(0, times = ncol(Quest))

#Run through columns to compute size difference
for(i in 1:ncol(Quest)){
  Size_Difference[i] = Quest[14,i]-Quest[1,i]
}

#Clean up size difference vector: (i) Remove 1st value (difference in days) and (ii) Recompute last value as fish died
Size_Difference = Size_Difference[2:19]
Size_Difference[18]=Quest[5,19]-Quest[1,19]

#Compute average growth rate
Average_growth = Size_Difference/length(Size_Difference)
#Split by Plants and Fishes

Size_Difference_Plants = Size_Difference[1:12]
Size_Difference_Fishes = Size_Difference[13:18]

Average_Growth_Plants = Average_growth[1:12]
Average_Growth_Fishes = Average_growth[13:18]

#Size Difference for Plants Graph#
#Set negative values as 0
Size_Difference_Plants [5]=0
Size_Difference_Plants[7]=0

#Plant Name - x-axis
plant_name = names(Quest)[2:13]

...

```{r}
#Chart for Plants
plant_chart = barplot(Size_Difference_Plants, names.arg = plant_name, main="Growth of Plants in Cm over 2 week period", xlab =
"Plant", ylab = "Total Growth (cm)",y=c(0,2.5))
text(plant_chart, Size_Difference_Plants, labels=Size_Difference_Plants, pos=3)
#Average Plant growth for raft system: 1.08 cm
#Average plant growth for pipe system: 1.32 cm2

...

```{r}
#Size Difference for Fishes Graph#
#Set negative values as 0
Size_Difference_Fishes[6]=0

#Fishes Name - x-axis
fish_name = names(Quest)[14:19]

#Chart for Fishes

```



```

fish_chart = barplot(Size_Difference_Fishes,names.arg=fish_name, main="Growth of Fish in Grams over 2 week period",
xlab="Fish",ylab="Total Growth (g)",ylim =c(0,30))
text(fish_chart, Size_Difference_Fishes, labels=Size_Difference_Fishes, pos=3)

#Average of Raft System is 15.745 g of growth
#Average Pipe Sysetm is 12.62 g of growth

#growth of fish 1:117.5%
#Fish 2 112.271%
#Fish3 107.1%
#FISH 4 105.19%
#Fish 5 135.92%
...

```{r}
data <- read.csv("~/Desktop/Fish Quest Study/Quest (1).csv")
#Load New Dataframe with Plants Data
PlantRaft <- data %>%
  select(Plant.1, Plant.2, Plant.3, Plant.4, Plant.5, Plant.6)
PlantPipe <- data %>%
  select(Plant.7, Plant.8, Plant.9, Plant.10, Plant.11, Plant.12)
#Test the Data frame
#sample_n(Plants,14)
#T test for the Plant Data
#t.test(Plants, conf.level = .95)

t.test(PlantRaft, PlantPipe, alternative = "two.sided", var.equal = FALSE)

...

```{r}
#Load New Dataframe with Fish Data
FishPipe <- data %>%
  select(Fish.1, Fish.2, Fish.3)
FishRaft <- data %>%
  select(Fish.4, Fish.5, Fish.6)
#Test the Data frame
#sample_n(Fish,14)
#T test for the Fish Data
#t.test(Fish, conf.level = .95)
t.test(FishPipe, FishRaft, alternative = "two.sided", var.equal = FALSE)

...

```

**Figure 1.** Code used to find P-Value and Graph Data

Appendix D

Notes

Day	Failures	Repairs	Observations
1			There is a lot of bacterial buildup in the system, this is good as it has added a lot of nutrients to the water and created a miniature ecosystem within the tank itself.
2			The plants have grown minimally so far, but that is to be expected, as they need time to acclimate to the new environment, but I believe that they will soon begin to grow rapidly.
3	Water loss	Water filled up again via a small amount of hose water. Note possible increases in chlorine.	Water level appears to be decreasing, it is possible that this is being caused by the heat and sunlight causing evaporation, as it does not appear that there is a leak in the tank.

4			The fish in the pipe system appear to have spawned, as today multiple tilapia fry were found in the pond. This is interesting, as fish will not normally spawn unless they feel they are in a safe and comfortable location. The meaning of this is huge, as it is possible to have a replicating system, where from one system's fish you can start multiple individual farms. They are currently being grown at home in order to determine species.
5			
6	Plant 7 died due to clogging.		Plant 7 is dead. After some investigation the reason was found. It appears that debris brought up from the pond via the pump clogged the basket, blocking water from reaching the plant. Overall, the solution to this failure would be to place some form of grate or better filter to catch the debris. This has been noted.
7			
8			
9			
10			Pump flow decreasing, cause found to be leaves and other matter blocking the water intake. Blocking objects removed.
11			
12			
13			
14			

**Figure 1.** Qualitative information taken on the Pipe System. On days with nothing written, no significant changes in the system occurred.

Day	Failures	Repairs	Observations
1			There is a lot of algal buildup inside the tank. This poses a risk of possible Nitrification in the future. Although fish 4 and 5 are accustomed to this and are fine, I believe that Fish 6 (newly introduced specimen) will die due to being new and any stress causing possible increased breathing.
2			The algal growth does appear to be decreasing, the reason is not currently known.
3			In contrast to the pipe system, it appears that there is no water loss in the raft system. It is possible that the raft covering most of the water is stopping a great deal of evaporation.
4	Algal Buildup		Algal buildup is starting to return, even in the filter there is some algal buildup. This has been cleaned out.
5	Fish Death	N/A	Today fish 6 died, as per my prediction there is likely not enough oxygen in the water to sustain
6			
7			
8			
9			
10			
11	Plant Death (Fussiness)		Plant 5 died today; the cause is as of now unknown. Pests have been ruled out due to their inability to reach the plants thanks to the vaseline baby powder barrier and covering the plants. As of right now the cause is most likely 'fussiness'. According to Mr. Grant, my mentor, some plants simply will not grow, and there is nothing you can realistically do about it.
12			
13			
14			

**Figure 2.** Qualitative information taken on the Raft System. On days with nothing written, no significant changes in the system occurred.