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Service Delivery Strategies for Alleviating Pandemic Suffering while Maintaining Profitability

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The post-pandemic world requires a renewed focus from service providers in ensuring that all customer segments receive the essential services (food, healthcare, housing, education, etc.) they need. Philanthropic service providers are unable to cope with the increased demands caused by the social, economic, and operational challenges induced by the pandemic. Customer self-selecting no-pay service strategies are becoming popular in various settings. Obtaining insights into how they can efficiently balance societal and financial goals is critical for a for-profit service provider. We develop and analyze a quantitative model of customer utilities, vertically-differentiated product assortment, pricing, and market size to understand how service providers can effectively use customer segmentation and serve the poor at the bottom of the pyramid. We identify conditions under which designing the service delivery to be accessible to the poor can simultaneously benefit the for-profit service provider, customers, and the entire society. Our work provides a framework to obtain operational, economic, and strategic insights into socially responsible service delivery strategies.

Key words: Service Delivery, Free Service, Segmentation, Philanthropy, Income Equality, Social Welfare

1. Introduction

COVID-19 related disruptions to work, life, and finances, the resulting economic downturn, increased unemployment, and the sudden reduction in customers' ability to pay for essential services (e.g., healthcare, food, housing, education) have transformed the perspectives of service providers. Exacerbated by the millions that lost health insurance coverage and faced financial predicament due to the Covid-19 pandemic (Stolberg 2020), charitable healthcare services that traditionally cared for the customer segment at the bottom of the pyramid are facing major funding challenges and are struggling to maintain their operations (AHA 2020). The percentage of doctors providing charity care has declined over the years (Cunningham and May 2006). Traditional for-profit hospitals are having to make up for this slack, but are also using it to enhance their image and create goodwill for strategic purposes (Hirth 1997, Kuttner 1999).

Organizations are now, more than ever, trying to ensure that the lower-end of their customer base continues to avail of necessary services and have started to consider implementing strategies that encourage those unable to pay to receive essential services at no cost. For example, Dean's Restaurant and Bakery in Knoxville, TN, offers free meals to elderly customers who cannot get supplies or prepare meals. Many New York City hotels made free rooms available for quarantining patients, healthcare professionals, and social workers. As a result of this transformation, the *self-selecting no-pay service offering* strategies are becoming ubiquitous. Under this scheme, customers who cannot afford to pay can opt to receive service at no or little cost, yet service organizations achieve their financial objectives. The mechanism(s) through which service organizations can achieve this balance between societal and financial goals is the focus of this research.

Self-selecting no-pay service offerings are not new. "*50% of its patients receive services either free of cost or at a steeply subsidized rate, yet the organization remains financially self-sustainable.*" proclaims the website of India's 43-year old Aravind Eye Care System comprising 13 eye hospitals, six outpatient centers, and 75 primary care centers that have performed six million surgeries and handled 56 million outpatient visits. While its mission to "eliminate needless blindness" is the main driving force, financial health is a close second due to the "no margin, no mission" mantra (coined by sister Irene Krauss of the Daughters of Charity National Health Care System) that drives the modern healthcare (and most non-profit) organizations in the world. In 2010, it captured a net profit of $7.9 million on the revenues of $20 million, the performance that puts it at par with many highly successful commercial ventures.

Self-selecting no-pay service offerings can also be found in a wide variety of other industries. Ballard Spahr LLP, a nationally renowned law firm with about 650 lawyers in 15 offices, recently won the Marvin E. Frankel award for increasing their pro-bono representation by almost seven hundred hours. The University of Texas recently announced a plan to provide a full scholarship to in-state undergraduate students whose families have annual incomes below $65,000. Mannan's of Washington D.C. invites the homeless to eat for free, serves about 16,000 free meals per year, and is financially sustainable for the past six years it has been in business. Dr. Kongkrit Chaiyasate (Oak Grove, MI), through Ray of Hope Medical Missions, offers his services for free to correct cleft palate in patients, often small children, from developing countries. Michelle Lumadue, an independent and licensed cosmetologist, volunteers at Akron Children's Hospital and provides her services for free to patients and their caregivers.

Why do these highly accomplished and well-trained experts, service professionals, and organizations who have invested rather heavily in themselves and have well-defined monetary objectives give their services away for free? Do these charitable activities help them better achieve their financial performance targets? What are the conditions under which these strategies should be considered, and how should they be designed and implemented? How will these strategies improve the quality of life in the post-pandemic world that is expected to be rampant with unemployment, income inequality, and reduced mobility? These are the questions we address in this paper by developing a structured quantitative framework to capture the following phenomena:

Philanthropic customer utility amplification — A provider's participation in these charitable activities results in an amplification of the paying customers' willingness-to-pay enabling the provider to charge a higher price for its products. A paying customer at Aravind Eye Hospital is well aware that a portion of his/her payment is going toward helping a low-income person receive the surgery they very much need. Recognizing this social impact, the paying customer's utility from patronizing Aravind Eye Hospital is amplified. As a result, they are willing to pay more (than under the traditional circumstance) for the same service. Similar arguments can be made for the other service examples of the sandwich shop, the hair-stylist, the plastic surgeon, and the lawyer's office. The key here is the necessity of the service and inequity in affordability. In a hypothetical setting in which a service provider offers teeth whitening services, free for those that cannot pay — which is mainly perceived to be cosmetic and not a necessity in life — the paying customer will not see this as a charitable activity and may not receive additional utility from this provider's service. Thus the philanthropic amplification of utility would be non-existent. Such philanthropic utility amplification was first observed in the experiments conducted by Trudel and Cotte (2009). Tully and Winer (2014) performed a meta-analysis of more than eighty research papers across a large number of product categories and found that 60 percent of respondents are willing to pay a premium for socially responsible products. Specific to the service industry, Parsa et al. (2015) provide evidence that consumers with high involvement in, and positive attitudes toward, corporate socially responsible practices are willing to pay a premium. Forester (2008) provides an economic rationale for the benefits to benefactors – paying clientele – of the service offerings by the charitable care provider to attain self-sustainability.

Restrictions-induced no-pay utility reduction — When the no-pay option is selected, the service provider may not provide a specific scheduled time for the service, restrict the options that the customers can choose from, and/or deny access to secondary facilities such as the preparation and recovery rooms. These restrictions reduce the utility a no-pay customer will realize. At the Aravind Eye Hospital, a no-pay customer may feel disappointed, insulted, or angered by the restrictions imposed on them since they cannot recover in the attached air-conditioned rooms even if they were available. Such a restriction is reasonable since if the customer could pay for the recovery room, they should have used that to pay for the surgery and not avail of the no-pay option. Nevertheless, the restriction will have some psychological effect, and the no-pay utility reduction is used to capture it. The service provider may have the ability to impact this utility reduction by appropriately designing the service flow to manage the interaction between the paying and no-pay customers and appropriately monitoring the information flows about all the available services.

Charity- and volume-driven service delivery marginal cost reduction — Providing charitable free services and the resulting increased customer volume will result in a reduction in marginal cost due to the following reasons:

1. Increased service volume will enable the service professionals to go up the learning curve much faster and accumulate a skill set that is valued by the marketplace. Recognizing this, many service professionals choose to start their careers (often at a lower than market salary) at a charitable organization. After a few years, having compiled a larger than normal work experience, they make a transition to the traditional market at a significantly higher salary level. The transition point is chosen by the service professional to maximize their career earning potential, and the organization saves in salary costs from the time of hire to the transition time.

2. Not all service professionals that start their careers at a charitable organization leave to realize their market potential. Some identify themselves very well with the social mission of the service provider and realize non-monetary life and career fulfillment that more than compensates for the lower salary they earn for their entire careers.

The COVID-19 pandemic has widened the gap between the haves and the have-nots, significantly increasing income inequality. Recognizing the suffering experienced by many people, customers are growing their philanthropic perspective. During our field study, we learned that customers are now increasingly willing to pay more for the services, particularly those offered by the philanthropic providers, fully acknowledging that some of their payment is being used to support the struggling customers.[1]. The customers that cannot pay for the essential services are more willing to bear the encumbrances of the self-selecting no-pay option and are willing to choose that option. The service professionals are now more inclined to cherish the social mission of their service and are willing to work more for less.

[1] The philanthropic healthcare service providers that participated in our field study are Aravind Eye Care System (https://aravind.org/), L.V. Prasad Eye Institute (https://www.lvpei.org/), Fernandez Hospital (https://www.fernandezhospital.com/), and Sankar Foundation (http://www.sankarfoundation.org/) In another private study at one of the service providers, it is estimated that almost 35 percent of the revenue generated from the paying customers is used to cover the costs of serving the customers at the bottom of the pyramid for free.

These changes, brought about in the past few months, have accelerated the implementation of the self-selecting, no-pay strategies, and service providers are looking for analytical, managerial, and strategic guidance that this research will provide. We formulate, analyze, and solve mathematical customer utility models with vertically differentiated service offerings and evaluate the role the phenomena mentioned above play in shaping the strategic decisions associated with whether a service provider should offer the self-selecting no-pay option to its customers. If it does, we provide insights into how it should decide the capacity levels, product variety, prices, and the service blueprint. Our focus on a for-profit service provider that operates in a philanthropic service delivery environment by devising market segmentation strategies is relevant for diverse settings covered in the existing literature, e.g., processed food and agricultural products (Yayla-Kullu et al. 2020), revenue management (Liu and Zhang 2013), education (Young 2020), humanitarian operations (Besiou and Van Wassenhove 2020), etc.

The existing literature provides many studies that focus on philanthropic service providers' approaches to attain self-sustainability and achieve social and financial goals. In this regard, ideas such as devising ecosystems around the poor and serving them, and offering the services for free to *any* segment of customers are quite popular. For instance, de Véricourt and Lobo (2009) examine a resource and revenue management problem in non-profit operations to achieve an efficient trade-off between the revenue-generation and mission objectives by serving the rich and the poor. Gupta et al. (2018) demonstrate that the marketing activities (at Aravind Eye Care System) that are targeted only to poor patients produce the spillover benefit of attracting paying patients to its hospitals. In the setting of software as a service, Li et al. (2019) examine the implications of free samples offered by a for-profit service provider to customers to show that free samples of the entire content, rather than substitutes, can be very effective in increasing revenues for the firm. Kong et al. (2019) examine the use of information and communication technologies (in healthcare) and provide guidelines for service providers exploring technology-based avenues to reach the masses in remote areas. In this regard, outreach services such as telemedicine, teleconsulting, mobile diagnostics through innovative interventions are some of the recent approaches that allow healthcare service providers to meet their service delivery objectives (see, e.g., Misra et al. (2020)). Saviano et al. (2010) examine strategies to achieve the balanced triple target of efficiency, effectiveness, and sustainability in healthcare service systems. Our work presented in this paper adds to this stream of literature by highlighting the significance of market segmentation using free services for self-selecting customers as a way to achieve social and financial goals for for-profit service providers.

At the core of most for-profit service providers' business models is the market segmentation strategy using an efficient balance between product/service quality levels and prices in a product/service line (see Mussa and Rosen (1978), Moorthy (1984) for the seminal studies). Our work presented in this paper enriches a broader stream of literature on managing product/service variety (see Krishnan and Ulrich (2001), Ramdas (2003) for in-depth reviews). The same phenomenon is observed in non-profit settings that typically adopt cross-subsidization based approaches as well (see, Weisbord (1998)). (An interested reader is referred to Rangan (2009) for further details at Aravind Eye Care System.) All over the world, the interest of practitioners and policy-makers in investing in social enterprises to reach out to the bottom of the pyramid is growing. However, rigorous evaluations to investigate the impact and quality of services and determine the effectiveness of cross-subsidization strategies in philanthropic healthcare service delivery settings are sparse (see Bhattacharya et al. (2010)). Tung and Bennett (2014), on the other hand, analyze private for-profit providers offering services to the poor on a large scale and assess the future prospects of the bottom of the pyramid models in health. World Bank (2017) examines business model innovations across five sectors – Education, Energy, Finance, Healthcare, and Water and Sanitation (WASH). They highlight why scaling and replication are important for enterprises delivering goods and services in low-income markets and how selected enterprises scale and replicate. In this regard, the work by Joncourt et al. (2019) revises the bottom of the pyramid business model idea. It develops a framework highlighting key dimensions for management research such as business ecosystems, financial viability, innovativeness, resource scarcity, the role of the poor, and scalability. Our work presented in this paper also adds to the domain of non-profit operations and strategies, as synthesized by Berenguer and Shen (2020), by providing insights into service delivery approaches through market segmentation and scale economies that typically benefit for-profit service providers.

This paper develops, analyzes, and solves a quantitative model of customer utilities, vertically-differentiated product assortment, pricing, and market size to understand how service providers can use customer segmentation effectively and serve the poor at the bottom of the pyramid. The motivation for our work presented in this paper comes from a field study with philanthropic healthcare service providers in India. We show that a for-profit service provider's strategy of serving the poor at the bottom of the pyramid by extending the self-selecting no-pay option to customers may enhance its service quality, market coverage, profitability, consumer surplus, and social welfare compared to that in the traditional mode of service delivery generating positive revenues from each of the market segments. These Pareto optimal outcomes result from the customers' utility amplification and the volume-based cost reduction attained by the service provider in the high-volume environment. We demonstrate that the service provider shares the benefits of economies of scale with the customers by offering superior-quality (optional) service components to paying customers that facilitate segmenting the market and achieving the business models' sustainability under the cross-subsidization environment. Our counter-intuitive result is that offering a high-quality service component to the poor for free need not be beneficial as the consumer surplus, aggregated for *all* customers in the market, decreases beyond a threshold service *quality* for the poor. In contrast, the service provider's profitability *always* reduces. In this regard, attaining an efficient balance between the customers' utility and the cost-reduction benefits is critical to enhancing the service provider's profitability, which is essential to ensure sustainability. We extend our model to examine the implications of income (in)equality for the philanthropic service provider's service offerings. Self-selecting no-pay strategies are more effective (i.e., profit, customer surplus, and social welfare are all larger) when income inequality is higher.

The rest of the paper is organized as follows. In the following section, we provide an overview of the modeling approach and present the models for a service provider under two different settings – traditional and philanthropic modes of service delivery. In Section 3, we analyze our models and identify the conditions under which the profit-maximizing service provider adopts one mode of service delivery over the other. Section 4 provides insights into the implications of critical model parameters for the outcome variables such as the service provider's profitability, market segmentation, consumer surplus, and social welfare. In Sections 5 and 6, we extend our models to enhance the service provider's decision-making scope. In Section 7, we enrich our proposed model to capture income inequality as a proxy for the customers' utility function. Section 8 summarizes our findings and concludes the paper. Proofs of the technical results described in the main paper and additional results are presented in a supplement.

2. Model Building

2.1. Model Setup

We consider a service provider offering a service that consists of two components, (i) necessary service component; and (ii) optional service component. Every customer that receives service at this service provider must obtain the former, and the latter is an optional add-on. At the Aravind Eye Hospital, the necessary service is the cataract surgery, while the optional service is the air-conditioned recovery room. Every patient that comes through the Aravind Eye Hospital will have their eye operated upon, but then can choose whether to pay for and recover in the attached luxurious facilities or recover at home. Similar partitions in service can be done at other providers as well. At a sandwich shop, the necessary portion would be the sandwich itself, and the optional portion would be an accompanying specialty beverage. At a hairstylist, the necessary portion will be a wash and a cut, and the hot towel service, the shoulder and neck massage would be optional. At a hotel, the necessary portion would be a comfortable bed and a hot shower, while room service would be the optional portion. We model and analyze such a service provider under two different scenarios, as detailed below.

Traditional Mode : The service provider expects all customers to pay for service and charges separately for the necessary and the optional service components. Thus a customer must pay for and receive the necessary service component and choose whether to pay for and receive the optional service component. These decisions will be based on the relative values of customer utilities (for the necessary and optional service components) and the prices (for the necessary and optional service components) charged by the service provider.

Philanthropic Mode : The service provider gives the option to the customers to not pay for the necessary service if they are not able to pay. However, the no-pay customers cannot avail of the optional service. At the Aravind Eye Hospital, customers can receive a free cataract surgery, but cannot use the luxurious recovery rooms. At a sandwich shop, the no-pay customer can get a free sandwich, but cannot get a specialty beverage. At a hairstylist, the customers unable to pay can receive a free wash and a cut, but cannot receive the hot towel service and the neck and shoulder massage. At a lawyer's office, the customer could avail of pro-bono immigration services, but cannot avail of fee-based estate planning services.

Using these two modes of service delivery, we would like to answer the following research questions:

1. Under what conditions would a service provider move from the traditional mode to the philanthropic mode?

2. How will the service provider set the prices for these two components under each mode of operation?

3. What level of quality will the service provider choose for the optional service component?

4. How do the service provider profit and social welfare compare across these two modes of operation?

The service providers in our motivating examples attain an optimal balance between the number of no-pay and paying customers served that maximizes the operating profit entailing the organization's sustainability. Accordingly, we formulate the philanthropic service provider's problem in our model as maximizing its profit that is defined as the aggregate of the revenue earned minus the service delivery costs, including the cost of providing the free service to the self-selecting no-pay customers – the service provider's philanthropy.

2.2. Traditional Mode of Service Delivery

In the traditional mode of service delivery, the service provider charges price p_n for the necessary service component, and price $p_o(q)$ for the optional service component at *quality* level q. A customer receives utility u_n from the necessary service component and $u_o(q)$ from the optional service component at quality level q. A customer purchases only the necessary service component when $u_n - p_n > 0$ and $u_o(q) - p_o(q) < 0$. On the other hand, the customer pays for and receives the necessary and optional service components only when $u_n - p_n > 0$ and $u_o(q) - p_o(q) > 0$. The approach to model the customer self-selecting the necessary service component and/or the optional service component reflects the fact that the optional service component is purchased *only* when the necessary service component, by itself, meets the customer's utility requirements. To relate with our motivating examples, a customer would explore the option of purchasing a luxury room (optional service component) only if its target utility is met from the cataract surgery (necessary service component) offered by a service provider.

To capture heterogeneity among the customers in the utility derived from the service provider's services and their unequal willingness-to-pay for the services, we consider that the customer's utility u_n to be uniformly distributed between zero and one. Also, $u_o(q) = k_u u_n q$, where $k_u > 0$ is the scale parameter that captures the utility derived by u_n-customer from the optional service component compared to that from the necessary service component. The higher the value of the parameter k_u, the higher is the relative utility of the optional service component.

When $k_u < 1$, the relative utility of the optional service component is lower than the utility derived from the necessary service component. The scenario captures the settings such as heart surgeries and cancer treatments wherein the customers do not value the optional service components more than the necessary surgeries that are critical, and at times, treating conditions that are life-threatening (see, e.g., Khanna et al. (2005) and Khanna and Bijlani (2011) for an overview of Narayana Hrudayalaya Heart Hospital in India, a service provider that is operationally comparable to Aravind Eye Care System and L.V. Prasad Eye Institute). On the other hand, $k_u > 1$ captures the settings such as cataract surgeries, cosmetic surgeries, dental treatments that are typically less critical and have become commodity services over the years. For such services, the attractiveness of the services for the customers is the optional service components, e.g., that in medical tourism (see, e.g., Gahlinger (2008)). Later in Section 5.4, we highlight the implications of the relative utility of the optional service component for the service provider's preferred service delivery mode – traditional or philanthropic.

A customer will choose to pay for and receive only the necessary service component if $u_n - p_n > 0$ and $u_o(q) - p_o(q) < 0$, i.e., if $u_n > \tilde{u}_l^T$ and $u_n < \tilde{u}_h^T$. Here $\tilde{u}_l^T = p_n$ and $\tilde{u}_h^T = p_o/(k_u q)$. On the other hand, a customer will choose to pay for and receive both necessary and optional service components if $u_n - p_n > 0$ and $u_o(q) - p_o(q) > 0$, i.e., if $u_n > \tilde{u}_l^T$ and $u_n > \tilde{u}_h^T$. It may be noted that the customer that buys the necessary and optional service components pays $(p_n + p_o)$ in aggregate for the service. To ensure that the model is meaningful, we require $\tilde{u}_h^T \geq \tilde{u}_l^T$.

Let $\tilde{d}_n^T$ be the fraction of the customers that buy only the necessary service component, and $\tilde{d}_o^T(q)$ be the fraction of the customers that purchase both necessary and optional service components. Thereby, we obtain $\tilde{d}_n^T = \tilde{u}_h^T - \tilde{u}_l^T$ and $\tilde{d}_o^T(q) = 1 - \tilde{u}_h^T$. The total fraction of the market covered by the service provider in the traditional mode is $(1 - p_n)$.

Without loss of generality, we consider that the service provider's *base* cost of offering the necessary service component to a customer is $c_n > 0$, the cost of providing the optional service component at quality level q is $c_o(q)$. Let $c_o(q) = k_q q^2$, where $k_q > 0$ is the scale parameter for the quality cost of the optional service component. Our approach to capturing the cost of quality for the service provider as a (quadratic) convex increasing function of the quality level, which implies decreasing returns to scale, is widely adopted in the existing literature (see, e.g., Heese and Swaminathan (2006)). In view of our motivating examples, we assume that the service provider does not achieve the (average) cost reduction benefits via the economies of scale by serving only the paying customers in the traditional mode of service delivery.

We assume that the number of customers in the market is $m > 0$ and is exogenously determined. (Later in Section 5, we extend the model to determine the optimal market size for the service provider endogenously.) Let $k_m m^2$ be the service provider's cost of serving the market of size m.

The profit for the service provider in the traditional mode of service delivery is described as follows:

$$\tilde{\pi}^T(q, p_n, p_o) = (p_n - c_n)\left(\frac{p_o}{k_u q} - p_n\right) m + \left(p_n + p_o - k_q q^2 - c_n\right)\left(1 - \frac{p_o}{k_u q}\right) m - k_m m^2 \qquad (1)$$

The service provider's problem is $\pi^T = \max_{q, p_n, p_o \geq 0} \tilde{\pi}^T(q, p_n, p_o)$ s.t. $0 \leq p_n \leq p_o / k_u q \leq 1$.

In our analysis, we also examine the implications for, among other variables, the consumer surplus (S) experienced by the customers and the social welfare (W).

The consumer surplus experienced by the customers in a segment is defined as the difference between the customers' willingness-to-pay and the actual price they pay, aggregated for all customers in the segment. Accordingly, the consumer surplus for the customers that purchase only the necessary service component is given as: $\tilde{S}_n^T = m \int_{\tilde{u}_l^T}^{\tilde{u}_h^T} (u_n - p_n)\, du_n = (p_o - p_n k_u q)^2 m / (2k_u^2 q^2)$. Similarly, the consumer surplus for the customers that purchase both necessary and optional service components is described as: $\tilde{S}_o^T = m \int_{\tilde{u}_h^T}^{1} (u_n - p_n + u_o(q) - p_o(q))\, du_n =$

$(k_u q - p_o)\,[p_o\,(1 - k_u q) + k_u q\,(1 + k_u q - 2p_n)]\,m/\,(2k_u^2 q^2)$. As it would be evident in the following section, $\tilde{S}_f^T$, the consumer surplus for the customers that do not purchase the paying service from the service provider is zero, by definition.

The social welfare is defined as the sum of the service provider's profit and the consumer surplus experienced by the customers in the market. In the traditional mode of service delivery of the service provider, the social welfare is described as $\tilde{w}^T = \tilde{\pi}^T + \tilde{S}_n^T + \tilde{S}_o^T + \tilde{S}_f^T$. Similarly, in the philanthropic mode of service delivery of the service provider, the social welfare is described as $\tilde{w}^P = \tilde{\pi}^P + \tilde{S}_n^P + \tilde{S}_o^P + \tilde{S}_f^P$.

2.3. Philanthropic Mode of Service Delivery

For ease of exposition in the philanthropic mode of service delivery, we continue with the same notation as that from the traditional mode of service delivery. Thereby, let the service provider's price for the necessary service component be p_n, and the price for the optional service component at quality level q be $p_o\,(q)$. A paying customer receives utility βu_n from the necessary service component and $\beta u_o\,(q)$ from the optional service component at level q, where $\beta > 1$ is the philanthropic amplification of customer utility. In the philanthropic mode of service delivery, as discussed earlier, the service provider offers a no-pay option to the customers for the necessary service component. However, the optional service component delivery is not available to the no-pay customers. We assume that the no-pay customer receives utility ωu_n from the necessary service component, where $\omega \in [k_\omega, 1]$, $0 < k_\omega < 1$, captures the restriction-induced utility reduction.[2] The higher (lower) the value of ω, the lower (higher) is the restriction-induced utility reduction.

A customer will choose the no-pay option when $\omega u_n > \beta u_n - p_n$, i.e., if $u_n < \tilde{u}_l^P$ where $\tilde{u}_l^P = p_n/\,(\beta - \omega)$. A customer will choose to pay for and receive only the necessary service component if $\beta u_n - p_n > \omega u_n$ and $\beta u_o\,(q) - p_o\,(q) < 0$, i.e., if $u_n > \tilde{u}_l^P$ and $u_n < \tilde{u}_h^P$ where $\tilde{u}_h^P = p_o/(k_u \beta q)$. On the other hand, a customer will choose to pay for and receive both necessary and the optional service components if $\beta u_n - p_n > \omega u_n$ and $\beta u_o\,(q) - p_o\,(q) > 0$, i.e., when $u_n > \tilde{u}_l^P$ and $u_n > \tilde{u}_h^P$. To relate with our motivating examples and also to capture the most general setting in which *all* customer segments in the market are feasible, we require $\tilde{u}_h^P \geq \tilde{u}_l^P$.

Let $\tilde{d}_n^P$ be the fraction of the customers that buy only the necessary service component, and $\tilde{d}_o^P\,(q)$ be the fraction of the customers that buy both necessary and optional service components. Similarly, let $\tilde{d}_f^P$ be the fraction of the customers that adopt the no-pay service. Thereby, we obtain

[2] All of our mathematical and computational results continue to hold under conditions $\omega \in [k_\omega, \beta)$ that captures $1 < \omega < \beta$. However, we do not focus on this setting because we believe it is not practically justifiable within the framework of our motivating examples.

$\tilde{d}_n^P = \tilde{u}_h^P - \tilde{u}_l^P$, $\tilde{d}_o^P(q) = 1 - \tilde{u}_h^P$, and $\tilde{d}_f^P = \tilde{u}_l^P$. It is immediate that the service provider caters to the entire market of size m.

As discussed earlier, the service provider in the philanthropic mode of service delivery benefits from reducing the average cost of providing the necessary service component to the customers. The entailing economies of scale in service delivery are essentially driven by serving the pool of no-pay customers available, in addition to the paying customers (see Shah and Murthy (2004) for further details). One may consider the scale economies in service delivery based on the widely popular approach that models the total cost as an increasing concave function with a decreasing slope in the number of customers served (see, e.g., Pinker and Shumsky (2000); McRae et al. (2020) and the references therein for studies in the healthcare sector). However, for analytical tractability in Section 5, we consider the per-unit cost saving to be additive that captures a first-order approximation of the benefits (see, e.g., Kim and Chhajed (2000), Subramanian et al. (2013)). In particular, let the unit cost for the service provider to cater to a customer be $(c_n - k_s m)$. Here, $k_s > 0$, referred to as the degree of the economies of scale, is a parameter that captures the average cost reduction based on the number of customers served. When the degree of scale economies is higher, i.e., k_s is higher, the volume-based average cost reduction is quicker. To make the cost function meaningful such that $c_n > k_s m$, we assume that c_n is sufficiently large and k_s is relatively small. (A careful observation will reveal that the functional form of the scale economies in service delivery does not change the structural and qualitative results, except that in Section 5, presented in this paper.) It may be observed that the average cost of providing the necessary service component decreases due to scale effects. In contrast, the cost of providing the optional service component does not reflect that phenomenon.

The profit for the service provider in the philanthropic mode of service delivery is described as follows:

$$\tilde{\pi}^P(q, p_n, p_o) = p_n \left(\frac{p_o}{\beta k_u q} - \frac{p_n}{\beta - \omega} \right) m + \left(p_n + p_o - k_q q^2 \right) \left(1 - \frac{p_o}{\beta k_u q} \right) m - (c_n - k_s m) m - k_m m^2 \tag{2}$$

The service provider's problem is $\pi^P = \max_{q, p_n, p_o \geq 0} \tilde{\pi}^P(q, p_n, p_o)$ s.t. $0 \leq p_n / (\beta - \omega) \leq p_o / (\beta k_u q) \leq 1$.

The consumer surplus experienced by various customer segments are described as follows. For the customers that purchase only the necessary service component: $\tilde{S}_n^P = m \int_{\tilde{u}_l^P}^{\tilde{u}_h^P} (\beta u_n - p_n)\, du_n = [p_n \beta k_u q - p_o (\beta - \omega)] [p_n k_u q (\beta - 2\omega) - p_o (\beta - \omega)] m / \left[2\beta (\beta - \omega)^2 k_u^2 q^2 \right]$. For the customers that purchase both necessary and optional service components: $\tilde{S}_o^P = m \int_{\tilde{u}_h^P}^{1} (\beta u_n - p_n + \beta u_o(q) - p_o(q))\, du_n =$

$(\beta k_u q - p_o)\left[p_o(1-k_u q) + k_u q(\beta + \beta k_u q - 2p_n)\right] m/(2\beta k_u^2 q^2)$. The consumer surplus for the customers that adopt the no-pay option for the necessary service component is described as follows: $\tilde{S}_f^P = m\int_0^{\tilde{u}_l^P}(\omega u_n)\,du_n = \omega p_n^2 m/\left[2(\beta-\omega)^2\right]$.

3. Analytical Results

In this section, we analyze the service provider's problems for the two settings: the traditional mode of service delivery and the philanthropic mode of service delivery. For brevity, we present only the optimal solution for critical variables in the main paper; other variables are described in the supplement.

3.1. Traditional Mode of Service Delivery

We present the optimal solution to the service provider's profit-maximization problem in the traditional mode of service delivery using superscript T.

Proposition 1. *Given the quality level of the optional service component q, the optimal prices for the necessary and optional service components of the service provider in the traditional mode of service delivery are given as: $p_n^T(q) = (1+c_n)/2$ and $p_o^T(q) = [q(k_u + k_q q)]/2$.*

It may be noted that the service provider's optimal price for the optional service component increases in the quality level of q. Additionally, the optimal prices for both service components are independent of the market size.

Proposition 2. *The optimal quality level of the optional service component of the service provider in the traditional mode of service delivery is described as: $q^T = \max\{c_n k_u/k_q, k_u/(3k_q)\}$.*

When $c_n > 1/3$, $q^T = c_n k_u/k_q$ implying that the customer demand for only the necessary service component vanishes; an irrelevant scenario within the framework of our motivating examples. Thereby, henceforth, we assume that $c_n < 1/3$. It implies that the optimal quality of the optional service component in the traditional mode of service delivery is $q^T = k_u/(3k_q)$.

The implications of the parameters k_u and k_q for the quality of the optional service component are as expected. Additionally, it may be noted that the optimal quality level is independent of the market size.

3.2. Philanthropic Mode of Service Delivery

We present the optimal solution to the service provider's profit-maximization problem in the philanthropic mode of service delivery using superscript P.

Proposition 3. *Given the quality level of the optional service component q, the optimal prices for the necessary and optional service components of the service provider in the philanthropic mode of service delivery are given as:* $p_n^P(q) = (\beta - \omega)/2$ *and* $p_o^P(q) = [q(\beta k_u + k_q q)]/2$.

Interestingly, the necessary service component's optimal price is proportional to the difference between the philanthropic customer utility amplification and the restriction-induced utility reduction for the no-pay option. Additionally, we observe that the service provider does not extract the entire utility differential from the customers. It provides incentives to the customers to pay for the necessary service component, instead of adopting it for free, by sharing a portion of the utility differential. The optimal price for the optional service component increases in the quality level of the component and the philanthropic amplification of the customer utility in the philanthropic mode of service delivery. However, the optimal prices for both the service components are independent of the market size.

Proposition 4. *The profit maximizing quality level for the optional service component of the service provider in the philanthropic mode of service delivery is described as:* $q^P = \beta k_u/(3k_q)$.

The optimal quality level of the optional service component increases in the utility amplification parameter in the philanthropic mode of service delivery. Also, the quality level is independent of the service provider's target market size.

4. Comparative Statics

This section compares the optimal solutions to the service provider's problems in the two settings – traditional and philanthropic modes of service delivery. We examine the implications of the service provider's strategic choice of service delivery mode for the service components' optimal prices, customer demands, consumer surplus, and the service provider's profitability. We mainly focus on critical aspects of the philanthropic mode of service delivery, namely (i) the philanthropic amplification of customer utility (β), (ii) the restriction-induced utility reduction for the no-pay option (ω), and (iii) the degree of scale economies (k_s).

4.1. Implications for Optional Service Component

Proposition 5. *Due to the philanthropic amplification of utility* ($\beta > 1$)*, the (optimal) quality and price of the optional service component offered by the service provider in the philanthropic and traditional modes of service delivery are such that* $q^P > q^T$ *and* $p_o^P > p_o^T$.

Under the service provider's philanthropic mode of service delivery, the customers' utility amplification results in increased willingness-to-pay for the optional service component. It allows the service provider to offer higher quality for the optional service component and charge a higher price that *may* result in higher profitability (implications for profitability are discussed in detail in Section 4.5).

4.2. Implications for Necessary Service Component

PROPOSITION 6. *If* $(\beta - \omega) < (\geq)\, 1 + c_n$, *we obtain* $p_n^P < (\geq)\, p_n^T$.

Proposition 6 compares the price of the necessary service component in the philanthropic mode of service delivery with that in the traditional mode of service delivery. It shows that the necessary service component's price is less (more) only when the difference between the philanthropic customer utility amplification and the restriction-induced no-pay utility reduction is relatively small (large). The service provider faces severe price-pressure on the necessary service component when the advantage of adopting the philanthropic mode of service delivery, as reflected in the difference between the philanthropic customer utility amplification and the restriction-induced no-pay utility reduction, is not significantly high. In this case, the service provider's optimal strategy is to reduce the price for the necessary service component while adopting the philanthropic mode than that in the traditional mode of service delivery. On the other hand, when the advantage of adopting the philanthropic mode of service delivery is higher due to the higher difference between the philanthropic customer utility amplification and the restriction-induced no-pay utility reduction, the service provider can increase its profitability by increasing the price for the necessary service component above that in the traditional mode of the service delivery.

4.3. Implications for Paying Customers

PROPOSITION 7. *The number of customers that buy the paid service components in the philanthropic and traditional modes of service delivery is such that* $d_n^P + d_o^P > d_n^T + d_o^T$.

Proposition 7 highlights the service provider's capability to increase the number of paying clientele that buys either only the necessary (paid) service component or both necessary and optional service components by extending its service to the poor for free. By adopting the philanthropic mode of service delivery, the service provider increases its revenue by offering superior quality for the optional service component at a higher price. It also increases the number of customers buying the necessary service component, implying an increase in the total number of paying customers served by the service provider. The latter effect is due to the customers' utility amplification and the increased price-pressure for the service provider on the necessary service component. We also observe in our analysis that the size of each of the customer segments increases in the market size m targeted by the service provider in both traditional and philanthropic modes of service delivery.

The results presented in Propositions 6 and 7 bring out interesting insights in managing the pricing and demand for the necessary service component. In the philanthropic mode of service delivery, under certain situations, the service provider *may* obtain more profit than that in the traditional mode of service delivery by increasing the price of the necessary service component and the market share of the paying customers simultaneously. We examine the implications for the service provider's profitability in Section 4.5.

4.4. Implications for Consumer Surplus

PROPOSITION 8. *The implications of the service provider's mode of service delivery for the consumer surplus is such that* $S_n^P > S_n^T$ *and* $S_o^P > S_o^T$.

Proposition 8 shows that the (consumer) surplus experienced by the customers that buy either only the necessary service component or both necessary and optional service components in the philanthropic mode of service delivery is more than their corresponding values in the traditional mode of service delivery. Consequently, the consumer surplus experienced by all types of customers in the market in the philanthropic mode is more than that in the traditional mode of service delivery. The surplus for the customers that buy both necessary and optional service components increases due to the philanthropic amplification of the utility and the higher quality of the optional service component, even though the price of the optional service component increases as well. On the other hand, the increase in the surplus experienced by the customers that purchase only the necessary service component is primarily attributed to the philanthropic utility amplification and the increase in the size of the customer segment.

4.5. Implications for Service Provider's Profitability and Service Delivery Modes

PROPOSITION 9. *Adopting the philanthropic mode of service delivery yields higher profit to the service provider than the traditional mode of service delivery, i.e.,* $\pi^P > \pi^T$, *only when the philanthropic amplification of utility is above threshold* $\underline{\beta}(\omega, k_s)$ *or the restriction-induced no-pay utility is above a certain threshold, i.e., the parameter* ω *is below threshold* $\overline{\omega}(\beta, k_s)$ *or the degree of scale economies is above threshold* $\underline{k_s}(\beta, \omega)$, *where*

$$\underline{\beta}(\omega, k_s) = \frac{-27k_q + \left\{729k_q^2 + 432k_u^2 k_q \left[\omega + (1+c_n)^2\right] + 64k_u^2\left(k_u^2 - 27k_q k_s m\right)\right\}^{1/2}}{8k_u^2} \tag{3}$$

$$\overline{\omega}(\beta, k_s) = \frac{4\left(\beta^2 - 1\right)k_u^2 + 27k_q\left[\beta - (1+c_n)^2\right] + 108k_q k_s m}{27k_q} \tag{4}$$

$$\underline{k_s}(\beta, \omega) = \frac{27k_q\left[(1+c_n)^2 - \beta + \omega\right] - 4\left(\beta^2 - 1\right)k_u^2}{108k_q m} \tag{5}$$

Proposition 9 shows that the philanthropic mode of service delivery is profitable to the service provider only under certain conditions. When the customers' philanthropic utility amplification is sufficiently large, the service provider can earn more profit than that in the traditional mode of service delivery by offering a higher quality of the optional service component at a higher price. As described in Proposition 6, the necessary service component's price may also be increased, yielding a higher revenue. Furthermore, the service provider's profitability increases by the increased market share of the customers that adopt the paid service instead of the no-pay service option.

When the restriction-induced no-pay utility reduction is lower, i.e., ω is higher, it increases the competitiveness of the no-pay service option against the paid components of the service. The higher price-pressure on the paid components for the service provider reduces its profitability in the philanthropic mode of service delivery. Thereby, as described in Proposition 9, the philanthropic mode of service delivery is more profitable than the traditional mode only when the restriction-induced no-pay utility is lower, i.e., when ω is below a threshold.

When the degree of scale economies k_s is sufficiently high, and above a threshold, the service provider's profitability in the philanthropic mode of service delivery is higher due to the scale economies. When the scale economies are lower, the strategy of catering to the entire market by offering the no-pay option to the customers increases the service provider's costs without attaining significant benefits, making the traditional mode of service delivery a preferred strategy.

Proposition 10. *The thresholds* $\underline{\beta}(\omega, k_s)$, $\overline{\omega}(\beta, k_s)$, *and* $\underline{k_s}(\beta, \omega)$ *are such that*

1. $\partial\underline{\beta}(\omega, k_s)/\partial\omega > 0$, $\partial\underline{\beta}(\omega, k_s)/\partial k_s < 0$, *and* $\partial\underline{\beta}(\beta, \omega)/\partial c_n > 0$.
2. $\partial\overline{\omega}(\beta, k_s)/\partial\beta > 0$, $\partial\overline{\omega}(\beta, k_s)/\partial k_s > 0$, *and* $\partial\overline{\omega}(\beta, k_s)/\partial c_n < 0$.
3. $\partial\underline{k_s}(\beta, \omega)/\partial\beta < 0$, $\partial\underline{k_s}(\beta, \omega)/\partial\omega > 0$, *and* $\partial\underline{k_s}(\beta, \omega)/\partial c_n > 0$.

Proposition 10 shows that adopting the philanthropic mode of service delivery is increasingly profitable for the service provider when the degree of scale economies and the philanthropic amplification of utility increase. On the contrary, adopting the philanthropic mode of service delivery is less profitable when the base cost of offering the necessary service component is higher, and the restriction-induced no-pay utility reduction is lower.

When the service provider's degree of scale economies (k_s) is higher, its profitability is higher primarily due to the (average) cost reduction achieved by serving a large number of customers in the market. In this case, the service provider need not increase its profitability by extracting more surplus from the consumers by charging higher prices for the paid components of the service, as reflected in $\underline{\beta}(\omega, k_s)$ decreasing and $\overline{\omega}(\beta, k_s)$ increasing in k_s. On the contrary, when the base cost of offering the necessary service component (c_n) is higher and the restriction-induced no-pay utility reduction is lower (ω is higher), the price-pressure on the paid components of the service is higher. To enhance its profitability, the service provider is required to charge higher prices that are feasible only when the customers' willingness-to-pay for the components is higher, as reflected in $\underline{\beta}(\omega, k_s)$ increasing in c_n and ω. These results can also be described from the fact that $\overline{\omega}(\beta, k_s)$ decreases in c_n and increases in β. The implications of the threshold $\underline{k_s}(\beta, \omega)$ can be described likewise.

5. Endogenously Determined Market Size

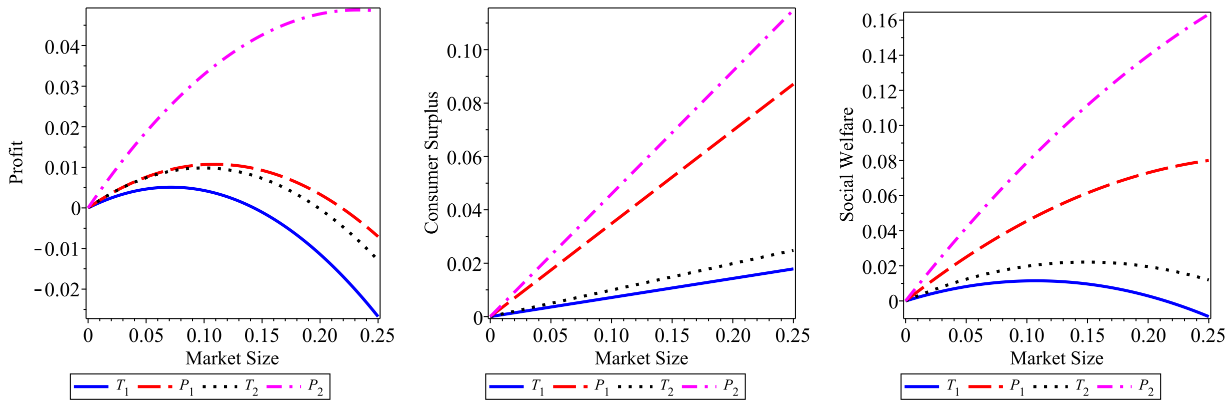
In this section, we extend our models presented in Section 2 to consider the case where the service provider endogenously determines the size of its target market, m. We aim to examine the implications of critical dimensions of the traditional and philanthropic service delivery modes for the service provider's strategy to serve the customers. We highlight the significance of the service provider endogenously determining the market sizes, present the corresponding optimal solutions, and later examine the implications on the service provider's preferred mode of service delivery.

As mentioned earlier, $k_m m^2$ is the service provider's cost of developing the market of size m, and the service provider endogenously determines the number of customers to target its service to. The convex increasing cost function reflects the decreasing returns to scale. The market development cost involves, in our motivating examples, components such as expenses toward conducting outreach awareness and screening camps for residents in remote and underprivileged areas, providing food, transportation, shelter, and basic necessities at the campsites, conducting educational and training sessions in the region, holding community meetings and events to raise awareness, etc.

5.1. Implications of Exogenously Determined Market Size

For brevity, we partially demonstrate the implications of the market size for the optimal solutions in Figure 1 for different levels of the relative utility of the optional service component (k_u). When the market size is exogenously determined, we observe that the number of customers buying the service from the service provider (not shown here for brevity) and the consumer surplus monotonically increase in the market size. However, the service provider's profit and the social welfare are concave functions of the market size. The implications of the relative utility of the optional service component for the optimal solution are analogous under both traditional and philanthropic service delivery settings.

Given k_u (e.g., $k_u = 0.25$), the service provider's profit increases in the market size when m is relatively small, resulting in increasing social welfare. However, when the market size increases beyond a threshold, the service provider's cost of developing the market dominates the additional



(a) (b) (c)

Note: Parameter values: $c_n = 0.25, k_q = 1, k_m = 1, k_s = 0.1, \beta = 2, \omega = 0.25$. "T" and "P" denote the traditional and philanthropic modes of service delivery, respectively. For T_1 and P_1, $k_u = 0.25$. For T_2 and P_2, $k_u = 1.25$.

Figure 1 Implications of Market Size

revenue garnered, decreasing profitability. Beyond another threshold for the market size, the service provider incurs a loss. The implications for the social welfare are similar. Figure 1 also shows that the service provider's profitability and the social welfare in the philanthropic mode of service delivery are higher than those in the traditional mode of service delivery. It is due to the customers' philanthropic amplification in the philanthropic service delivery mode. Additionally, increasing the relative utility of the optional service component further increases the service provider's profit and the social welfare. These findings justify the need for endogenously determining the market size for the profit-maximizing service provider.

5.2. Optimal Market Size

This section describes the service provider's profit-maximizing market size under each of the service delivery modes. To solve the service provider's profit-maximizing problems in the two modes of service delivery, we assume that $k_m > k_s$. It implies that developing a market is more costly for the service provider than the cost reduction benefits obtained via scale economies.

PROPOSITION 11. *The optimal market sizes for the service provider in the traditional and philanthropic modes of service delivery are described as follows:* $m^T = \left[4k_u^2 + 27k_q\left(1-c_n\right)^2\right] / \left[216k_q k_m\right]$ *and* $m^P = \left[4\beta^2 k_u^2 + 27k_q\left(\beta - \omega - 4c_n\right)\right] / \left[216k_q\left(k_m - k_s\right)\right]$.

It may be noted that the optimal market size to target for the service provider in the philanthropic mode of service delivery increases in β, and it decreases in ω. To ensure that the optimal market size m^P is positive, we consider that $\beta > \grave{\beta}_m(\omega)$ and $\omega < \grave{\omega}_m(\beta)$, where

$$\grave{\beta}_m(\omega)=\frac{-27k_q+3\left\{81k_q^2+48k_u^2k_q(\omega+4c_n)\right\}^{1/2}}{8k_u^2}\quad\text{and}\quad\grave{\omega}_m(\beta)=\frac{4\beta^2k_u^2+27k_q(\beta-4c_n)}{27k_q}\tag{6}$$

In the philanthropic mode of service delivery, the service provider caters to the entire market due to the no-pay option being offered for the necessary service component and because the customers with lower utility *always* adopt this option. The no-pay service offering does not generate any revenue for the service provider, and it is a cost-center in economic planning. Thereby, it is *never* economical for the service provider to extend the no-pay option to the customers (as reflected in $m^P<0$) unless the philanthropic utility amplification is sufficiently large or the customer utility from the no-pay option is sufficiently low. (Later in Sections 5.4 and 5.5 we obtain further insights into the service provider's choice between the philanthropic and traditional modes of service delivery based on its profitability.)

PROPOSITION 12. *The optimal market size for the service provider to target in the philanthropic mode of service delivery is more than that in the traditional mode of service delivery only when the customer utility amplification is above threshold* $\underline{\beta}_m(\omega,k_s)$ *or the restriction-induced no-pay utility reduction parameter is below threshold* $\overline{\omega}_m(\beta,k_s)$ *or the degree of scale economies is above threshold* $\underline{k_s}_m(\beta,\omega)$*, where*

$$\underline{\beta}_m(\omega,k_s)=\Bigg\{-27k_qk_m+\Bigg\{729k_q^2k_m^2+432k_u^2k_qk_m\left\{k_m\left[\omega+(1+c_n)^2\right]-k_s(1-c_n)^2\right\}+64k_u^4k_m(k_m-k_s)\Bigg\}^{1/2}\Bigg\}\times\left\{8k_u^2k_m\right\}^{-1}\tag{7}$$

$$\overline{\omega}_m(\beta,k_s)=\frac{4k_u^2\left[k_s+(\beta^2-1)k_m\right]+27k_qk_m\left[\beta-(1+c_n)^2\right]+27k_qk_s(1-c_n)^2}{27k_qk_m}\tag{8}$$

$$\underline{k_s}_m(\beta,\omega)=\frac{\left\{27k_q\left[(1+c_n)^2-\beta+\omega\right]-4k_u^2(\beta^2-1)\right\}k_m}{4k_u^2+27k_q(1-c_n)^2}\tag{9}$$

Proposition 12 identifies the conditions for the service provider to enhance its target market size in the philanthropic mode of service delivery by serving a larger pool of customers than that in the traditional mode of service delivery. It shows that the service provider's strategy to increase its target market size is optimal only when the philanthropic utility amplification is sufficiently large and it is beyond the threshold $\underline{\beta}_m(\omega,k_s)$. Alternatively, this can happen when the no-pay option for the necessary service component is sufficiently less competitive than the paid service components, i.e., when ω is smaller and below the threshold $\overline{\omega}_m(\beta,k_s)$. Sufficiently large economies of scale also incentivize the service provider to enhance its target market size in the philanthropic mode of service delivery compared to that in the traditional mode.

When the customers' philanthropic amplification of utility is higher, the service provider *may* increase its profitability by increasing the service components' prices, thereby increasing the revenue. When the customer utility from the no-pay option is lower, the price-pressure on the paid components is lower, enabling the service provider to increase the prices of the service components to increase its revenue. The service provider also targets a larger market and achieves higher cost reduction benefits from the scale economies while incurring the market development costs. The higher the degree of scale economies, the higher are the incentives for the service provider to increase its target market size in the philanthropic mode of service delivery than that in the traditional mode, as can also be observed from $\underline{\beta}_m(\omega, k_s)$ decreasing in k_s and $\overline{\omega}_m(\beta, k_s)$ increasing in k_s.

5.3. Implications of Critical Factors for the Optimal Solution in the Philanthropic Mode of Service Delivery

In this section, we analyze the implications of important parameters in our model for the optimal solutions – the prices of the paid service components, the quality level of the optional service component, the number of paying customers, the service provider's profit, and the consumer surplus – under the service provider's traditional and philanthropic modes of service delivery. The critical factors that we consider are (i) the philanthropic amplification of customer utility β, (ii) the restriction-induced utility reduction parameter for the no-pay option ω, and (iii) the degree of scale economies k_s.

Proposition 13. *The implications of the parameters β, ω, and k_s for the optimal solution in the philanthropic mode of service delivery are described as follows:*

1. $\partial\pi^P/\partial\beta > 0$, $\partial\left(d_n^P + d_o^P\right)/\partial\beta > 0$, $\partial d_f^P/\partial\beta > 0$, $\partial\left(S_n^P + S_o^P + S_f^P\right)/\partial\beta > 0$, *and* $\partial W^P/\partial\beta > 0$.
2. $\partial\pi_o^P/\partial\omega < 0$, $\partial\left(d_n^P + d_o^P\right)/\partial\omega < 0$, $\partial d_f^P/\partial\omega > 0$, *and* $\partial W^P/\partial\omega < 0$. *On the other hand,* $\partial\left(S_n^P + S_o^P + S_f^P\right)/\partial\omega$ *is concave in* ω.
3. $\partial\pi^P/\partial k_s > 0$, $\partial\left(d_n^P + d_o^P\right)/\partial k_s > 0$, $\partial d_f^P/\partial k_s > 0$, $\partial\left(S_n^P + S_o^P + S_f^P\right)/\partial k_s > 0$, *and* $\partial W^P/\partial k_s > 0$.

The consumer surplus in the philanthropic mode of service delivery maximizes at $\omega^P = \left[4\beta^2 k_u^2 + 27k_q\left(\beta - 6c_n\right)\right]/\left(81k_q\right)$.

Proposition 13 shows that the service provider's profit, the number of paying customers, the number of customers adopting the no-pay option, the consumer surplus, and the social welfare all monotonically increase in the philanthropic amplification of utility (β) and the degree of scale economies (k_s) in the philanthropic mode of service delivery. The impact of the restriction-induced utility reduction parameter (ω) for the service provider's profit, the number of paying customers, and the social welfare is monotonic and negative.

However, it is interesting to note the implications of the restriction-induced utility reduction for the consumer surplus. The consumer surplus exhibits an inverted U-shape, resulting in a specific value of the restriction-induced utility reduction at which it attains the maximum. The customer utility from the no-pay option increases in ω, increasing the price-pressure on the paid components of the service. When ω is small, the price-pressure is not severe, and thereby, the consumer surplus increases in ω. On the other hand, when ω is relatively large, the price-pressure on the paid components of the service is severe. This makes the service provider target a smaller market, resulting in a decreased consumer surplus.

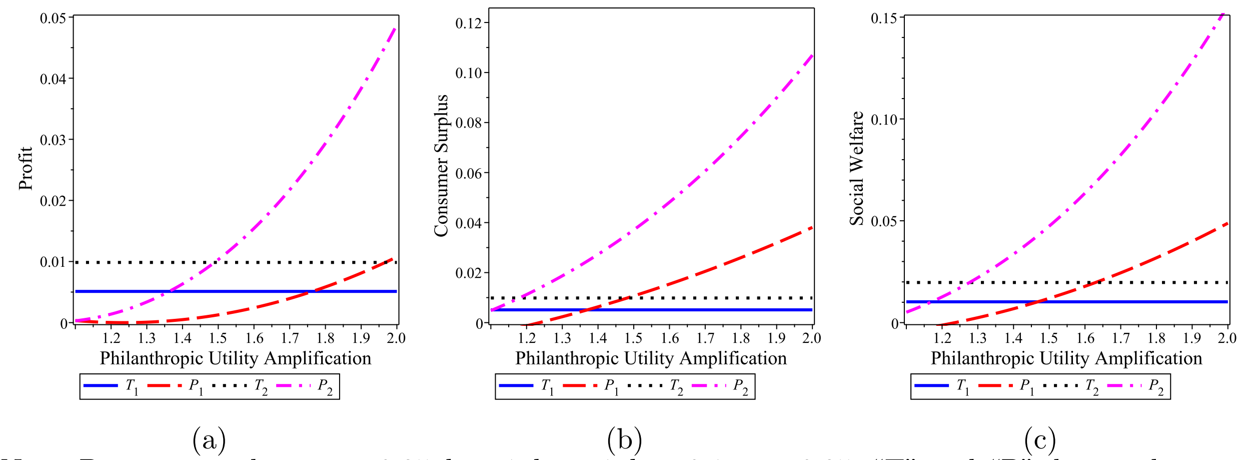
Our results show that the increasing customer valuation of the no-pay option due to a superior quality service offered by the service provider need not benefit the customers. These findings have immediate implications for the service provider's choice of the facilities to be provided to the customers adopting the no-pay option for the necessary service component while balancing its profitability against the consumer surplus. Later in Section 6, we extend our model to obtain insights into the service provider's optimal choice of the parameter ω.

5.4. Implications of Critical Factors: Traditional versus Philanthropic Mode of Service Delivery

In this section, we compare the optimal solutions in the traditional and philanthropic modes of service delivery. As it will be evident in the following, we observe that the service provider's preferred choice of the service delivery mode – traditional or philanthropic – based on its profitability exhibits threshold policy-based implications, as presented in Proposition 9, for the setting in which the market size was exogenously determined. Interestingly, we also observe that the structural results characterizing threshold policy-based implications also extend to other relevant dimensions: the optimal market size, the number of paying customers served, the consumer surplus, and the social welfare. We observe that the parameters' impact exhibits threshold policy-based implications as described for the optimal market size, presented in Proposition 12.

5.4.1. Implications of Philanthropic Utility Amplification

For ease of exposition, in Figure 2 we demonstrate the implications of the philanthropic utility amplification parameter β for the optimal solutions for different values of k_u. Given k_u (e.g., $k_u =$ 0.25), the higher the β, the higher the utility derived by the customers from the paid components of the service, and thereby, their willingness-to-pay for the service is also higher. This enables the service provider, as discussed earlier, to increase the prices for the necessary and optional service



Note: Parameter values: $c_n = 0.25, k_q = 1, k_m = 1, k_s = 0.1,\ \omega = 0.25$. "T" and "P" denote the traditional and philanthropic modes of service delivery, respectively. For T_1 and P_1, $k_u = 0.25$. For T_2 and P_2, $k_u = 1.25$.

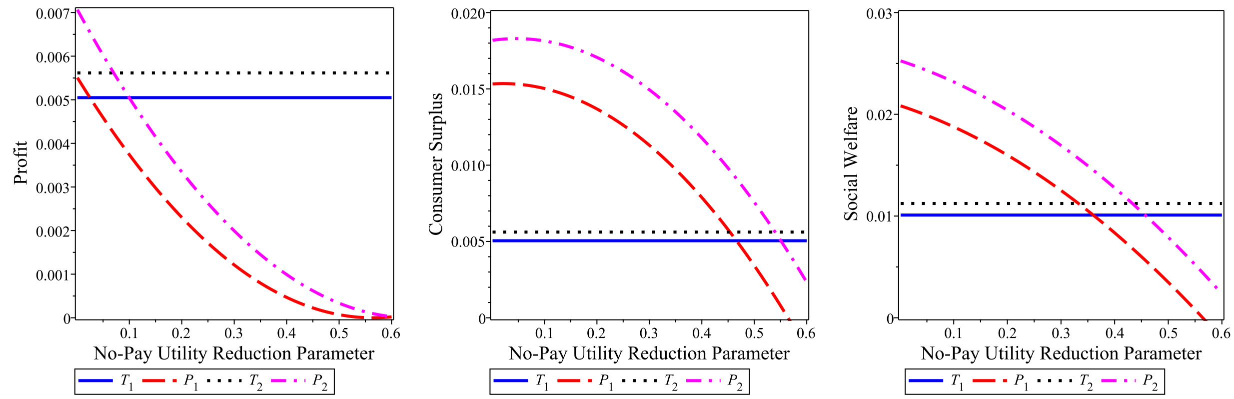
Figure 2 Implications of Philanthropic Utility Amplification

components, and it increases its profit. However, the service provider's profit in the philanthropic mode of service delivery is not more than that in the traditional mode of service delivery unless the customers' philanthropic amplification of utility is sufficiently large, and it is beyond a threshold. When β is relatively small, the philanthropic mode of service delivery does not increase the service provider's revenue enough to compensate for the additional cost incurred in serving the (self-selecting) non-paying customers. Additionally, like profit, the number of paying customers in the philanthropic mode also surpasses that in the traditional mode of service delivery only when β is beyond a threshold (not shown here for brevity). The combined effect is also reflected in the consumer surplus and the social welfare in the philanthropic mode surpassing that in the traditional mode of service delivery beyond a threshold for β (see Figures 2 $-(b)$ and 2 $-(c)$).

Figure 2 also shows that the thresholds for the philanthropic utility amplification decrease in k_u, the relative utility of the optional service component. It implies that the philanthropic mode of service delivery is more profitable for the service provider when the relative utility of the optional service component is higher.

5.4.2. Implications of Restriction-Induced Utility Reduction

Figure 3 demonstrates the impact of the restriction-induced utility reduction parameter ω on the optimal solutions for different values of k_u. Given k_u (e.g., $k_u = 0.25$), the service provider's profitability in the philanthropic mode of service delivery is more than that in the traditional mode of service delivery when the restriction-induced utility reduction is higher, i.e., when ω is lower,



(a) (b) (c)

Note: Parameter values: $c_n = 0.25, k_q = 1, k_m = 1, k_s = 0.1, \beta = 1.55$. "T" and "P" denote the traditional and philanthropic modes of service delivery, respectively. For T_1 and P_1, $k_u = 0.25$. For T_2 and P_2, $k_u = 0.5$.

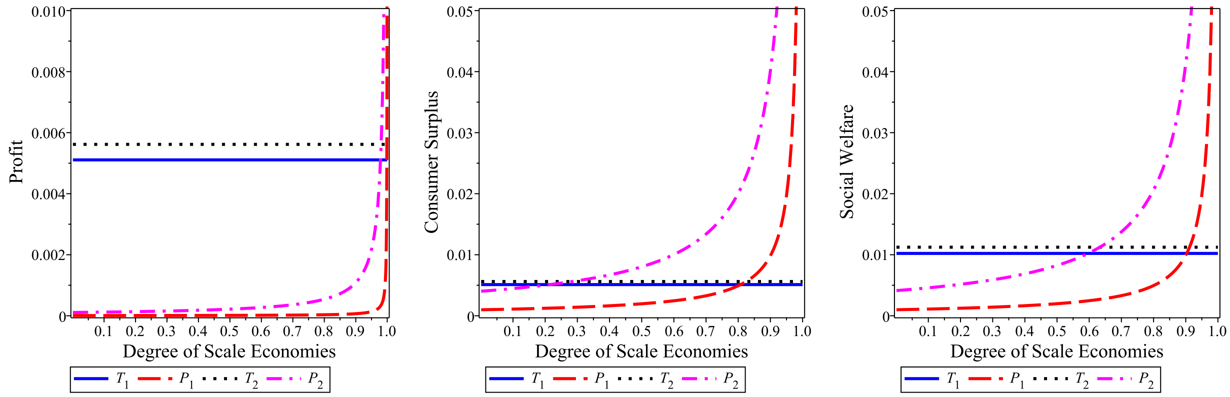
Figure 3 Implications of the Restriction-Induced Utility Reduction for the No-Pay Option

and it is below a threshold (see Figure 3 $-(a)$). The implications for the number of paying customers buying either only the necessary service component or both necessary and optional service components are structurally similar (not shown here for brevity). The impact of the parameter ω can be attributed, as discussed earlier, to the increased competitiveness of the no-pay option against the paid components when ω is higher. Figures 3 $-(b)$ and 3 $-(c)$ show that the consumer surplus and the social welfare in the philanthropic mode of service delivery are lower than that in the traditional mode of service delivery beyond certain thresholds for ω.

The ω thresholds that determine the preference for the philanthropic mode over the traditional mode of service delivery increase in the relative utility for the optional service component. It results in the enhanced profitability for the service provider under the philanthropic mode of service delivery.

5.4.3. Implications of Economies of Scale

Figure 4 demonstrates the implications of the degree of scale economies, captured by parameter by k_s, for the optimal solutions for different values of k_u. Given k_u (e.g., $k_u = 0.25$), the implications of the parameter k_s are similar to those of the philanthropic amplification parameter, as presented in Figure 2. The service provider's profitability in the philanthropic mode of service delivery is not more than that in the traditional mode unless the degree of scale economies is sufficiently large, and it is beyond a threshold (see Figure 4 $-(a)$). When k_s is relatively small, the cost advantage of scale economies is insufficient to cover added costs because of serving the (self-selecting) non-paying customers. In that case, the service provider targets a smaller market, and the number of



(a) (b) (c)

Note: Parameter values: $c_n = 0.25, k_q = 1, k_m = 1, \beta = 1.5, \omega = 0.5$. "T" and "P" denote the traditional and philanthropic modes of service delivery, respectively. For T_1 and P_1, $k_u = 0.25$. For T_2 and P_2, $k_u = 0.5$.

Figure 4 Implications of Economies of Scale

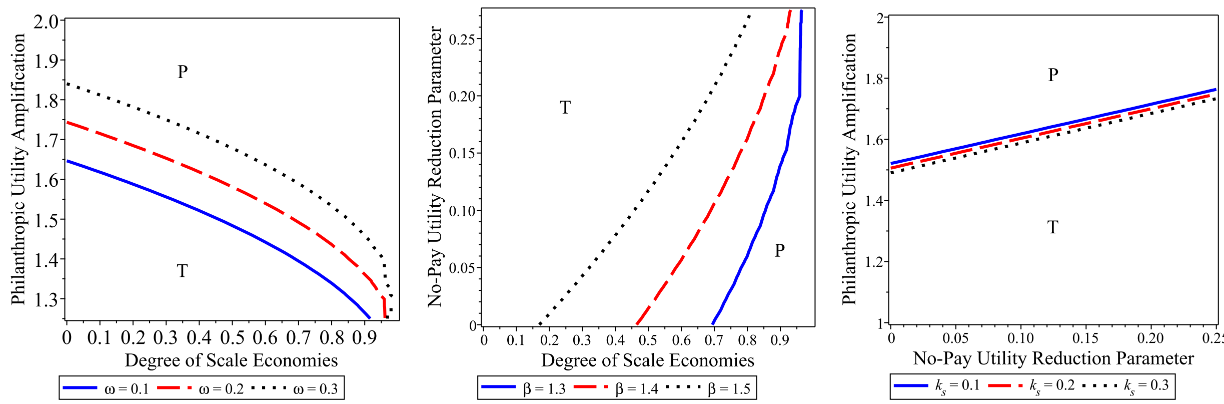
paying customers adopting the services is also smaller in the philanthropic mode of service delivery (not shown here for brevity). Consequently, the consumers, in aggregate, experience less surplus than that under the traditional mode of service delivery (see Figure 4 $-(b)$), and the social welfare decreases as well (see Figure 4 $-(c)$).

Figure 4 also shows that the thresholds for the degree of scale economies decrease in k_u, the relative utility of the optional service component. It implies that the philanthropic mode of service delivery, as discussed earlier, is more profitable for the service provider when the relative utility of the optional service component is higher.

5.5. Trade-Offs Between Critical Factors: Implications for Service Delivery Modes

In Sections 5.4.1-5.4.3, we discussed the implications of the critical factors of the philanthropic mode of service delivery separately. In Figure 5, we demonstrate the interplay between these factors that determine the service provider's choice of the traditional versus philanthropic mode of service delivery.

Figure 5 $-(a)$ highlights the inverse relationship between the service provider's degree of scale economies (k_s) and the customers' philanthropic utility amplification (β), given the restriction-induced utility reduction parameter (ω). Each *isoprofit* curve in the figure corresponds to the combination of k_s and β, given ω, for which the service provider's profits in the traditional and philanthropic modes of service delivery are equal. For a given level of the restriction-induced utility reduction (e.g., $\omega = 0.1$), we note that when the scale economies are higher, adopting the philanthropic mode of service delivery is profitable for the service provider even if the customers'



(a) (b) (c)

Note: Parameter values: $c_n = 0.25, k_u = 0.25, k_q = 1, k_m = 1$. "T" and "P" denote the traditional and philanthropic modes of service delivery, respectively.

Figure 5 Service Provider's Profitability: Implications for Service Delivery Modes

philanthropic utility amplification is lower. In this case, the service provider's incentives to adopt the philanthropic mode of service delivery are driven by the cost reduction benefits attained due to scale economies, instead of the customers' increased willingness-to-pay that enables the service provider to increase the prices for its paid components. Additionally, the upward shifts in the isoprofit curves with the increasing values of restriction-induced utility reduction parameter imply that the customers' philanthropic utility amplification and the degree of scale economies required for the service provider to adopt the philanthropic mode of service delivery must be higher.

Figure 5 − (b) highlights the analogous relationship between the service provider's degree of scale economies (k_s) and the restriction-induced utility reduction parameter (ω), given the customers' philanthropic utility amplification (β). Each isoprofit curve in the figure corresponds to the combination of k_s and ω, given β, for which the service provider's profits in the traditional and philanthropic modes of service delivery are equal. Recall that the price-pressure on the service provider's paid components of the service is higher when the restriction-induced utility reduction for the customers is lower, i.e., ω is higher. For a given level of the customers' philanthropic utility amplification (e.g., $\beta = 1.3$), we note that when the scale economies are higher, adopting the philanthropic mode of service delivery is profitable for the service provider even if the restriction-induced utility reduction for the customers is lower, i.e., ω is higher. In this case, the service provider's incentives to adopt the philanthropic mode of service delivery are driven by the cost reduction benefits attained due to scale economies that can absorb the negative effects of the lower restriction-induced utility reduction. Additionally, the upward shifts in the isoprofit curves with the increasing philanthropic utility amplification imply that the restriction-induced utility reduction and the degree of scale economies required for the service provider to adopt the philanthropic mode of service delivery can be lower.

Figure 5 $-$ (c) highlights the similar relationship between the customers' philanthropic utility amplification (β) and the restriction-induced utility reduction parameter (ω), given the degree of scale economies (k_s). Each isoprofit curve in the figure corresponds to the combination of ω and β, given k_s, for which the service provider's profits in the traditional and philanthropic modes of service delivery are equal. For a given degree of scale economies (e.g., $k_s = 0.1$), the upward sloping isoprofit curve shows that when the competitiveness of the no-pay service option is higher due to higher ω, the customers' utility amplification required to justify the service provider adopting the philanthropic mode of service delivery must be higher. The service provider can moderate the increasing price-pressure on the service's paid components due to the lower restriction-induced utility reduction by increasing the quality of the optional service component and charging a higher price to increase the revenue. The said response is feasible only when the customers' utility and willingness-to-pay for the service's paid components are higher. On the other hand, the downward shifts in the isoprofit curves with the increasing scale economies imply that the customers' philanthropic utility amplification and the restriction-induced utility reduction required for the service provider to adopt the philanthropic mode of service delivery can be lower.

6. Determining Restriction-Induced Utility Reduction

As discussed in Section 5.3, determining the optimal level of the restriction-induced utility reduction parameter (ω) is critical for the philanthropic service provider. The choice of ω involves designing a service package (analogous to quality level) that may be seen as *necessary* by the customers. For instance, we observe an example of such a decision at the philanthropic healthcare service providers in our field study in the form of answering the question of whether to accommodate a patient in separate diagnostic and investigation rooms or to attend multiple patients simultaneously in a single room. Additionally, it is critical to determine the minimum level of facilities to be offered, such as the comfort level of the resting place and the waiting area, post-treatment recovery facility, etc. The service provider's offerings essentially determine the minimum level of the *necessary* component that influences the convenience level of the patients at the bottom of the pyramid. It has immediate implications for building a suitable infrastructure within its premises that impacts the cost structure.

In recent years, one of the healthcare service providers in India has experienced a substantial increase in the government and non-government grants, private donations, institutional funding, and the inflow of paying clientele from countries including the UK and the US, in response to its path-breaking success in serving the people at the bottom of the pyramid for free. For instance, the number of non-paying patients served has increased in the last decade at the CAGR (Compound Annual Growth Rate) of 4.3 percent. After adjusting for the number of patients served and inflation, the cost of serving these patients has increased by more than 12.6 percent. During the same period, the inflow of surplus funds, after adjusting for the revenue from the paying clientele at the competitive market prices, has increased by more than 18 percent. Our observations from the field suggest in our model that an increase in the parameter ω is expected to increase the parameter β. It has also resulted in an increased inflow of super-rich clientele that has helped the service provider treat more than 50 percent of its patients for free while ensuring operational and financial sustainability via cross-subsidization among a record number of patients being treated every year in the world.[3] We capture this phenomenon in the following analysis by making the philanthropic utility amplification (β) a function of the restriction-induced utility reduction parameter (ω).

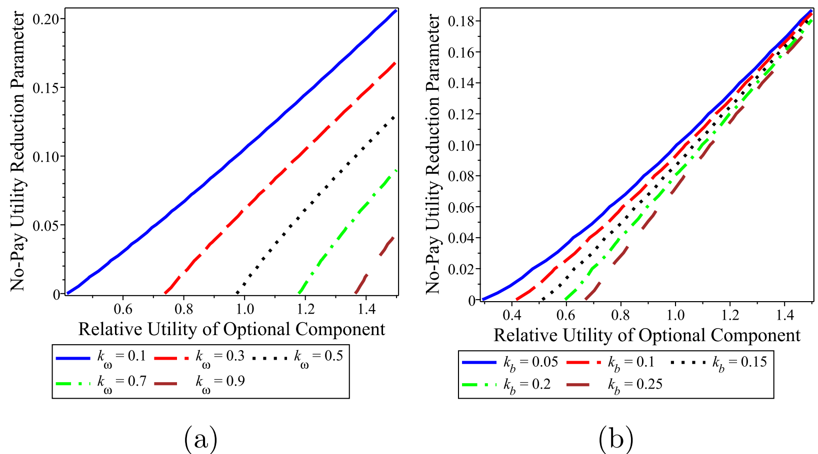
We define $\beta = \theta\,(1 + k_b\omega)$. Here, $\theta = 1/\,(1 + k_b k_\omega)$, and $k_b > 0$ is a scale parameter. It may be noted that $\beta = 1$ for $\omega = k_\omega$, and $\beta > 1$ for $\omega \in (k_\omega, 1]$. Let $k_o\omega^2$, $k_o > 0$, be the cost of designing a service package for each customer in the target market. The cost is constant per customer and it reflects the decreasing returns in the quality level of the service offered, ω. In this case, the service provider's profit function is as described in (2) with the additional cost component of the aggregate of the service package cost ($k_o\omega^2 m$). The service provider's problem is to maximize its own profit by determining $p_n, p_o, q, m \geq 0$ and $\omega \in [k_\omega, 1]$. The analysis approach parallels that described in Sections 3 and 5.

Proposition 14. *If $k_0 \leq k_u^2 k_b^2 \theta^2/\,(27k_q)$, then the service provider's profit-maximizing level of the restriction-induced utility reduction parameter ω is such that $\hat{\omega}^P \in \{k_\omega, 1\}$.*

On the contrary, if $k_0 > k_u^2 k_b^2 \theta^2/\,(27k_q)$, then the service provider's profit-maximizing level of the restriction-induced utility reduction parameter ω is such that $\hat{\omega}^P \in \{[8k_u^2 k_b \theta^2 - 27k_q\,(1 - k_b\theta)]\,/\,[8\,(27k_q k_o - k_u^2 k_b^2 \theta^2)]$

The situations wherein the level of the parameter ω that maximizes the service provider's profit is equal to either k_ω or 1 are trivial. Hence, we assume that $k_0 > k_u^2 k_b^2 \theta^2/\,(27k_q)$ and consider $\hat{\omega}^P = [8k_u^2 k_b \theta^2 - 27k_q\,(1 - k_b\theta)]\,/\,[8\,(27k_q k_o - k_u^2 k_b^2 \theta^2)]$ in further analysis. For brevity, we present the important results in Figure 6. (The technical details are provided in Section 2 in the supplement.)

[3] The specific details are divulged to us by the director of one of the healthcare service providing institutions in our field study. We do not provide specific identifiable details in the paper for confidentiality purposes and to respect the donors' wishes.



Note: Parameter values: $c_n = 0.25, k_q = 1, k_m = 1, k_s = 0.1, k_o = 1$. In Figure 6 $-(a)$, $k_b = 0.25$, and in Figure 6 $-(b)$, $k_\omega = 0.25$.

Figure 6 Implications for Optimal Level of Restriction-Induced Utility Reduction of the No-Pay Option

Figure 6 describes the impact of the relative utility of the optional service component (k_u) on the optimal level of restriction-induced utility reduction parameter (ω). In panel (a), the implications are presented for different values of the parameter k_ω, and in panel (b), we choose various levels of the parameter k_b. It may be noted that the optimal level of the restriction-induced utility reduction decreases, i.e., ω increases, with the relative utility of the optional service component. It implies that the service provider offers increasingly superior service packages to the customers at the bottom of the pyramid as the customers value the optional service component increasingly more. With the increasing utility of the optional service component, the customers' willingness-to-pay for the optional service component increases, resulting in the service provider's increased profitability. It allows the service provider to enhance the *quality* of the necessary service component to the no-pay customers, and accordingly, increase the customers' utility parameters β and ω.

For the commodity healthcare services, e.g., cataract surgeries, competing service providers' market segmentation strategies are governed by optional service components involving exclusive offerings such as a five-star hotel experience, dedicated clinical and support staff, medical tourism, etc. To maintain their brand image and to keep up with the institutional philosophy, the philanthropic service providers (in our study) offer the *basic* services to the poor that are comparable to the competing for-profit service providers in the country. Additionally, due to the increased competition, the quality levels of the necessary service components at these service providers have improved substantially over the years. On the other hand, for high-profile healthcare services such as heart surgeries and cancer treatments, as mentioned earlier, the relative utility for the optional component is not high, suggesting the lower quality of the service with no-pay option and relatively few adopters of the services. These findings partially explain why the presence of for-profit philanthropic healthcare providers is prominently observed in the eye-care sector, that has made India a leader in the low-cost, high-quality care segment, versus in the cancer-care and heart-care sectors (see World Bank (2017) and Saldinger (2018) to obtain insights into challenges in replication and scaling.).

7. Implications of Income Inequality

Income inequality has been a long-standing social concern in the world. The issue is particularly severe in underdeveloped and developing countries. The COVID-19 pandemic has further exacerbated this income inequality. As discussed earlier, service providers are expected to (re)design their service delivery strategies while responding to increasing income inequality and reaching out to the poor in large numbers. To attain financial sustainability under the cross-subsidization environment, enhancing the efficiency to serve the rich and the poor simultaneously has become critical. This section extends our model for the philanthropic mode of service delivery by capturing income inequality among customers to obtain insights into the service delivery strategy for the philanthropic service provider.

We consider that the utility derived by the customers, in a *given* market, from the necessary component in the philanthropic mode of service delivery of the service provider follows the Burr distribution with parameters a_1, a_2, and a_3, where $a_i > 0, i = \{1, 2, 3\}$. Let $g(\cdot)$ and $G(\cdot)$ be the probability density function and the cumulative distribution function, respectively, for the customer utility u_n. Thereby,

$$g(u_n; a_1, a_2, a_3) = \left(\frac{a_2 a_3}{a_1}\right)\left[\left(\frac{u_n}{a_1}\right)^{a_2-1}\right]\left[1+\left(\frac{u_n}{a_1}\right)^{a_2}\right]^{-a_3-1}, \quad u_n \geq 0$$
$$G(u_n; a_1, a_2, a_3) = 1-\left[1+\left(\frac{u_n}{a_1}\right)^{a_2}\right]^{-a_3}, \quad u_n \geq 0$$

The parameter a_1 is the scale parameter, and the parameters a_2, a_3 are the shape parameters. The higher the value of the shape parameter a_3, the higher (lower) is the income equality (inequality). (See Tadikamalla (1980) and Yari and Tondpour (2017) for further details.)

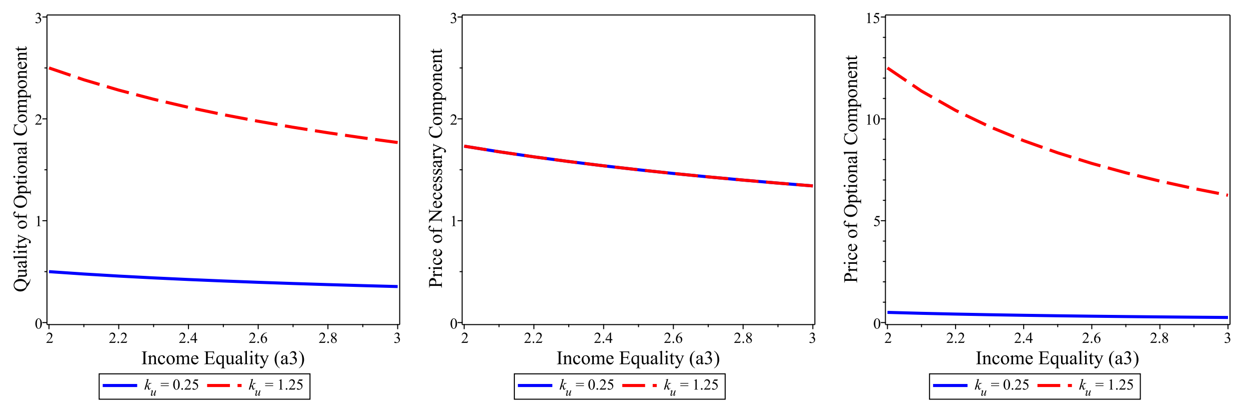
It is reasonable to assume that the customers' utility function is an affine function of the income level. The higher the customer's income, the higher is the (capability or) willingness-to-pay for the service. Accordingly, our approach to model the customers' utility function using the Burr distribution, which is commonly adopted to model income inequality in the existing literature, is justifiable. An interested reader may refer to, e.g., Gavirneni and Kulkarni (2016) for an application of, and insights into, adopting the Burr distribution to model inequality (e.g., distribution) in the customer waiting cost under queuing environments.

We repeat the analytical procedure described in Section 2.3 to determine the fraction of the customers that adopt any of the service packages offered by the service provider: only the necessary (paid) service component, both necessary and optional service components, or the no-pay option for the necessary service component. (In this section, we use the notation $\check{X}$ to define variable X, wherever necessary.) We obtain

$$\check{d}_n^P = \left\{1 + \left[\frac{p_n}{(\beta - \omega)\, a_1}\right]^{a_2}\right\}^{-a_3} - \left\{1 + \left[\frac{p_o}{(\beta k_u q)\, a_1}\right]^{a_2}\right\}^{-a_3} \tag{10}$$

$$\check{d}_o^P = \left\{1 + \left[\frac{p_o}{(\beta k_u q)\, a_1}\right]^{a_2}\right\}^{-a_3} \quad \text{and} \quad \check{d}_f^P = 1 - \left\{1 + \left[\frac{p_n}{(\beta - \omega)\, a_1}\right]^{a_2}\right\}^{-a_3} \tag{11}$$

We substitute (10)-(11) into (2) and solve the service provider's (constrained) problem of maximizing the profit in the philanthropic mode of service delivery. For brevity, we demonstrate the implications of income equality (captured using the parameter a_3) for the optimal solution in Figures 7 and 8.



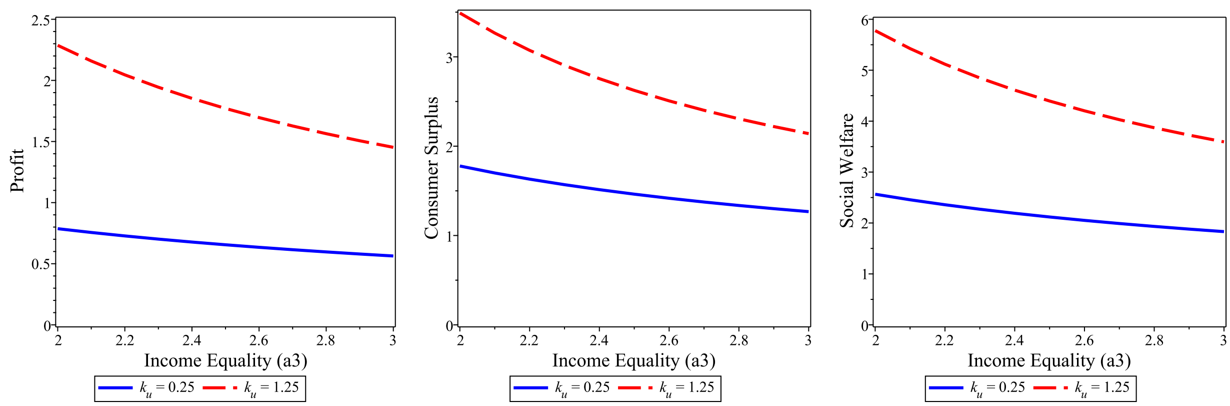
(a) (b) (c)

Note: Parameter values: $c_n = 0.25, \beta = 2, \omega = 0.5, k_q = 1, k_m = 1, k_s = 0.1, m = 1, a_1 = 2, a_2 = 2.$

Figure 7 Optimal Solution: Implications of Income Equality

From Figure 7, we note that the optimal quality level and price for the optional service component decrease in income equality. Due to the complementarity between the necessary and optional service components' prices, the necessary service component's price also decreases in income equality. These findings can be attributed to the fact that the likelihood of the customer's utility being greater than or equal to u_n decreases in the shape parameter(s), and thereby, so does the willingness-to-pay for the service. Accordingly, it is not surprising to see that the for-profit service providers offer a relatively large variety of optional service components in the metro and tier-I cities that demonstrate lower income equality than in tier-II cities, as observed in our motivating examples as well.

Figure 7 also demonstrates that the quality and price of the optional service component increase in the relative utility of the optional service component. This result is similar to what we discussed in Section 5.4.



(a) (b) (c)

Note: Parameter values: $c_n = 0.25, \beta = 2, \omega = 0.5, k_q = 1, k_m = 1, k_s = 0.1, m = 1, a_1 = 2, a_2 = 2$.

Figure 8 Implications of Income Equality

Figure 8 demonstrates the implications of income equality for the outcome variables. The negative impact of increasing income equality (or decreasing income inequality) on the service components' quality and prices gets transferred to the service provider's profit. It is counter-intuitive to note that the consumer surplus, and consequently, the social welfare also decreases as income equality among the customers in the market increases. On the other hand, the number of customers adopting the service provider's paid service increases, and thereby, the number of customers that adopt the no-pay option decreases. With the increasing income equality, the service provider's incentives to extract price-premium from the *rich* customers by offering a high-quality optional service component decreases. The lower-quality component is also priced lower, making the component affordable to many customers with lower willingness-to-pay. It reduces the service provider's profitability and the consumer surplus in aggregate, resulting in lower social welfare.

8. Conclusions and Future Research

Ensuring the sustainability of for-profit philanthropic (and non-profit) service providers reaching out to the poor at the bottom of the pyramid has always been challenging for various businesses the world over. Extending free services to the poor has been a popular strategy among government and non-governmental institutions. Industries worldwide also offer numerous examples of for-profit service providers extending the self-selecting no-pay service option to customers to serve the poor for free while serving the rich to generate the necessary revenues. Our work presented in this paper provides operational, economic, and strategic insights into the rationale for for-profit service providers offering free services. Our stylized model identifies conditions based on the customers' service utility functions and the service provider's cost functions under which adopting the philanthropic mode of service delivery yields superior performance for the service provider in terms of the quality of the service offerings, market coverage, and profitability. We also show that such settings benefit the customers and the entire society, in general, *only* under certain conditions. Our work is particularly critical in the post-pandemic world that has posed severe challenges to the existing businesses and consumers. Accordingly, our results enrich the existing literature focusing on market segmentation and for-profit operations with philanthropic service delivery.

Our stylized model presented in this paper offers a framework for future research to obtain operational, economic, and strategic insights into philanthropic service delivery. For instance, one may extend our modeling framework to examine the implications of the service provider's no-pay option while balancing the trade-off between its profitability and consumer surplus. In this regard, one may consider a service provider's objective function as a combination of its profit and consumer surplus. Appropriately designing an objective function for a mission-driven service provider becomes paramount in the increasingly competitive markets (see, e.g., Holguín-Veras et al. (2013)). Characterizing the economies of scale in service delivery to the masses in a philanthropic setting will be particularly critical for for-profit organizations. Similarly, obtaining insights into the customers' utility functions, their choice-making, and the interlinkages with the service provider's service delivery processes will help achieve scaling and replication benefits in various industries. Likewise, enriching the framework of value co-production in services proposed by Karmarkar and Roels (2015) will be essential to obtain further insights into the sustainability of non-profit and for-profit philanthropic operations. We leave many such issues for future research.

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Service Delivery Strategies for Alleviating Pandemic Suffering while Maintaining Profitability: Supplement

1. Proofs of the Results Presented in the Main Paper

Proof of Proposition 1. Consider the service provider's profit function described in (1). We obtain

$$\frac{\partial \tilde{\pi}^T}{\partial p_n} = (1 + c_n - 2p_n)\, m \quad \text{and} \quad \frac{\partial^2 \tilde{\pi}^T}{\partial p_n^2} = -2m$$
$$\frac{\partial \tilde{\pi}^T}{\partial p_o} = \frac{[q\,(k_u + k_q q) - 2p_o]\, m}{k_u q} \quad \text{and} \quad \frac{\partial^2 \tilde{\pi}^T}{\partial p_o^2} = -\frac{2m}{k_u q}$$
$$\frac{\partial^2 \tilde{\pi}^T}{\partial p_n p_o} = 0$$

The profit function is jointly concave in p_n and p_o since $\partial^2 \tilde{\pi}^T / \partial p_n^2 < 0$, $\partial^2 \tilde{\pi}^T / \partial p_o^2 < 0$, and the determinant of the Hessian is $4m^2/k_u q > 0$. The first order conditions are necessary and sufficient to show the optimality of the solution. Clearly, the solution $p_n^T(q)$ and $p_o^T(q)$ described in the proposition satisfies the first order conditions $\partial \tilde{\pi}^T / \partial p_n = 0$ and $\partial \tilde{\pi}^T / \partial p_o = 0$, respectively. It is also clear that $p_n^T(q) \geq 0$ and $p_o^T(q) \geq 0$. Also, $p_n^T(q)$ is independent of p_o, and $p_o^T(q)$ is independent of p_n.

The customer demand only for the necessary service component, $d_n^T(q)$, and that for the necessary and optional service components, $d_o^T(q)$, are described as follows:

$$d_n^T(q) = \frac{(k_q q - k_u c_n)\, m}{2k_u} \quad \text{and} \quad d_o^T(q) = \frac{(k_u - k_q q)\, m}{2k_u} \tag{12}$$

From Lemma 1 (stated and proved in the Additional Results section), we note that $d_n^T(q) \geq 0$ and $d_o^T(q) \geq 0$, and thereby, the constraints $p_n \leq p_o / (k_u q) \leq 1$ are satisfied.

Likewise, the solution $p_n^T(q)$ and $p_o^T(q)$ described in the proposition is indeed optimal for the service provider's problem of maximizing its profit. □

Proof of Proposition 2. By substituting $p_n^T(q)$ and $p_o^T(q)$, described in Proposition 1, in the service provider's profit function $\tilde{\pi}^T$, described in (1), we obtain

$$\pi^T(q) = \frac{\left[q\,(k_u - k_q q)^2 + k_u\,(1 - c_n)^2 - 4k_u k_m m\right] m}{4k_u} \tag{13}$$
$$\frac{\partial \pi^T}{\partial q} = -\frac{(k_u - k_q q)\,(3k_q q - k_u)\, m}{4k_u} \quad \text{and} \quad \frac{\partial^2 \pi^T}{\partial q^2} = \frac{k_q\,(3k_q q - 2k_u)\, m}{2k_u}$$

For any $q < (\geq) \, 2k_u / (3k_q)$, $\partial^2 \pi^T / \partial q^2 < (\geq) \, 0$. Consider the solution $q^T = k_u / (3k_q)$. Clearly, $q^T < 2k_u / (3k_q)$ and it satisfies the first order condition $\partial \pi^T / \partial q = 0$. Considering the condition $q \geq \underline{q}^T$ described in Lemma 1, the solution q^T described in the proposition is indeed optimal.

For any $q < (\geq) \, 2k_u / (3k_q)$, we obtain $\partial^2 \pi^T / \partial q^2 < (\geq) \, 0$. The values of q that satisfy the condition $\partial \pi^T / \partial q = 0$ are given by $q^T = k_u / k_q$ and $q^T = k_u / (3k_q)$.

From (12), $q^T = k_u / k_q$ yields $d_o^T (q^T) = 0$; an irrelevant scenario.

Now, consider the solution $q^T = k_u / (3k_q)$. Clearly, $q^T < 2k_u / (3k_q)$. The solution satisfies the first order condition $\partial \pi^T / \partial q = 0$. Considering the condition $q \geq \underline{q}^T$, the solution q^T described in the proposition is indeed optimal. □

Proof of Proposition 3. The proof parallels that for Proposition 1. Consider the service provider's profit function described in (2). We obtain

$$\frac{\partial \tilde{\pi}^P}{\partial p_n} = \frac{(\beta - \omega - 2p_n) \, m}{\beta - \omega} \quad \text{and} \quad \frac{\partial^2 \tilde{\pi}^P}{\partial p_n^2} = -\frac{2m}{\beta - \omega}$$
$$\frac{\partial \tilde{\pi}^P}{\partial p_o} = \frac{[q \, (\beta k_u + k_q q) - 2p_o] \, m}{\beta k_u q} \quad \text{and} \quad \frac{\partial^2 \tilde{\pi}^P}{\partial p_o^2} = -\frac{2m}{\beta k_u q}$$
$$\frac{\partial^2 \tilde{\pi}^P}{\partial p_n p_o} = 0$$

The profit function is jointly concave in p_n and p_o since $\partial^2 \tilde{\pi}^P / \partial p_n^2 < 0$, $\partial^2 \tilde{\pi}^P / \partial p_o^2 < 0$, and the determinant of the Hessian is $4m^2 / [(\beta - \omega) \, \beta k_u q] > 0$. The first order conditions are necessary and sufficient to show the optimality of the solution. Clearly, the solution $p_n^P (q)$ and $p_o^P (q)$ described in the proposition satisfies the first order conditions $\partial \tilde{\pi}^P / \partial p_n = 0$ and $\partial \tilde{\pi}^P / \partial p_o = 0$, respectively. Also, $p_n^P (q)$ is independent of p_o, and $p_o^P (q)$ is independent of p_n.

The customer demand only for the necessary service component, $d_n^P (q)$, and that for the necessary and optional service components, $d_o^P (q)$, are described as follows:

$$d_n^P (q) = \frac{k_q q m}{2\beta k_u} \quad \text{and} \quad d_o^P (q) = \frac{(\beta k_u - k_q q) \, m}{2\beta k_u} \tag{14}$$

From Lemma 2, we note that $d_n^P (q) \geq 0$ and $d_o^P (q) \geq 0$ satisfy the constraints $p_n / (\beta - \omega) \leq p_o / (\beta k_u q) \leq 1$.

Likewise, the solution $p_n^P (q)$ and $p_o^P (q)$ described in the proposition is indeed optimal for the service provider's problem of maximizing the profit. □

Proof of Proposition 4. The proof parallels that for Proposition 2. By substituting $p_n^P (q)$ and $p_o^P (q)$, described in Proposition 4, in the service provider's profit function $\tilde{\pi}^P$, described in (2), we obtain

$$\pi^P (q) = \frac{\left[q \, (\beta k_u - k_q q)^2 + \beta \, (\beta - \omega) \, k_u - 4\beta k_u c_n - 4\beta k_u \, (k_m - k_s) \, m \right] m}{4\beta k_u} \tag{15}$$

$$\frac{\partial \pi^P}{\partial q} = \frac{(\beta k_u - 3k_q q)(\beta k_u - k_q q) m}{4\beta k_u} \quad \text{and} \quad \frac{\partial^2 \pi^P}{\partial q^2} = \frac{k_q (3k_q q - 2\beta k_u) m}{2\beta k_u}$$

Consider $\overline{q}^P = 2\beta k_u / (3k_q)$ described in Lemma 2. For any $q < (\geq) \overline{q}^P$, $\partial^2 \pi^P / \partial q^2 < (\geq) 0$. Consider the solution $q^P = \beta k_u / (3k_q) < \overline{q}^P$. It satisfies the first order condition $\partial \pi^P / \partial q = 0$. Thereby, the solution q^P described in Proposition 4 is indeed optimal. □

Proof of Proposition 5. From Propositions 2 and 4 and the assumption $c_n < 1/3$, it is immediate that $q^P > q^T$ when $\beta > 1$. The optimal prices for the optional service component in the two service delivery settings are given as follows: $p_o^T = 2k_u^2 / (9k_q)$ and $p_o^P >= 2\beta^2 k_u^2 / (9k_q)$. Clearly, for $\beta > 1$, $p_o^P > p_o^T$. □

Proof of Proposition 6. From Propositions 1 and 3, it may be noted that $p_n^T(q)$ and $p_n^P(q)$ are independent of the quality level q. The rest is straightforward. □

Proof of Proposition 7. The sizes of the customer segments in the philanthropic and traditional modes of service delivery are described as follows:

$$d_n^T = \frac{(1 - 3c_n) m}{6} \quad \text{and} \quad d_n^P = \frac{m}{6} \tag{16}$$

$$d_o^T = \frac{m}{3} \quad \text{and} \quad d_o^P = \frac{m}{3} \tag{17}$$

$$d_f^T = 0 \quad \text{and} \quad d_f^P = \frac{m}{2} \tag{18}$$

The number of customers buying the paid services in the traditional mode of service delivery is given by $d_n^T + d_o^T = m(1 - c_n)/2$, and that in the philanthropic mode of service delivery is $d_n^P + d_o^P = m/2$. The rest is straightforward from $c_n > 0$. □

Proof of Proposition 8. The consumer surplus for the customers in the two service delivery settings is described as follows:

$$S_n^T = \frac{(1 - 3c_n)^2 m}{72} \quad \text{and} \quad S_n^P = \frac{(\beta + 6\omega) m}{72} \tag{19}$$

$$S_o^T = \frac{[k_u^2 + 3k_q(2 - 3c_n)] m}{54k_q} \quad \text{and} \quad S_o^P = \frac{[\beta^2 k_u^2 + 3k_q(2\beta + 3\omega)] m}{54k_q} \tag{20}$$

$$S_f^T = 0 \quad \text{and} \quad S_f^P = \frac{\omega m}{8} \tag{21}$$

It is immediate from $\beta > 1$ and the assumption $c_n < 1/3$ that $S_n^P > S_n^T$ and $S_o^P > S_o^T$. The rest is straightforward, and hence, omitted. □

Proof of Proposition 9. The optimal profits for the service provider in the two service delivery settings are described as follows:

$$\pi^T = \frac{\left\{27k_q(1 - c_n)^2 + 4k_u^2 - 108k_q k_m m\right\} m}{108k_q} \tag{22}$$

$$\pi^P = \frac{\{27k_q(\beta-\omega-4c_n)+4\beta^2k_u^2-108k_q(k_m-k_s)m\}m}{108k_q} \tag{23}$$
$$\pi^P-\pi^T = \frac{\left\{4\beta^2k_u^2+27\beta k_q-\left\{4k_u^2+27k_q\left[\omega+(1+c_n)^2\right]-108k_qk_sm\right\}\right\}m}{108k_q}$$

It may be noted that π^T is independent of β, ω and k_s. π^P increases monotonically in β and k_s, and it decreases monotonically in ω, all from the following:

$$\frac{\partial\pi^P}{\partial\beta} = \frac{(8\beta k_u^2+27k_q)m}{108k_q} > 0, \qquad \frac{\partial\pi^P}{\partial\omega} = -\frac{m}{4} < 0, \quad \text{and} \quad \frac{\partial\pi^P}{\partial k_s} = m^2 > 0$$

Define $\underline{\beta}(\omega,k_s) \geq 0$ such that $\pi^P \geq (<)\,\pi^T$ for $\beta \geq (<)\,\underline{\beta}(\omega,k_s)$. $\underline{\beta}(\omega,k_s)$ as described in (3) is the non-negative solution to $\pi^P-\pi^T=0$. Define $\overline{\omega}(\beta,k_s) \geq 0$ such that $\pi^P \geq (<)\,\pi^T$ for $\omega \leq (>)\,\overline{\omega}(\beta,k_s)$. $\overline{\omega}(\beta,k_s)$ as described in (4) is the non-negative solution to $\pi^P-\pi^T=0$. Similarly, define $\underline{k_s}(\beta,\omega) > 0$ such that $\pi^P \geq (<)\,\pi^T$ for $k_s \geq (<)\,\underline{k_s}(\beta,\omega)$. □

Proof of Proposition 10. From (3), it is straightforward to note that $\underline{\beta}(\omega,k_s)$ is decreasing in k_s, and it increases in c_n and ω. From (4), we note that $\overline{\omega}(\beta,k_s)$ increases in β and k_s, and it decreases in c_n. The rest follows immediately. Also, from (5), we note that $\underline{k_s}(\beta,\omega)$ increases in β and c_n, and it decreases in ω. □

Proof of Proposition 11. From (22) and (23), we obtain

$$\frac{\partial\pi^T}{\partial m} = \frac{27k_q(1-c_n)^2+4k_u^2-216k_qk_mm}{108k_q} \quad \text{and} \quad \frac{\partial^2\pi^T}{\partial m^2} = -2k_m$$
$$\frac{\partial\pi^P}{\partial m} = \frac{27k_q(\beta-\omega-4c_n)+4\beta^2k_u^2-216k_q(k_m-k_s)m}{108k_q} \quad \text{and} \quad \frac{\partial^2\pi^P}{\partial m^2} = -2(k_m-k_s)$$

Clearly, $\partial^2\pi^T/\partial m^2<0$, and $\partial^2\pi^P/\partial m^2<0$ by the assumption $k_m>k_s$. The first order conditions are necessary and sufficient to show the optimality of a solution. m^T and m^P satisfy $\partial\pi^T/\partial m=0$ and $\partial\pi^P/\partial m=0$, respectively. □

Proof of Proposition 12. From Proposition 11, we obtain

$$m^P-m^T = \frac{4k_u^2[k_s+(\beta^2-1)k_m]+27k_qk_m\left[\beta-\omega-(1+c_n)^2\right]+27k_qk_s(1-c_n)^2}{216k_q(k_m-k_s)k_m}$$

It may be noted that m^P-m^T is monotonically decreasing in ω. Define $\overline{\omega}_m(\beta,k_s)$, as described in (8), such that $m^P \geq (<)\,m^T$ for $\omega \leq (>)\,\overline{\omega}_m(\beta,k_s)$. Likewise, we define $\underline{\beta}_m(\omega,k_s) \geq 0$, as described in (7), such that $m^P \geq (<)\,m^T$ for $\beta \geq (<)\,\underline{\beta}_m(\omega,k_s)$. Here, $\underline{\beta}_m(\omega,k_s)$ is the non-negative root of the condition $m^P-m^T=0$. Similarly, m^P-m^T is monotonically increasing in k_s. Define, $\underline{k_s}_m(\beta,\omega) \geq 0$, as described in (9), such that $m^P \geq (<)\,m^T$ for $k_s \geq (<)\,\underline{k_s}_m(\beta,\omega)$. □

Proof of Proposition 13. We substitute m^P in S_n^P, S_o^P, and S_f^P, described in (19)-(21), and π^P, described in (23). From (16)-(18), using m^P, we obtain d_n^P, d_o^P, and d_f^P as follows.

$$\pi^P\left(m^P\right)=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]^2}{46656k_q^2\left(k_m-k_s\right)}$$
$$d_n^P\left(m^P\right)=\frac{4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)}{1296k_q\left(k_m-k_s\right)}$$
$$d_o^P\left(m^P\right)=\frac{4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)}{648k_q\left(k_m-k_s\right)}$$
$$d_f^P\left(m^P\right)=\frac{4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)}{432k_q\left(k_m-k_s\right)}$$
$$S_n^P\left(m^P\right)=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]\left(\beta+6\omega\right)}{15552k_q\left(k_m-k_s\right)}$$
$$S_o^P\left(m^P\right)=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]\left[\beta^2k_u^2+3k_q\left(2\beta+3\omega\right)\right]}{11664k_q^2\left(k_m-k_s\right)}$$
$$S_f^P\left(m^P\right)=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]\omega}{1728k_q\left(k_m-k_s\right)}$$

The social welfare in the philanthropic mode of service delivery is described as follows:

$$W^P\left(m^P\right)=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta+\omega-2c_n\right)\right]\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]}{23328k_q^2\left(k_m-k_s\right)}$$

The consumer surplus aggregated for all customer segments in the philanthropic mode of service delivery is given as follows: $S_t^P=S_n^P+S_o^P+S_f^P=\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]\left[4\beta^2k_u^2+27k_q\left(\beta+3\omega\right)\right]/\left[46656k_q^2\left(k_m\right.\right.$
We further note that

$$\frac{\partial\pi^P}{\partial\beta}=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]\left(8\beta k_u^2+27k_q\right)}{23328k_q^2\left(k_m-k_s\right)}>0\quad\text{since }\omega<\dot{\omega}_m\left(\beta\right)\text{, by assumption}$$
$$\frac{\partial\pi^P}{\partial\omega}=-\frac{4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)}{864k_q\left(k_m-k_s\right)}<0\quad\text{since }\omega<\dot{\omega}_m\left(\beta\right)\text{, by assumption}$$
$$\frac{\partial\pi^P}{\partial k_s}=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)\right]^2}{46656k_q^2\left(k_m-k_s\right)^2}>0\quad\text{since }\omega<\dot{\omega}_m\left(\beta\right)\text{, by assumption}$$
$$\frac{\partial\left(d_n^P+d_o^P\right)}{\partial\beta}=\frac{8\beta k_u^2+27k_q}{432k_q\left(k_m-k_s\right)}>0$$
$$\frac{\partial\left(d_n^P+d_o^P\right)}{\partial\omega}=-\frac{1}{16\left(k_m-k_s\right)}<0$$
$$\frac{\partial\left(d_n^P+d_o^P\right)}{\partial k_s}=\frac{4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)}{432k_q\left(k_m-k_s\right)^2}>0\quad\text{since }\omega<\dot{\omega}_m\left(\beta\right)\text{, by assumption}$$
$$\frac{\partial d_f^P}{\partial\beta}=\frac{8\beta k_u^2+27k_q}{432k_q\left(k_m-k_s\right)}>0$$
$$\frac{\partial d_f^P}{\partial\omega}=-\frac{1}{16\left(k_m-k_s\right)}<0$$
$$\frac{\partial d_f^P}{\partial k_s}=\frac{4\beta^2k_u^2+27k_q\left(\beta-\omega-4c_n\right)}{432k_q\left(k_m-k_s\right)^2}>0\quad\text{since }\omega<\dot{\omega}_m\left(\beta\right)\text{, by assumption}$$
$$\frac{\partial S_t^P}{\partial\beta}=\frac{\left[4\beta^2k_u^2+27k_q\left(\beta+\omega-2c_n\right)\right]\left(8\beta k_u^2+27k_q\right)}{23328k_q^2\left(k_m-k_s\right)}>0\quad\text{since }c_n<1/3\text{, by assumption}$$

$$\frac{\partial W^P}{\partial \beta} = \frac{\left[4\beta^2 k_u^2 + 27k_q\left(\beta - 3c_n\right)\right]\left[8\beta k_u^2 + 27k_q\right]}{11664k_q^2\left(k_m - k_s\right)} > 0 \quad \text{since } c_n < 1/3, \text{ by assumption}$$
$$\frac{\partial S_t^P}{\partial \omega} = \frac{4\beta^2 k_u^2 + 27k_q\left(\beta - 3\omega - 6c_n\right)}{864k_q\left(k_m - k_s\right)}, \quad \text{and} \quad \frac{\partial^2 S_t^P}{\partial \omega^2} = -\frac{3}{32\left(k_m - k_s\right)} < 0 \quad \text{since } c_n < 1/3, \text{ by assumption}$$
$$\frac{\partial W^P}{\partial \omega} = -\frac{\omega + c_n}{16\left(k_m - k_s\right)} < 0$$
$$\frac{\partial S_t^P}{\partial k_s} = \frac{\left[4\beta^2 k_u^2 + 27k_q\left(\beta - \omega - 4c_n\right)\right]\left[4\beta^2 k_u^2 + 27k_q\left(\beta + 3\omega\right)\right]}{46656k_q^2\left(k_m - k_s\right)^2} > 0 \quad \text{since } \omega < \grave{\omega}_m\left(\beta\right), \text{ by assumption}$$
$$\frac{\partial W^P}{\partial k_s} = \frac{\left[4\beta^2 k_u^2 + 27k_q\left(\beta - \omega - 4c_n\right)\right]\left[4\beta^2 k_u^2 + 27k_q\left(\beta + \omega - 2c_n\right)\right]}{23328k_q^2\left(k_m - k_s\right)^2} > 0 \quad \text{since } \omega < \grave{\omega}_m\left(\beta\right), \text{ by assumption}$$

Clearly, S_t^P is a concave function of ω. It is straightforward to check that ω^P, as described in the proposition, satisfies $\partial S_t^P / \partial \omega = 0$. □

2. Determining Restriction-Induced Utility Reduction: Technical Results

In this section, we use the notation $\hat{X}$ to define variable X, wherever necessary.

The service provider's problem is described as follows:

$$\hat{\pi}^P\left(q, p_n, p_o, m, \omega\right) = p_n\left(\frac{p_o}{\theta\left(1 + k_b\omega\right)k_u q} - \frac{p_n}{\theta\left(1 + k_b\omega\right) - \omega}\right)m + \left(p_n + p_o - k_q q^2\right)\left(1 - \frac{p_o}{\theta\left(1 + k_b\omega\right)k_u q}\right)m$$
$$- \left(c_n - k_s m\right)m - k_m m^2 - k_o\omega^2 m \tag{24}$$

For brevity, we do not present the detailed analysis of the model to obtain the optimal solution. Given ω, the optimal solution to (24) is described as follows:

$$\hat{m}^P = \frac{\hat{\tau}^P}{216k_q\left(k_m - k_s\right)}$$
$$\hat{q}^P\left(\omega\right) = \frac{\theta\left(1 + k_b\omega\right)k_u}{3k_q}$$
$$\hat{p}_n^P\left(\omega\right) = \frac{\theta\left(1 + k_b\omega\right) - \omega}{2} \quad \text{and} \quad \hat{p}_o^P\left(\omega\right) = \frac{2\theta^2\left(1 + k_b\omega\right)^2 k_u^2}{9k_q}$$
$$\hat{d}_n^P\left(\omega\right) = \frac{\hat{\tau}^P}{1296k_q\left(k_m - k_s\right)}, \quad \hat{d}_o^P\left(\omega\right) = \frac{\hat{\tau}^P}{648k_q\left(k_m - k_s\right)}, \quad \text{and} \quad \hat{d}_f^P\left(\omega\right) = \frac{\hat{\tau}^P}{432k_q\left(k_m - k_s\right)}$$
$$\hat{\pi}^P\left(\omega\right) = \frac{\left(\hat{\tau}^P\right)^2}{46656k_q^2\left(k_m - k_s\right)} \tag{25}$$
$$\text{where} \quad \hat{\tau}^P = -27k_q\left(4c_n + 4k_o\omega^2 + \omega\right) + \theta\left(1 + k_b\omega\right)\left[27k_q + 4k_u^2\theta\left(1 + k_b\omega\right)\right] \tag{26}$$

Proof of Proposition 14. For the feasibility of a solution to the service provider's problem of maximizing the profit, $\hat{\pi}^P\left(\omega\right)$ described in (25), such that the demand for each customer segment – $\hat{d}_n^P\left(\omega\right)$, $\hat{d}_o^P\left(\omega\right)$, and $\hat{d}_f^P\left(\omega\right)$ – is non-negative, we need $\hat{\tau}^P \geq 0$. Additionally, the service provider's profit, $\hat{\pi}^P\left(\omega\right)$, is positive and the model for endogenously determining the value of the parameter ω is relevant only if $\hat{\tau}^P > 0$. Thereby, we consider the situations wherein $\hat{\tau}^P > 0$ and determine the profit-maximizing level of ω for the service provider.

From (25) and (26), we obtain

$$\frac{\partial \hat{\pi}^P}{\partial \omega} = \left[\frac{1}{23328k_q^2\left(k_m - k_s\right)}\right]\left(\hat{\tau}^P \frac{\partial \hat{\tau}^P}{\partial \omega}\right), \qquad \frac{\partial^2 \hat{\pi}^P}{\partial \omega^2} = \left[\frac{1}{23328k_q^2\left(k_m - k_s\right)}\right]\left[\hat{\tau}^P \frac{\partial^2 \hat{\tau}^P}{\partial \omega^2} + \left(\frac{\partial \hat{\tau}^P}{\partial \omega}\right)^2\right]$$
$$\frac{\partial \hat{\tau}^P}{\partial \omega} = -8\omega\left(27k_q k_o - k_u^2 k_b^2 \theta^2\right) + 8k_u^2 k_b \theta^2 - 27k_q\left(1 - k_b\theta\right), \qquad \frac{\partial^2 \hat{\tau}^P}{\partial \omega^2} = -8\left(27k_q k_0 - k_u^2 k_b^2 \theta^2\right)$$

Consider $k_0 > k_u^2 k_b^2 \theta^2 / \left(27k_q\right)$. Define $\dot{\omega}^P = \left[8k_u^2 k_b \theta^2 - 27k_q\left(1 - k_b\theta\right)\right] / \left[8\left(27k_q k_o - k_u^2 k_b^2 \theta^2\right)\right]$ that uniquely satisfies $\partial \hat{\tau}^P / \partial \omega = 0$ and $\partial^2 \hat{\tau}^P / \partial \omega^2 < 0$. It implies that $\hat{\tau}^P$ is strictly concave in ω and it attains the maxima at $\dot{\omega}^P$. It is easy to note that the sign of $\partial \hat{\tau}^P / \partial \omega$ determines by the sign of $\partial \hat{\pi}^P / \partial \omega$. Thereby, $\partial \hat{\pi}^P / \partial \omega > (\leq) 0$ for $\omega < (\geq) \dot{\omega}^P$ suggesting that $\hat{\pi}^P$ is unimodal. Consequently, $\dot{\omega}^P$ uniquely satisfies $\partial \hat{\pi}^P / \partial \omega = 0$ and offers a (global) maxima for $\hat{\pi}^P$. By the feasibility condition $\omega \in [k_\omega, 1]$, the optimal level of the parameter ω is given by $\hat{\omega}^P = \max\{k_\omega, \min\{\dot{\omega}^P, 1\}\}$.

Consider $k_0 < k_u^2 k_b^2 \theta^2 / \left(27k_q\right)$. It is immediate that $\partial^2 \hat{\tau}^P / \partial \omega^2 > 0$, and by the strict convexity, $\hat{\tau}^P$ attains the minima at $\dot{\omega}^P$. It also suggests that $\partial \hat{\pi}^P / \partial \omega < (\geq) 0$ for $\omega < (\geq) \dot{\omega}^P$ suggesting that $\hat{\pi}^P$ attains the minima uniquely at $\dot{\omega}^P$. Thereby, the optimal level of the parameter ω is at either of the extremes, i.e., k_ω or 1.

Consider $k_0 = k_u^2 k_b^2 \theta^2 / \left(27k_q\right)$. $\partial^2 \hat{\tau}^P / \partial \omega^2 = 0$ and $\partial \hat{\tau}^P / \partial \omega^2$ is independent of ω. For $8k_u^2 k_b \theta^2 > 27k_q\left(1 - k_b\theta\right)$, the optimal level of the parameter $\hat{\omega}^P = 1$, and for $8k_u^2 k_b \theta^2 \leq 27k_q\left(1 - k_b\theta\right)$, $\hat{\omega}^P = k_\omega$.
□

Considering the interior optimum $\dot{\omega}$, we obtain

$$\hat{S}_n^P = \frac{\hat{\tau}^P\left[\theta\left(1 + k_b\omega\right) + 6\omega\right]}{15552k_q\left(k_m - k_s\right)}, \quad \text{and} \quad \hat{S}_o^P = \frac{\hat{\tau}^P\left\{\theta\left(1 + k_b\omega\right)\left[k_u^2\theta\left(1 + k_b\omega\right) + 6k_q\right] + 9\omega k_q\right\}}{11664k_q^2\left(k_m - k_s\right)}$$
$$\hat{S}_f^P = \frac{\hat{\tau}^P \omega}{1728k_q\left(k_m - k_s\right)}$$
$$\hat{W}^P = \frac{\hat{\tau}^P\left\{\theta\left(1 + k_b\omega\right)\left[4k_u^2\theta\left(1 + k_b\omega\right) + 27k_q\right] - 27k_q\left(2c_n + 2k_o\omega^2 - \omega\right)\right\}}{23328k_q^2\left(k_m - k_s\right)}$$

3. Additional Results

Lemma 1. *To ensure that the customer demand for only the necessary service component and that for the necessary and optional service components are non-negative in the traditional mode of service delivery, i.e., $d_n^T \geq 0$ and $d_o^T \geq 0$, it is necessary that the service provider offers the quality level for the optional service component such that $q \geq \underline{q}^T = c_n k_u / k_q$ and $q \leq \overline{q}^T = k_u / k_q$.*

Proof of Lemma 1. From (12), we note that $d_n^T(q)$ is increasing in q. Define $\underline{q}^T$ such that $d_n^T(q) \leq (>) 0$ for $q \leq (>) \underline{q}^T$. On the contrary, $d_o^T(q)$ is decreasing in q. Define for $\overline{q}^T$ such that $d_o^T(q) \geq (<) 0$ for $q \leq (>) \overline{q}^T$. By the assumption $c_n < 1/3$, we note that $\underline{q}^T < \overline{q}^T$. The rest is straightforward, and hence, omitted. □

By offering the quality level q for the optional service component below the threshold $\overline{q}^T$, the service provider can segregate the market for two types of customers: those of the first type that purchase only the necessary service component, and those of the second type that purchase both the necessary and the optional service components. However, if the quality level q is below the threshold $\underline{q}^T$, then every customer that buys the necessary service component also purchases the optional service component as it is affordable to them all due to the very low price charged by the service provider. These findings show that a sufficiently high quality of the optional service component is essential to segment the market, which is in the interest of the service provider.

LEMMA 2. *To ensure that the customer demand for only the necessary service component and that for the necessary and the optional service components are non-negative in the philanthropic mode of service delivery, i.e.,* $d_n^P \geq 0$ *and* $d_o^P \geq 0$*, it is essential that the service provider does not offer the quality level* q *for the optional service component beyond threshold* $\overline{q}^P$*, i.e.,* $q < \overline{q}^P = 2\beta k_u/3k_q$.

Proof of Lemma 2. From (14), we note that $d_n^P(q) > 0$.

On the contrary, $d_o^P(q)$ is decreasing in q. Define $\overline{q}^P = 2\beta k_u/3k_q$. For $q \leq \overline{q}^P$, we obtain $d_o^P(q) > 0$.

The rest is straightforward, and hence, omitted. □

As observed in the traditional mode of service delivery, by offering the quality level q for the optional service component below a threshold, the service provider is able to segregate the market into two types of customers. However, we observed that the lower threshold for the quality level of the optional service component to create market segments is zero. It shows that in the philanthropic mode of service delivery, the demand for the service provider's necessary service component *always* exists.