The Economics of Investments in Accessibility for Persons with Disabilities

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Abstract

Emerging trends in technology are providing opportunities for a broader range of mobile and pervasive assistive technologies (MPAT) to positively impact persons with disabilities in terms of independent living and employment. However, such technologies typically require significant investments by entities that offer such options. It is not clear how such firms compete in a market with other firms that may not provide such options. Understanding such competition can help promote greater investments in accessibility infrastructure by entities and provide insights into how federal efforts can further boost such efforts. To that end, this paper presents a game-theoretic framework of market competition between two firms where one invests in accessibility (bearing additional upfront costs) and compares it with another one that does not. Numerical evaluations demonstrate the range of parametric values where accessibility investments pay off.

Introduction

Disability is part of the human condition. Almost everyone will be temporarily or permanently impaired at some point in life and those who survive to old age will experience increasing difficulties in functioning beyond the age of 40 [1]. Despite advances resulting from the Rehabilitation Act of 1973 and Americans with Disabilities Act (ADA) (and similar efforts around the world), people with disabilities remain part of the underserved population with regards to employment, income, and health care [3]. A big part of this challenge is lack of or limited options for access to information and or built environments.

Assistive technologies (ATs) can serve to ameliorate detrimental impacts of disability on body function or structure, environmental obstructions, and societal barriers. Well-known assistive technologies include wheelchairs, vision-correcting lenses, and hearing aids, all of which address a problem in body function or structure, help the user navigate environmental obstructions, and through increased inclusion, overcome societal barriers. Accessibility for digital media have seen a lot of positive developments over the last decade [14]. More recent developments in pervasive and mobile computing have led to a specific sub-category of ATs called Mobile and Pervasive Assistive Technologies (MPATs). MPATs have emerged because mobile and pervasive devices have become platforms of choice to enable assistive technologies that improve the quality of life of people with disabilities. Pervasive sensors and actuators can provide vital information about the environment to those who traverse it, while mobile devices allow for computing and communications. Coupled with the fact that mobile devices are also compact, widespread and socially acceptable, MPATs can be leveraged to achieve ubiquitous assistance for activities of daily living (such as mobility, information access, interaction with the environment, or with other people) [2, 9, 20, 25, 29, 32].

However, just like wheelchairs need to be supported by investments in infrastructure (ramps), many MPATs often need to be supported by back-end infrastructure to enable or enhance their functionality. For example, many of the recent advances in navigation and wayfinding in built environments with MPATs require infrastructure modifications or augmentations such as addition of radio-frequency identification (RFID) tags, Bluetooth Low Energy (BLE) beacons, or other location-tagging devices [25, 36]. Another example of such a scenario where MPATs are being used is that of national grocery chains setting up kiosks for customers to scan items themselves using a device (smartphone) that is already accessible for users.

While laws such as the Americans with Disabilities Act (ADA) and Section 508 [3, 10] and equivalents have led to investments to modify physical spaces for accessibility (ramps to access buildings or vehicles) or create accessible technology, they have not yet led to similar investments to support MPATs which often fall beyond current legal requirements as "convenience technologies". Currently, such investments are either federally supported for some public spaces or limited to a few private efforts. For the most part, technology exists to make many environments (such as smartphone-based wayfinding for built environments) sufficiently or conveniently accessible, limited only by the inability to prepare the environment to deploy such MPATs. The primary challenge is often to get private entities willing to invest in making spaces accessible using MPATs.

Given that market forces often determine the feasibility of adopting accessibility options beyond the requirements of the laws, this paper explores the theoretical underpinnings of what may motivate entities or firms to invest in support of MPATs and in general AT infrastructure. In this paper we propose a game theoretic model that will help analyse the importance of various parameters and the incentives firms may need to provide better accessibility.

State of the Art

Numerous ATs have been developed over the years to assist persons with disabilities with activities of daily living such as wheelchairs and screen readers. Many MPATs have recently been developed for navigating and operating within built environments [4, 5, 7, 11, 13, 15, 18, 19, 24, 25, 31, 32]. While the success of some of these MPATs requires effort or investments only from the end-user (for e.g., [4, 5, 7, 11, 15, 32]), the vast majority of these MPATs require adequate investments from the enablers or managing entities (for e.g., [13, 18, 19, 24, 25, 31]). For MPATs where any kind of investments are needed, the enablers and managing entities need to carefully consider the benefits and costs and determine the economic feasibility of offering such products or services. Beyond legal and ethical considerations, eventually firms need business success to be sustainable. This necessitates adequate tools be available for making such decisions, especially for cases where a firm is contemplating increasing accessibility beyond minimum legal requirements to something more meaningful or convenient.

Methodology

The proposed economic framework developed in this paper considers two scenarios; one firm that adopts (supports and invests in) MPAT specially geared towards improving the quality of life for people with disabilities (called Firm 1), and another firm (Firm 2) that does not make specific investments to cater to the subset of the population with disabilities. By comparing the demand for Firm 1 in a Cournot competition [35] with Firm

2, a better understanding of the feasibility and challenges in consumers adopting the accessible choice (offered by Firm 1) can be gained.

For simplicity and intuitive results, we assume a market characterized with two firms (a 2-player market). We model firms that can be considered to operate in an oligopoly market structure. For example, the grocery market is concentrated with few major players, so modelling two firms (duopoly) is expected to capture most of the market dynamic. Assume that Firm 1 has adopted an MPAT system which is enabled through investments. For Firm 1 to offer the accessibility option, it must make significant investments in accessibility infrastructure. Firm 2 does not make such investments and hence can be characterized as the "accessibility-unfriendly" option.

Using the Mussa and Rosen's model of vertical product differentiation [35] where differences in consumer attitudes for accessible services are accounted for, demand facing the two firms can be derived. Solving the profit maximization problem for the two firms competing on capacity/output (Cournot competition), quantity demanded and price for each firm's service at equilibrium is determined. The impact of the underlying costs to the two firms are of particular interest to determine the feasibility of Firm 1 offering accessibility options. Firm 2 is assumed to incur a "base" cost of C_{base} which is assumed to be the cost to offer a unit quantity of the product without any additional costs incurred to provide accessibility. Firm 1 incurs an additional percentage cost C_a per unit of product for providing accessibility. The intuition here is that accessibility costs are likely to scale with overall costs of a firm. A larger firm with larger operational costs will have to spend more on accessibility. Economies of scale in accessibility investments can of course reduce these costs, in which case our cost function for Firm 1 will over-estimate costs and likely under-estimate the competitiveness of Firm 1. The cost function can be expressed as:

$$C_{base} \leq min\left(\frac{2k_1 - k_2}{1 + 2C_a}, \frac{k_1 k_2}{2k_1 - k_2(1 + C_a)}\right)$$

Where k_1 and k_2 are positive real numbers from the Mussa and Rosen model that describe the average consumer or user experience of shopping at Firms 1 and 2, and $k_1 \geq k_2$ due to our assumption that Firm 1 offers a more accessible experience without compromising on any needs of those customers who do not care for accessibility.

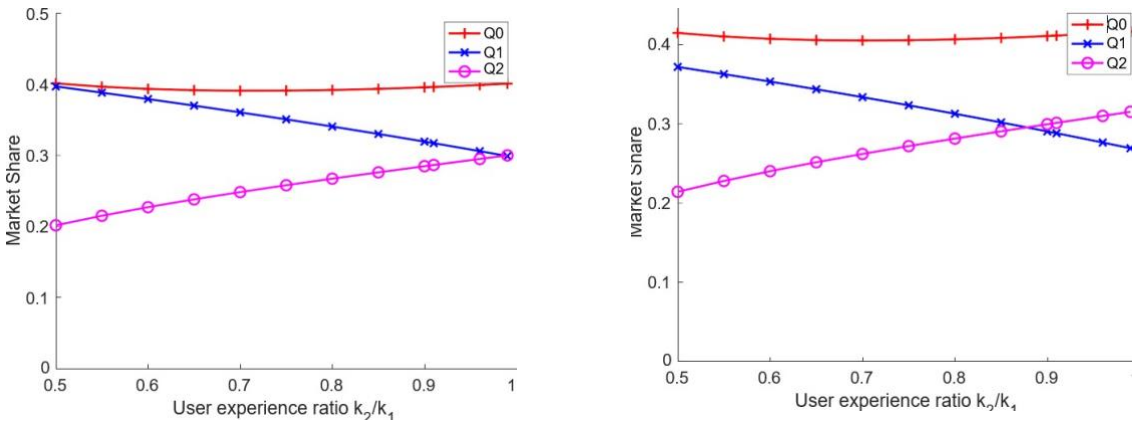
Numerical Evaluations

We perform numerical evaluations to demonstrate the model and its use in interpreting the impact of important parameters based on conditions derived from the theoretic model. The metrics under consideration are the following:

Market Share

It is interesting to study the evolution of market share for both firms as the cost of accessibility investments increase. One would expect Firm 1 to lose market share as its underlying costs increase, while Firm 2 is likely to benefit from this. Figure 1 shows how market share of both firms (Q_1 and Q_2) varies as the ratio of user experience k_2/k_1 increases. As expected, the market share for Firm 2 increases and even crosses that of Firm 1 as the user experience ratio get close to 1 with the point of crossover depending on the accessibility costs C_a incurred by Firm 1. Higher accessibility costs without a significant advantage in user experience allows Firm 2 to gain market share over Firm 1. Thus, Firm 1's user experience advantage must overcome its investments in accessibility for it to gain a market share advantage over Firm 2.

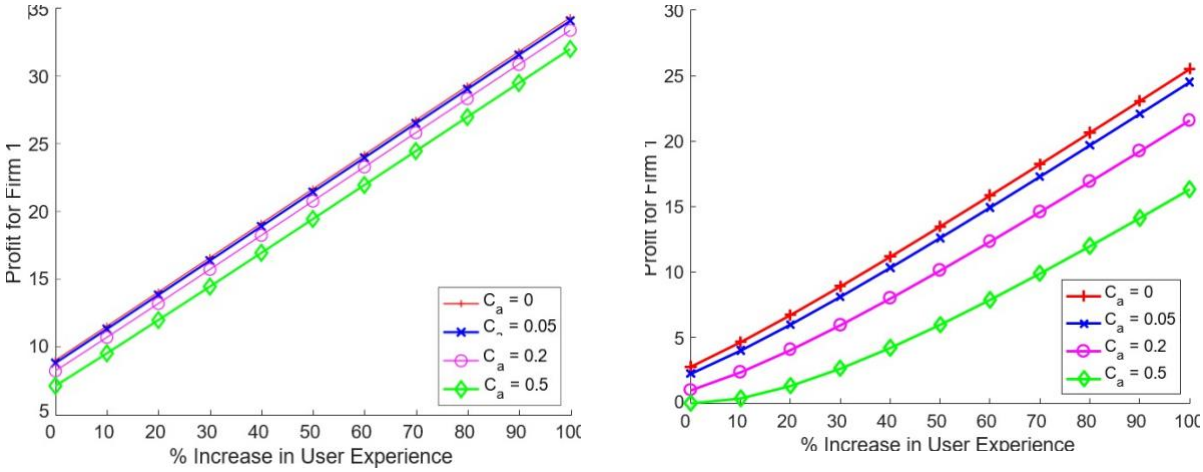
Fig 1: Market share for increasing k_2/k_1 ratios with C_{base} =10 and accessibility costs C_a=5% and 50%



Profit

The impact of both accessibility investments and unit costs of products on profits will help illustrate the scenarios where firms will be competitive. Profit for Firm 1 expectedly increases as the user experience advantage over Firm 2 increases. For larger unit cost products, (C_{base} = 50), profits are reduced due to loss of market share where the consumer decides not to choose either firm's services as seen in Figure 2. The major result here is that even with large accessibility costs, Firm 1 is still able to make a profit.

Fig 2: Profit vs user Experience advantage for Firm 1 for various accessibility costs when C_{base} = 10 and 50



Conclusion

This paper presents an economic framework to compare a firm that invests in providing accessibility possibly with another firm that does not. The model and its evaluation help understand what parameters are more significant to motivate accessibility infrastructure deployments. This framework can be used to answer questions such as given a firm's

operating costs and revenue, how will an additional investment in accessible spaces or technology improve or hurt market share and profits based on a user's experience.

The results presented indicate that any firm considering making accessibility investments can expect to make profits and gain an advantage over its competitors if the expected increase in average user experience is significant (quantified as 20% or more for parameters considered in this work) across all potential users. This reinforces the fact that firms should focus more on quantifying and improving average user experience, and that accessibility investments need not be a barrier. Future work will look into quantifying using case studies how much of an increase in user experience can be expected with accessibility investments.

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