Study on the Price Elasticity of Demand of Beijing Subway

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***Abstract*—With the gradually development of Beijing Subway network, passenger volume grows fast and the government bear more and more subsidies. We focus on the price elasticity of travel demand of Beijing Subway, in order to point out the relationship between them. We hope our study can provide the government important reference in designing more efficient price scheme and ensure the sustainable development of Beijing Subway.**

***Index Terms*—Beijing subway, price elasticity, travel demand**

I. Introduction

With the rapid urbanization, road network in Beijing is continuously improved in the past decades. But it cannot match the dramatically increased travel demand, and faces various kinds of traffic problems, including accidents, congestion, and air pollution etc., among which congestion is the most outstanding one. Learning from other cities, Beijing turns to urban rail transit to resolve its traffic problems. Beijing's urban rail transit system is composed of subway and light rail, which is generally called as Beijing Subway. And it quickly became the backbone of public transit, since it takes advantages of safe, rapid, on time, large capacity and comfort.

In order to provide the residents a more effective and convenient traffic mode, and to relieve the stress of road surface public transit (PT), Beijing continuously enforce the low fare policy and pay vast amount of subsidies to guarantee the normal operation of Beijing Subway. But with the surge in the traffic volume of Beijing Subway, especially after a doubled increase from 2004 to 2008 [1], the government will inevitably face an extremely large financial burden in (the) future, which will obviously influence the regular investment of Beijing's social-economy development. To avoid the unsustainable of Beijing Subway, many scholars are trying to propose a more reasonable price scheme [2], [3]. Facing possible volatility in ticket price, travelers may decide to modify their trip modes to reduce costs. To estimate how travelers respond to ticket price changes, we study the ticket price elasticity of the travel demand of Beijing Subway, and provide theoretical evidence to policy makers in developing more effective subway pricing schemes.

Price elasticity, as a most important indicator for pricing, has been studied in many fields recent years. Galarraga et al. proposes a combined approach for estimating willingness to pay for the attributes represented by energy efficiency labels and providing reliable price elasticity of demand (own and cross) for close substitutes [4]; Fan et al. estimated the price elasticity of electricity demand for South Australia attempts to determine whether there is any variation in price sensitivity with the time of day [5]; Schiff et al. estimated the demand elasticity of 16 different international visitors for New Zealand tourism [6]; Ruhm et al. examine how estimates of the price elasticity of demand for beer vary with the choice of alcohol price series examined [7].

The literature review mentioned above shows that the price elasticity of demand is widely studied and used in reality. Own-price elasticity is a useful measure of how customers adjust to increase in the price by adjusting their consumption. This is especially useful when evaluating long-term adjustments to changes in prices. We will focus on the own-price elasticity, since our major concern is how the changes in ticket price will affect the travel demands of Beijing Subway. In the rest of this paper, "own-price elasticity" is call as "price elasticity" for short and log-linear econometric model [5] is employed to estimate the price elasticity of travel demand for Beijing Subway.

The paper is organized as follows. In Section II, we recall the definition about the law of demand and the price elasticity, and briefly discuss how to use price elasticity to increase revenue as well. Section III addresses the fast growth of the passenger volume of Beijing Subway and the background behind it. Section IV makes an analysis of the change of price elasticity. Finally, we give some concluding remarks and topics for future research.

II. The Law of Demand and Price Elasticity

According to economic theory, the quantity demanded is the amount of any good, service or resource that people are willing and able to buy during a specified period at a specified price [8]. Many things influence buying plans, and one of them is price. To study the relationship between quantity demanded and price. We keep all other influences

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on buying plans the same and ask how does the quantity demanded of a good change as its price varies? The law of demand provides the answer.

The law of demand states other things remaining the same, if the price of a good rises, the quantity demanded of that good decreases; and if the price of a good falls, the quantity demanded of that good increase [9]. That's because, faced with a limited budget, people always have an incentive to find the best deals they can. If the price of an item falls and the prices of all other items remain the same, the item with the lower price is a better deal than it was before, so some people buy more of this item.

A demand curve is a graph of the relationship between the quantity demanded of a good and its price when all the other influences on buying plans remain the same. As shown in Fig. 1, the downward slope of the demand curve illustrates the quantity demanded of each price.

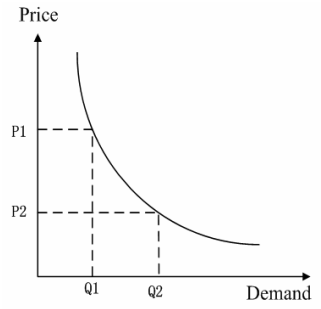

Figure 1. The demand curve.

Law of demand tells us that consumers will respond to a price drop by buying more, but it does not tell us how much more. In fact, we need to know more about a demand curve than the fact that it slopes downward. We want to know how responsive the quantity demanded is to the price change. Elasticity provides the information. The price elasticity of demand is a measure of the responsive of the quantity demanded of a good to a change in its price when all other influence on buyers' plans remains the same [10]. Then the price elasticity can be defined as:

$$E_d = \Delta Q\% / \Delta P\%. \tag{1}$$

where, $\Delta Q\%$ means the percentage change in quantity demanded, and $\Delta P\%$ means the percentage change in price. Because demand curves slope downwards, the percentage change in price and the percentage change in quantity demanded have opposite signs, and their ratio is negative. However, it is tedious and sometimes confusing for price elasticity to be negative. The absolute value usually is taken and is reported as a positive number in most situations.

The price elasticity range varies, and there are mainly five cases:

(a) The price elasticity of demand towards zero ($|E_d| = 0$), means that the quantity demanded keep the same no matter how the price changes, called perfectly inelastic;

(b) The price elasticity of demand is less than one ($|E_d| < 1$), means that when the price goes up by a given percentage, the quantity demanded falls by a smaller percentage, called inelastic;

(c) The price elasticity of demand equals to one ($|E_d| = 1$), that means the percentage increase in price exactly equals the percentage decrease in quantity demanded, called unit elastic;

(d) The price elasticity of demand is greater than one ($|E_d| > 1$), in this case, a small percentage change in price cause a big percentage change in quantity demanded, so called elastic;

(e) The price elasticity of demand towards infinity ($|E_d| = \infty$), means even a little change in price will make big difference in demand, called perfectly elastic.

In reality, price elasticity is generally of two types, inelastic and elastic, the other three are extreme assumptions. Now, according the definition of price elasticity of demand, we can easily have a clear understanding of whether manufacturer gets more or less profit by increasing or decreasing price. According to the basic principles of microeconomics, the relationship between quantity demanded and price is defined as:

$$Q = \alpha P^{\varepsilon}. \tag{2}$$

where, α is a constant, and the exponent ε refers to price elasticity. Then the revenue can be defined as:

$$B = PQ = \alpha P^{\varepsilon+1}. \tag{3}$$

For a given P, there is a unique Q correspond to it. Considering that, when the price has a change of ΔP, then the total revenue will change. The change of revenue can be obtained by looking at the quantity

$$\begin{aligned} \phi &= B(p+\Delta p) / B(p) = \alpha(p+\Delta p)^{\varepsilon+1} / \alpha P^{\varepsilon+1} \\ &= (1+\Delta p / P)^{\varepsilon+1}. \end{aligned} \tag{4}$$

thus, we can conclude that:

(a) $\varepsilon < -1$, $\varepsilon + 1 < 0$

$\Delta p < 0, \phi > 1$, means the total revenue increase;

$\Delta p > 0, \phi < 1$, means the total revenue decrease;

(b) $-1 < \varepsilon < 0$, $\varepsilon + 1 > 0$

$\Delta p < 0, \phi < 1$, means the total revenue decrease;

$\Delta p > 0, \phi > 1$, means the total revenue increase;

The above discussion shows that both the increase and decrease of price will make the revenue of manufacturer changes as hoped, it depends on the price elasticity. So it is preposterous to think small profits but quick turnover is right for everything and in all conditions. For a good whose price elasticity is elastic, we can have more revenue by increasing its price. While, for a good whose elasticity is inelastic, we should decrease its price to make more profit. The study on the price elasticity of demand of Beijing subway has practical significance, which is useful for the adjustment of ticket price.

III. Fast Travel Demand Growth of Beijing Subway

In this section, we provide some background of the passenger volume evolution of Beijing subway since the implementation of the reform and open policy in 1978. The volume of Beijing subway is influenced by a variety factors, we only make an investigation of population and economy, which are the fundamental and important ones.

The fast population growth is an important factor for the fast increase of subway passenger volume. Fig. 2 shows the demographic evolution of Beijing from 1978 to 2010 [11]. During these 33 years, the total population of Beijing has

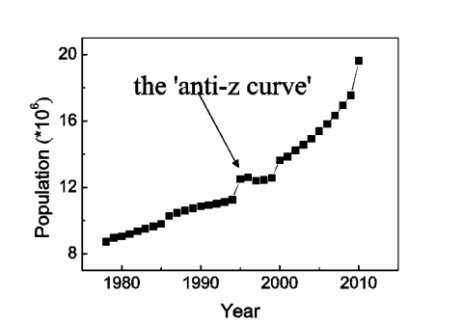

Figure 2. Population evolution of Beijing (1978-2010).

increased from 8.71 million to 19.62 million, which means total population has doubled. There are three periods of China's urbanization from 1960 until now, namely the rapid decline stage (1960-1978), the stable stage of ascension (1979-1995) and rapid promotion stage (1996-2010) [12]. So the population changes display an "anti-z curve", because of the economical development policies affected the growth of the population. The growth rate obviously becomes greater since 1996, indicates that the population increases due to the fast economy development.

The rapid development of economy also plays a major role in the growth of the subway passenger volume. China has enjoyed three decades of rapid economics development and social changes since the implementation of the reform and open policy in 1978. Following the Open-door policy, foreign loans and investment have poured into Beijing and other main cities following spectacular rates [13]. What's more, with the efforts of 15 years, China joined WTO successfully on 11 December 2001, becoming one of the 143 members. Thus, provide a greater opportunities for foreign investors to compete with domestic investors on a more equal basis and with overseas investors enjoying better protection than before through formal processes of judicial review and legal remedy. Fig. 3 and Fig. 4 shows the GDP of Beijing from 1978 to 2010 and the average disposable income in Beijing [11]. We can see that the people's living standard rises fast with the rapid development of economy.

The fast economic development and the population growth induce the fast increase of subway passenger volume. We investigate the fast growth of subway passenger volume by the following observations. Fig. 5 shows the trend of passengers carried by public transportation, including bus and subway. It is clear that the total passenger volume of public transportation and bus represent a linear growth as time going, with slight fluctuation. While, in less than forty years, the passenger volume of subway has increased by a factor of sixty, from the original less than 30 million at 1978 to more than

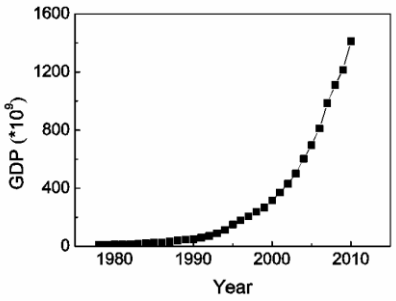

Figure 3. Gross domestic product (GDP) of Beijing (1978-2010).

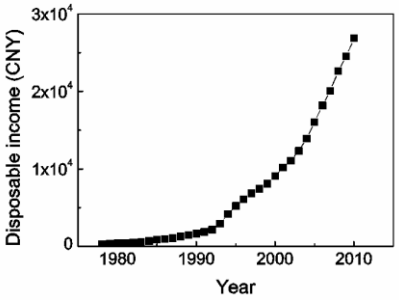

Figure 4. Disposable income in Beijing (1978-2010).

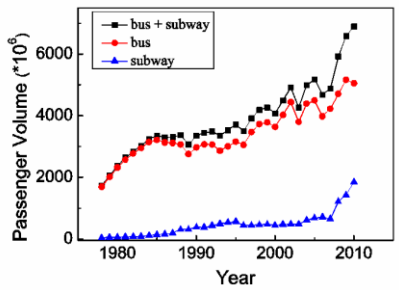

Figure 5. Passengers carried by mass transit systems of Beijing.

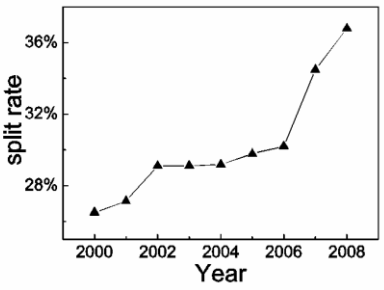

Figure 6. The split rate of public transportation.

1800 million at 2010 [11]. However, the rate of growth is not constant over time, slow from 1978 to 1995, steady

from 1996 to 2003, and fast from 2004 until now. The continuous growth of passenger volume indicates that the spilt rate of public transportation increases, as shown in Fig. 6[14] [15] [16]. Indeed, the government, designers and planners have spared no pains to improve the traffic condition in Beijing, and we witnessed big changes have taken place recent years.

IV. Analysis of Price Elasticity of Beijing Subway

We demonstrate the average ticket price (data in Fig. 7 are calculated at the price of 1990, due to the constantly changing inflation rate) and passenger volume of Beijing Subway on the top of Fig. 7 [11], [17] - [19], the three insets in the bottom of Fig. 7 shows the relationship between passenger volume and average price, note that, both of the two quantity have been taken logarithmic.

⑴ first stage (1991-1995): the relationship between ticket price and passenger volume obeys the law of demand and the price elasticity equals to 0.8811, negative. We can say the precondition of the law of demand is satisfied, namely ceteris paribus. For : ①Only line 1 and line 2 were under operation during this period, the total cost can be considered to be the same[20]; ② The permanent resident population in Beijing increases slowly these years, the passenger source seems stable. As a consequence, the ticket price and the passenger

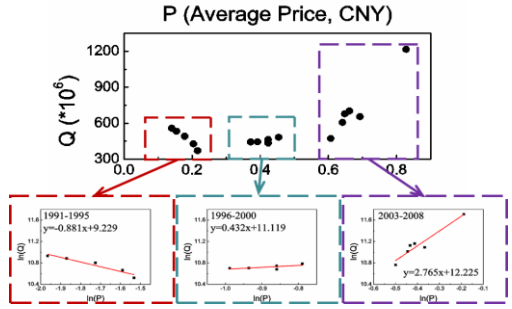

Figure 7. The relationship curve between ticket price and passenger volume.

volume changes coincide with the law of demand, that is to say, passenger volume tends to decrease when ticket price increases and if ticket price reduces the passenger flow increases.

⑵second stage(1996-2000): the relationship between ticket price and passenger volume deviate from the law of demand at some degree, that is to say passenger volume is increasing constantly while ticket prices keep rising, through the growth rate is low. That mainly because, with the development of social economy and improvement in the lives of the people, people's life related travel gradually increase and become more diverse, such as shopping, leisure fitness, out repast, see doctor, visit friends and families and so on. Fig. 8 illustrates the survey-based data of different trip purposes. There is no doubt that people's life related travel experienced a large growth. Besides, from the final report of travel surveys of Beijing 2000, the average trip was 2.77 per person per day and only 1.61 per person per day in 1986 [14]. What's more, people put forward higher request to travel quality because of the improvement of living standard, so more and more people prefer to choose subway, which is characterized by rapid, on time, comfortable and safe.

⑶The third stage(2003-2008): much like the second stage, passenger volume is increasing constantly while ticket prices keep rising, the difference lies in the growth rate of the third stage is much higher. The abnormal phenomenon may be caused by the following factors: ①With new subway lines being continuously put into operation, as well as the scale of the line network increasing gradually, the Beijing subway has entered into an era of network operations. As a consequence, induced the new source of tourists and attracted passengers who used to other traffic modes because of the increase of accessibility and the development of Real-estate along the lines [20]; ②The permanent population of Beijing reached an unprecedented growth speed during this period, the total population increased from 14.564 million at 2003 to 16.95 million at 2008, the growth rate close to the value 17%[11]. As a result, the jumps of the population lead to significant increase of the passenger flow, ③It is well know that, the ticket price of Beijing subway is lower than any other city in china, which make a big difference to the attraction of subway and more and more people choose subway to travel; ④ To give full a play of the role of pubic transportation and mitigate the serious traffic congestion situation, the government has put forward many policies, which in turn lead a part of passengers turn to subway. The above factors work together and finally cause the relationship between ticket price and passenger volume different from the general cases.

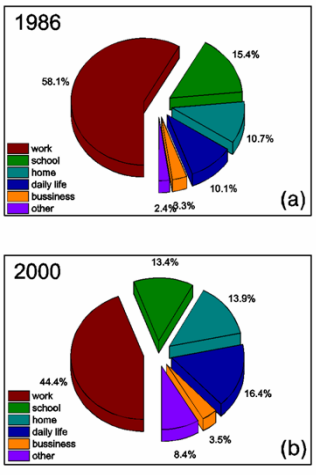

Figure 8. Trip purposes based on CAUPD (China Academy of Urban Planning and Design).

V. Conclusions

In this paper, we focus on the change of the price elasticity change of Beijing subway, and make some analysis on it. There is no doubt that with the growing traffic congestion of Beijing, the only and best solution is to create a better and more attractive mass transit system.

Urban subway, which is characterized by greater capacity, higher speed, more on time, less environment pollution and so on, is not only an important means to improve urban traffic congestion, but also act as the backbone of the urban public transportation. In order to improve the importance of subway in urban public transportation, our study on the price elasticity of Beijing subway has practical meanings.

It should be pointed out that the factors that influence the price elasticity of Beijing Subway are various, and the internal relations among them are complex. Our study also has much to do. Our future study aims to establish a model that can predict the price elasticity of Beijing subway; after this work have been done, we want to work out a practical price scheme for Beijing subway.

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