Congestion Pricing in China: Why?

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Abstract

Over the past two decades, China has seen worsening traffic congestion in all major cities. Like almost all other countries, China has relied on supply-side and regulatory instruments to mitigate urban congestion, including expanding road capacity and forcing private vehicles to stay off roads. However, such instruments could be often ineffective. This paper has three purposes. First, it proves that congestion pricing helps to internalize traffic externalities and reduce travel level. Second, the paper presents successful international experience in congestion pricing. Last, the paper discusses why China should implement congestion pricing. This paper attempts to promote demand-side policies in China, particularly congestion pricing.

Keywords: People's Republic of China, Development, Economics, Growth Management, Planning, Public Policy, Transportation

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1. Introduction

During the past two decades, China experienced a dramatic growth in the number of vehicles running on urban roads, especially private vehicles. In 1990, China had 5.5 million private vehicles. This number became 62.8 million in 2009 and 72.06 million by the end of June 2011, increasing more than 1200 percent in 20 years. By the mid-2011, private vehicles account for 73.2 percent of all vehicles running on the roads (NBSC, 2010; People's Daily, July 19, 2011). Not surprisingly, China sees severe traffic congestion in its major cities. Beijing, China's capital (*shou-du(1)* in Chinese), receives a nickname, *shou-du(3)*, meaning the worst congested city in China.

Like other countries, China mostly depends on supply-side policies to mitigate urban congestion, such as through expanding network capacity and improving traffic management. Unfortunately, supply-side policies are often not effective to reduce urban traffic congestion because urban commuting is subject to the theory of "triple convergences." As Downs (2004) observed, in response to a capacity addition, three immediate effects occur. First, drivers using alternative routes begin to use the expanded roads. Second, drivers traveling during off-peak hours shift to travel in the peak hours. Third, public transport users shift to driving their private vehicles. Transportation researchers have also identified several traffic paradoxes in which the usual remedy for congestion—expanding the road system—is ineffective or even counterproductive (Murchland, 1970; Arnott and Small, 1994; Braess et al., 2005; Ding and Song, 2011). Because of the triple convergences, traffic paradoxes, and a potential huge induced demand, it is impossible to remove peak-hour congestion from highways and roads by expanding road capacity.

In recent years, some Chinese cities attempted to use regulatory instruments to deal with the worsening urban congestion problem. For example, cities like Beijing and Shanghai implement quotas to limit the number of vehicles registrations each year. Beijing uses a lottery system, while Shanghai uses auctions. Beijing further requires all private cars to stay off roads one day a week, with the off-road day rotating every three months according their plate numbers. It also staggers working schedule for all city agencies, with government services starting at 9:00 A.M. A number of Chinese cities also implemented some demand-side policies to discourage people from driving private vehicles. For instance, Beijing raised parking fees significantly in the central areas on April 1, 2011. Hangzhou and Suzhou provide local residents with free bike services.

So far, no Chinese city has experimented congestion pricing. Urban commuting, as a derived demand, generates negative externalities as a vehicle slows down all cars behind and adds to air pollution. Because of these negative externalities, in the market equilibrium, drivers tend to drive more, causing a market failure and more congestion. In order to correct this market failure, a toll or road price needs to be levied on vehicles, so that traffic externality can be internalized and a social optimization could be reached. Congestion pricing directly affects commuting behavior because it not only depends when and where they commute but also how long they drive.

The rest of this paper is organized as follows. Section 2 proves that congestion pricing helps to internalize traffic externalities and reduce travel level. Section 3 presents some successful international experiences of congestion pricing. Section 4 argues why China should implement congestion pricing. This paper attempts to promote demand-side policies in China, particularly congestion pricing. Section 5 concludes.

2. Congestion Pricing: The Theory

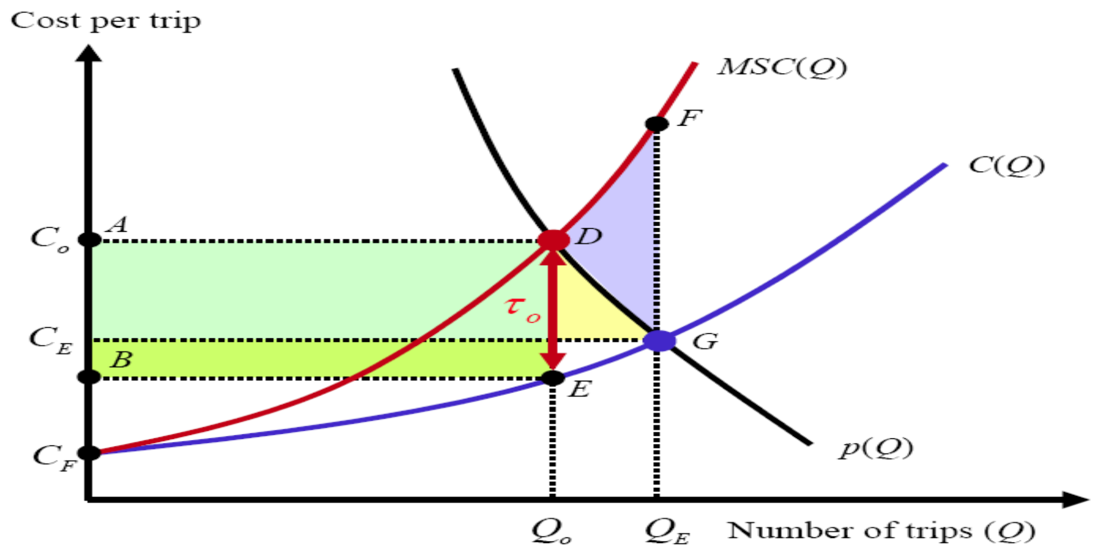
Commuting is a derived demand. People drive and only pay attention to how much it costs them to commute. They ignore externality they may cause on other travelers and the society such as time delay and air pollution. Therefore, the equilibrium number of commuters on the road is not social optimal. This can be shown theoretically below.

For each route or modal, let Q be the traffic volume and C be the average commuting cost. Here, commuting cost is generally defined, including monetary costs, time, safety, and pollution. The total commuting cost is CQ and the marginal social cost can be derived by,

$$MSC = \frac{d(CQ)}{dQ} = C + Q\frac{dC}{dQ} = C + EC$$

where *EC* is the externality cost ($Q\frac{dC}{dQ}$). If the average commuting cost increases with the number of commuters, like the case on congested urban roads, *EC* is positive and marginal social cost (*MSC*) will be higher than the private average cost (*C*). Consequently, the equilibrium travel volume (Q_E) will be larger than the social optimal traffic volume (Q_O), suggesting that too many commuters are on the roads. Q_E is determined based on the private average cost while Q_O is calculated based on the social marginal cost, as shown in Figure 1. If the average commuting cost decreases with the number of commuters, like the case of public transit because of scale economies, *EC* is negative and *MSC* will be lower than *C*. Consequently, Q_E will be less than Q_O, indicating too few passengers are using public transit. If commuters do not affect each other, the average commuting cost becomes constant and no congestion and externality exist.

Figure 1: Economics of Congestion Pricing



To reach social optimization, externality should be internalized. In the case of congested urban roads, this suggests a toll, $\tau = Q\dfrac{dC}{dQ}$, be charged on commuters. Because $Q\dfrac{dC}{dQ}$ depends on traffic volume, the toll should be higher for more congested roads or periods than the one for less congested roads or periods. The optimal toll revenue equals to $Q^2\dfrac{dC}{dQ}$ and it is determined at Q_O.

Several comments are worth noting. First, the purpose of congestion pricing is not to collect toll revenue per se. It is to correct the market failure caused by negative externality and thus reduce traffic level, from Q_E to Q_O. Second, congestion pricing generates efficiency gain, because it helps to save time, reduce pollution, and improve safety. Avoided inefficiency is the gained efficiency. Graphically, the efficiency gain is indicated by the area of *DFG* in Figure 1, where the marginal cost is higher than the marginal benefit. Third, congestion pricing does not eliminate congestion. It is to reduce traffic. As long as the marginal social cost does not exceed the marginal social benefit, certain level of traffic is desirable. Fourth, the toll internalizes traffic externality. Hence, it varies with the level of congestion, higher during the peak hours and lower or none during other periods of the day. Image a lower demand curve, such as the one for morning hours in weekends. The gap between the marginal social cost curve and the private average cost curve becomes narrower, suggesting a smaller traffic externality and thus a smaller toll. Fifth, some commuters may be hurt with lower consumer surplus. From the individual perspective, commuters suffer from two consumer surplus loses. One is the toll payment, *ABED*, that goes to the government. The other is the foregone consumer surplus indicated by the area of *DEG* in Figure 1. Therefore, congestion pricing had been regarded as an “economists’ dream but politicians’ nightmare”.

A number of previous studies have discussed the theory and issues related to congestion pricing. Evans (1992) examined when congestion pricing could be a good policy. Giuliano (1992) assessed the political acceptability of congestion pricing. Small (1992, 1993) investigated toll revenue and spending. Often, the public perceives toll as tax and commuters disliked the toll because they find it coercive, in that they have few if any practical alternatives to paying the toll. Small (1992) argued that distribution of toll revenue become important to gain public support.

3. Congestion Pricing: The International Experience

In recent years, congestion pricing is becoming more popular in practice and receiving stronger public support. It also has been implemented in many cities in different countries. This section presents some international experiences of congestion pricing.

3.1 Congestion Pricing in Singapore

The best-known example of congestion pricing is the Area Licensing Scheme (ALS) in Singapore where vehicles that wish to enter the central business district during peak hours must purchase a license (Watson and Holland, 1978; Keong, 2002; Phang and Toh, 2004; Decorla-Souza, 2006; Bhatt et al., 2008). In spring 1998, the city shifted the ALS to a fully electronic road pricing (ERP) system, with in-vehicle devices allowing payment by smart card and enforcement using cameras and license plate reading equipment. All vehicles (excluding emergency services) are levied on a per use basis and rates vary according to vehicle type, time, and location. Vehicle-type charges are based on a passenger car unit (PCU) measurement calculated from the amount of road space occupied. For example, motorcycles have a PCU of 0.5 while a large truck may pay twice as much given its PCU of 2.0.

Initially, the ERP gantry locations mirrored the RZ (restricted zone) entry points in the ALS, though the new system charged between S$0.5 and S$2.5, less for small PCU vehicles. By 2003, the ERP system had 45 gantries covering the RZ, each operating Monday through Friday from 7:30 A.M. to 7:30 P.M. plus gantries on four expressways and four major arterials operating between 7:30 A.M. and 9:30 P.M. Monday through Friday. In more recent years, the charge period in the central RZ is from 7:00 A.M. to 7:00 P.M., Monday through Friday, and charge rates vary from zero to approximately US$2.00 per crossing at a charge point (Bhatt et al., 2008).

The major difference between the ERP and the ALS systems is that the ERP charge is applicable for each passing while the ALS charge allowed multiple entries for that day. Hence, the ERP had influenced particularly the behavior of those who made multiple trips to the CBD. Further, with the ERP system, traffic was better spread out during the day, with the expressways and arterial roads carrying close to their designed capacity (Goh, 2002; Phang and Toh, 2004). In February 2003, the ERP charges were further fine-tuned to discourage motorists from waiting on road shoulders for price adjustments or from speeding to avoid toll charges. As argued by Goh (2002), the ERP system demonstrates several advantages. First, it rations vehicle flow efficiently because it charges directly and can be easily be adjusted to charge more during peak hours. Second, the charges per entry are more efficiently allocated than the daily permits with multiple entry privileges. Therefore, motorists are made more aware of the true cost of driving as charges are levied on a per-pass basis and can vary according to the congestion levels. The road user can better recover the full cost of the transport infrastructure.

Starting from April 1999, Singapore implemented the quarterly rate review system which adjusts congestion prices based on the target speed ranges between 45 and 65 km/h for expressways and between 20 and 30 km/h on arterial roadways. These ranges were set based on road capacities and the level of service E ratings, i.e., the speed-flow curves. Hence, it is a "pay as you drive system." Rates will fluctuate throughout the day depending on the time of travel and the specifications that are programmed into, with charges being the highest during the morning peak periods. Based on this principle, if a road has less than optimal traffic, the charge is decreased to encourage higher traffic volumes. On the other hand, if a road experiences over optimal traffic congestion, the charge is raised in hopes of deterring people from using that route.

The ERP system has produced a number of positive outcomes (Goh, 2002; Keong, 2002; Santos, 2005; Bhatt et al., 2008; http://www.edf.org). First, the system has been accepted by the public. Positive result of the ERP system's convenience and flexibility not only allows for responsive traffic volumes and road utilization but it also reduces road taxes and vehicle registration fees and allows for increases in Singapore's motor vehicle quota scheme. Second, traffic in the RZ decreased about 10–15 percent during the operating hours, traffic speeds increased by 10 m/h, public transportation increased by 20 percent, traffic accidents reduced by 25 percent, and much less CO2 was emitted. Third, financially, the ERP system also proves successful. According to Santos (2005), as of 2004, the annual operating cost of the system was about S$16 million, while the average gross revenues from 2001–2003 were S$80 million per year. Thus, the net toll revenue is about S$64 million per year, suggesting that the ERP is financially sustainable.

3.2 Congestion Pricing in London

Congestion pricing has also been implemented in Europe. The Greater London Authority was granted the power to charge for road use in 1999. After three years of planning, assembling, and sufficient financial leverage, on February 17, 2003, London implemented road pricing to combat congestion in central London. As argued by Litman (2006), central London is a strong candidate for congestion pricing, given its limited road space, densely populated CBD, and heavy road congestion.

The scheme involves a standard per-day charge for vehicles traveling within a zone bounded by an inner ring road. The system covers an eight square mile area (1.3 percent of Greater London); it was almost doubled in size in early 2007 when it was extended westward to include Kensington and Chelsea. Between 7:00 A.M. and 6:30 P.M. (modified in 2007 to 7:00 A.M.–6:00 P.M.), excluding public holidays, motorists are required to pay a daily fee of £5 during the week. Exemptions from this payment include cab drivers, roadside help, disabled people, and two wheelers. Area residents are subsidized with a 90 percent discount. Payment can be made in several different manners through internet payment sites, text messaging payment, retail outlets, and local payment machines. Periods of payments can be weekly (£25), monthly (£110), or annually (£1,250). In July 2005, the daily charge was increased from £5 to £8. This was done to achieve additional reductions in congestion as well as to fund further public transit improvements. There are several methods of payment. During the first year of implementation, 36 percent sales are paid via retail, 19 percent via the call center, 26 percent via the internet, 19 percent via the short message service on mobile phones, and less than one percent by post (Santos, 2005).

The pricing system is run by the Transport for London (TfL), the unified agency responsible for carrying out the Mayor's transit strategy. The system works through an intricate network of cameras placed at the 174 entry points to the central business district, as well as approximately 50 cameras throughout the zone. The video cameras record the license plate numbers of vehicles and match them with paid motorists through an intricate optimal character recognition (OCR) system. Due to privacy concerns, license plate images are erased from the system every evening. Vehicles that do not match any records of payment are fined in the sum of £80. This fine is reduced to £40 if it is paid within two weeks but increased to £120 if it is not paid after one month. Ken Livingstone, then the Mayor of London, made the remark that, "If a driver declined to pay fines, that the city would relentlessly track his car down, clamp it, tow it away and crush it—with or without the driver inside" (*New York Times*, 20 April 2003, by Randy Kennedy).

Congestion pricing program brought significant improvements in traffic congestion to the Central London, although various studies present different findings. According to Litman (2006), within the first few months of implementation, traffic was reduced by 20 percent or around 20,000 vehicles per day. In the first year, Nash (2007) found the number of vehicles entering the zone dropped by 14 percent. Leape (2007) showed that in the first year of the charge, traffic delays in London dropped by 30 percent, journey time reliability increased by 30 percent, and average speeds rose by 17 percent. The pricing system also changed who was using the roads: private car trips dropped by 34 percent, but bus, taxi, and bike trips all rose sharply. Inbound bus passenger numbers increased by 37 percent in the first year, about half of whom had previously traveled by car. Leape argued that the surge in bus passenger numbers is a key reason to enter the "virtuous circle" for bus transport. The higher cost of rush-hour car trips and increased bus travel speeds resulted in increasing passenger numbers and falling average costs. In turn, it led to improved service levels and lower fares that stimulate further shifts to public transport and additional reductions in congestion. Based on the findings of Bhatt et al. (2008), after the first year of operation, traffic circulating within the charging zone was reduced by 15 percent during charging hours. The number of vehicles entering the charging zone was reduced by 18 percent. Traffic delays were cut by 25 percent. Travel speeds increased by 30 percent in the zone. Bus use increased by 40 percent. Santos and Shaffer (2004) found that over the first year congestion decreased by 30 percent, traffic level within the charging zone fell by 16 percent, speed for car travel increased by more than 20 percent, and bus travel became more time reliable. Santos (2005) stated that an 18 percent drop in the traffic volume was recorded for the first two years of the program. Data from surveys from the project reveal that the average speed has increased by 37 percent, from an average speed of 8 miles per hour to 11 miles per hour.

There was a concern at the start of the program that traffic congestion would be diverted to different routes, causing inefficient and lower capacity roads to be filled with more drivers. However, the traffic spillover proved to be minimal. A key lesson from the London experience is that traffic has not overflowed onto neighboring roads. After a short adjustment period, free rings have traffic levels comparable to 2002 levels (http://www.edf.org/page.cfm?tagID=6241).

According to Santos (2005), the capital costs of the congestion pricing were approximately £200 million at 2002 prices, most were provided by the central government. The total annual cost £130 million included £5 million for administration, £90 million for operation, £20 million for additional bus costs, and £15 million for charge-payer compliance costs. In the first year, the program generated net revenue of £68 million, less than an original estimate of £120 million, probably due to too many exemptions, high discount, and higher levels of evasion. Revenues collected from congestion pricing, with £97 million in net revenues in the 2004/05 budget year, for instance, have been used to improve public transit and roadway system, such as adding subway stations, buses, and bus lanes. As results, bus congestion delays declined 50 percent, bus ridership increased 14 percent, and subway ridership increased one percent (http://www.tfl.gov.uk/tfl/cclondon/pdfs/thirdannualreportfinal.pdf). The Transport for London (2006) estimated that the congestion pricing program raises a surplus of £122 million per year.

Bhatt et al. (2008) summarized the TfL's reports that showed congestion pricing also improved air quality within and alongside the Inner Ring Road boundary of the zone. Levels of NOX fell by 13.4 percent between 2002 and 2003, CO2 by 15 percent and particulates (PM10) by 7 percent. Between 2002 and 2003, Beevers and Carslaw (2005) found that the total NOX emissions in the charging zone reduced by 12.0 percent, PM10 emissions reduced by 11.9 percent, and CO2 emissions reduced by 19.5 percent.

A final measure of London's success is the satisfaction of those involved. Seventy-eight percent of people who pay to enter the cordon area are satisfied with the system, and reinstatement of the system is scheduled for August 2007. Initial public skepticism has turned into support, with the level of acceptability of road pricing increasing from about 40 to above 50 percent before and after the introduction, respectively. In June 2004 London's Mayor Ken Livingston enjoyed popular re-election after adopting the charge (CURACAO, 2007; http://www.edf.org/page.cfm?tagID=6241).

3.3 Congestion Pricing in Stockholm

The election in 2002 resulted in social-democratic governments backed by the Left and Green parties, both at the national level and in the City of Stockholm. The newly-elected announced to introduce a full-scale congestion pricing program. The law authorizing congestion taxes was enacted in 2004, with the stated goals of reducing congestion, enhancing public transportation to increase accessibility, and improving the environment (CURACAO, 2007; Bhatt et al., 2008).

Stockholm initiated a trial period of cordon pricing for its central city between January 3 and July 31, 2006 (Decorla-Souza, 2006; http://www.edf.org/page.cfm?tagID=6241; Eliasson, 2008). The central city area of approximately 20 square miles was designated as the priced zone. The project was preceded by transportation improvements including 197 new buses, 16 new bus lines and more trains at peak hours. The charges were effective weekdays from 6:30 A.M. to 6:30 P.M. and the price was set at 10, 15 and 20 SEK (about US$1.33, 2.00 and 2.67 at 2006 rates) for off-peak, shoulder (7:00–7:30 A.M., 8:30–9:00 A.M., 3:30–4:00 P.M., 5:30–6:00 P.M.) and peak period (7:30–8:30 A.M., 4:00–5:30 P.M.), respectively (Eliasson, 2008). The charges were collected when entering or exiting the zone at 18 barrier free "control points" encircling the city center. The daily maximum charge, for multiple crossings was set at 60 SEK (about US$8.00) (Bhatt et al., 2008; http://www.transalt.org/campaigns/congestion/international). About 30 percent of vehicles entering the priced zone were exempted from charges, including taxis, hybrid cars, buses, foreign cars, handicap tagged cars, diplomats and police and emergency vehicles. Vehicles traveling through the priced zone without stopping were also exempted.

Three overhead gantries at each charge point electronically identified the passing vehicle if equipped with On-Board Transponder Unit (OBU) and allowed automatic charge deductions from pre-set accounts. License plate photos (front and rear) were captured for all vehicles with and without OBU. Vehicles without pre-set accounts or those without transponders had until noon time the next day to post payments that could be made on the web, at retail outlets, banks and kiosks. Fines for non-payment were set at 70 SEK (US$10) for the first reminder and went up to 500 SEK (US$70) for the second reminder (Bhatt et al., 2008).

According to Bhatt et al. (2008), overall traffic to and from the inner city declined by 10 to 15 percent and vehicle miles traveled in the charged zone decreased by 14 percent. Public transportation use increased by 6 to 9 percent. A significant portion of car users who gave up trips during the charge period shifted to transit. Few changed time of departure. No significant increase was observed in cycling, carpooling or telecommuting. Recent data show that the permanent charging program, reintroduced in 2007, appears to have reduced traffic by 18 percent. The proportion of exempted "green" cars has risen to 9 percent. Eliasson (2008) found that traffic across the charging zone decreased by around 30 percent during the first week, before settling down at a surprising stable decrease of around 22 percent less traffic than corresponding periods of 2005. When charges were abolished August 1, 2006, there was a remaining traffic decrease of around 5–10 percent compared to the 2005 level. When charges were reintroduced in August 2007, traffic once again decreased around 20 percent compared to 2005 levels. The number of vehicle kilometers driven in the inner city decreased by around 16 percent. According to http://www.edf.org/page.cfm?tagID=6241, Stockholm's successes show a 15 percent reduction in traffic, a 10–14 percent drop in CO2 emissions, and preventing 30 premature deaths by reducing NOX.

The total start-up cost of the system was 1900 million SEK, including information campaigns and extensive system tests. Together with additional cost of public funds and correction for indirect taxes, this gives a total social start-up cost of 2900 million SEK (about $400 million). The yearly operational cost of the system (220 million SEK) includes not only running costs but also necessary reinvestments and maintenance such as replacement of cameras and other hardware. In terms of economic welfare, Eliasson (2006) estimated that the trial program would have produced net annual benefit of nearly 700 million SEK ($90 million) against the investments and annual operating costs listed above. These data would suggest a payback period of about 4 years. Eliasson (2008) showed that the Stockholm system yields a large social surplus, well enough to cover both investment and operational costs. A permanent congestion-tax system is calculated to yield an annual social surplus of about SEK 650 million (after deducting operating costs).

As in London, positive results led to an increase in support. CURCAO (2007) provides a summary of the public attitudes toward Stockholm congestion pricing scheme before and after the six-month trial in 2006: "In autumn 2005, about 55 percent of all county citizens believed that it was a 'rather/very bad decision' to conduct the congestion-tax trial. Since the congestion tax was introduced in January 2006, this percentage has continuously fallen. In April and May 2006, 53 percent of all citizens believed that it was a 'rather/very good decision' while 41 percent believed that it was a 'rather/very bad decision.' Significantly, even those traveling by car to/from the inner city during the charge period in the most recent two 24-hour periods have become more positive by several percentage units. In May 2006 car driver were approximately equally for and against the road pricing trial." Two months after the trial, on September 17, 2006, 51.7 percent of voters passed a referendum to reinstate the charge, effect in July 2007. The congestion pricing system enjoys broad support from liberal and conservative political groups (Eliasson, 2008; http://www.transalt.org/campaigns/congestion/international). Eliasson (2008) argued that Stockholm charging scheme is successful because of its working technical system, effective information campaign, visible congestion reduction, extensive and scientific evaluation, and clear objectives.

3.4 Congestion Pricing in the USA

Scholars in the United States have done a tremendous amount of theoretical research on congestion pricing (e.g., Decorla-Souza and Kane, 1992; Giuliano, 1992; Small, 1992; Poole, 1992; Arnott and Small, 1994; Lee and Gordon, 2006; Small et al., 2006). In practice, a number of congestion pricing projects have been implemented in the USA (Harrington et al., 1998; VDOT, http://www.virginiadot.org/info/resources/congestion_pricing/cp_in_us.pdf). For example, high occupancy toll (HOT) lanes are currently under development on the I-495 corridor in Northern Virginia. A toll is required for solo drivers and low-occupancy vehicles that want to use high-occupancy vehicle lanes, while carpoolers, vanpoolers, motorcycles, buses and emergency vehicles could use the lanes free of charge. A 2-lane-8-mile reversible facility was constructed in the median of I-15 in San Diego, California in 1996. Solo drivers could use these HOV-3 lanes if they purchased monthly "ExpressPass" permits for $70. In 1998, a fully automated dynamic pricing pilot project was implemented to deduct per-trip fees from pre-established accounts as opposed to charging a monthly flat fee. To accommodate the changing price, the ExpressPass was replaced by electronic transponders (FasTrak) that could be affixed to drivers' car windshields. Today a posted schedule informs drivers of the highest toll they should expect to pay during the hour of operation. Tolls typically vary from $0.50 to $4 depending on congestion. In Lee County, Florida, variable pricing was established in 1998 on the Cape Coral and Midpoint Bridges. To encourage drivers to adjust their travel times, these bridges offer half-price tolls in the time period just before and just after peak travel periods. Typical tolls cost between $0.50 and $1. Only drivers who have a pre-paid account with LeeWay—Florida's Electronic Tolling system—are eligible for the discount. The I-394 MnPASS Express Lanes (HOT Lanes) opened in Minneapolis, Minnesota in 2004. Drivers could use these lanes if they obtained an MnPASS electronic transponder. Preliminary evaluations have proven that congestion pricing is an effective traffic management tool that ensures free-flowing speeds for transit and carpoolers, helps vehicles better utilize HOV-lane capacity, and even provides congestion relief for non-MnPASS lane users. In Houston, Texas, a congestion pricing project named QuickRide was established in 1998 on an existing 13-mile HOV lane stretch of the I-10. It allows a limited number of carpools with only two riders (HOV-2) to buy into the reversible HOV-3 lane during peak travel periods. During this time, participating HOV-2 vehicles pay a $2 per trip toll, while HOV-3 vehicles continue to travel free of charge. Solo drivers are not allowed to use the HOV lanes. To avoid causing congestion for HOV-3 riders, the number of HOV-2 vehicles permitted to travel on these lanes is limited. Like the I-15 project in San Diego, QuickRide is also automated using windshield-mounted transponders and overhead readers.

A better known US example is the State Route (SR) 91 Freeway in Southern California, the world's first high-occupancy or toll (HOT) or express toll lanes, which was opened in December 1995. A private consortium, operating under a 35-year concession, added four lanes to SR 91, one of Southern California's most congested freeways. Carpools with three or more passengers could use the new lanes at half price; all other cars (no trucks were allowed) would pay a toll set high enough to ensure high-volume but uncongested traffic flow at all hours.

Initially, the combination of added capacity on SR 91 and the fact that many vehicles switched to the new lanes brought significant reductions in peak-period congestion on the regular or general-purpose lanes (in addition to free-flow conditions in the express lanes). But after about five years, enormous growth in traffic in this commuter corridor led to the return of serious congestion in the general-purpose lanes. The concession agreement included a rigid non-competition clause, preventing the addition of any more general-purpose capacity. This situation proved politically untenable, leading to the purchase of the express lanes by the Orange County Transportation Authority (OCTA) seven years after they had opened to traffic.

Recognizing that correct pricing was the only way the lanes could deliver the promised benefit of a reliable, uncongested trip, the OCTA created an algorithm that uses measured traffic density in the express lanes, hour-by-hour, seven days a week. For any one-hour time block during peak travel times, where set traffic conditions are at risk of becoming more congested, as measured over a 12-week period, the toll rate for that time block is increased accordingly. For example, effective on January 1, 2010, the hourly rate on Thursday, eastbound, varied from $1.30 during off peak hours to $9.90 in 4:00–5:00 P.M. and $9.05 in 5:00–6:00 P.M.. The adjustment process also checks for under-use and permits automatic downward adjustments. For instance, effective on July 1, 2011, the hourly rate on Thursday, eastbound, varied from $1.30 during off peak hours to $9.45 in 4:00–5:00 P.M. and $9.30 in 5:00–6:00 P.M.

Empirical evidence shows that congestion pricing has worked very well on SR 91. Not only did it reduce toll-payers commuting time by 20–30 minutes and make trips more time reliable, but it also significantly improved road efficiency. As traffic engineers know, under severe congestion, freeway vehicle throughout can be drastically reduced. Pricing ensures that freeway operational efficiency is not lost due to excess demand. According to Paniati (2006), in the peak hours, the average speed on the free lanes is about 15 mph, while it is about 65 mph. Each of the HOT lanes on SR 91 carries twice the number of vehicles that the adjacent toll-free lanes to. Since each vehicle on the HOT lanes carries more people on average, the difference is even greater with regard to the number of persons.

It is worth mentioning that several proposals of congestion pricing failed in gaining public support. In a February 2005 referendum in Edinburgh, UK, voters rejected a congestion tax proposal. Likewise, in a December 2008 referendum in Manchester, UK, voters overwhelmingly rejected a congestion charging plan that officials had spent millions promoting, despite the promise of £2.8 billion in mass transit spending from the central government upon approval.

Officials had hoped to have the congestion tax infrastructure in place by 2013 so that they could charge commuters a rate of £5 to drive into the city center during work hours (http://www.thenewspaper.com/news/26/2625.asp). A third unsuccessful effort is the City of New York's proposal (http://en.wikipedia.org/wiki/New_York_congestion_pricing). New York congestion pricing was first proposed on April 22, 2007 as one component of New York City Mayor Michael Bloomberg's plan to improve the city's future environmental sustainability. It was a proposed traffic congestion fee for vehicles traveling into or within the Manhattan CBD. On August 14, 2007, the U.S. Department of Transportation awarded from the Urban Partnership program $354 million to New York City, of which, $10.4 million is allocated for launching the congestion pricing program. The idea of congestion pricing was endorsed by the then Governor Spitzer and Senate Majority Leader Joseph Bruno. On January 31, 2008, the New York City Traffic Congestion Mitigation Commission approved a plan for congestion pricing, which was passed by a vote of 13 to 2. On March 31, 2008, the proposal was approved by the New York City Council, by a vote of 30 to 20. However, despite an extraordinary majority of New Yorkers supported congestion pricing, on April 7, 2008, after a closed-door meeting, the Democratic Conference of the State Assembly decided not to vote on the proposal. The State Assembly Speaker Sheldon Silver opposed the plan, claiming that commuters would choose to park in neighborhoods just outside the pricing zone and the installation of cameras for tracking purposes might have raised civil liberties concerns. Some other opponents called the proposal a "regressive tax" on the poor and middle class.

4. Congestion Pricing in China: Why?

Should China promote congestion pricing? Yes, absolutely, for a number of reasons. First, this paper has proved the existence of traffic externality. In equilibrium, urban roads carry more vehicles than what a social optimum supposes to have, suggesting that people drive too much. To internalize the externality and thus correct the market failure, a toll needs to be charged, which asks drivers to pay the full cost they cause on the society. As argued earlier, congestion pricing could produce efficiency gain, from time saving, pollution reduction, and safety improvement.

Second, the above international experiences suggest that congestion pricing could be quite successful in reducing traffic levels, saving travel time, improving air quality, generating net revenues, enhancing road efficiency, and even increasing public acceptability. Technology is no longer an issue for congestion pricing implementation. For proposals that failed to be implemented, it was due to the lack of public support. However, as the London and Stockholm experiences suggested, public perception about congestion pricing could be improved with implementation. People need time and facts to learn about and accept the concept of congestion pricing.

Third, congestion pricing helps to discourage vehicle use if not vehicle ownership. In the past two decades, China saw a huge growth in vehicle ownership. As mentioned in the introduction section, in 1990, China had 5.5 million private vehicles. This number became 62.8 million in 2009 and 72.06 million by the end of June 2011, increasing more than 1200 percent in 20 years. The growth of private vehicles in major cities is even faster. On average, Beijing registered 1900 private cars a day in 2010, expecting to reach 7 million in 2015. No question, China sees severe traffic congestion on its urban roads, which not only wastes tremendous amount of time of urban commuters but also causes many fatal traffic accidents. Yet, most urban residents still do not have cars. Hence, if the current trend continues, more and more people will purchase vehicles and switch from using public transit to private driving. It is important to making potential and existing travelers recognize and pay their full cost of driving, so they could make more rational choices in terms of purchasing and using vehicles. With congestion pricing, some people may continue to use public transit and postpone purchasing vehicles, some people may not drive even with a car ownership, and some may drive less. In short, it is important to send a correct price signal so that people can make more economical decisions.

Fourth, expanding road capacity in Chinese cities has been proven ineffective and unsustainable in dealing with congestion, largely due to the induced travel demand and the triple convergences in the commuting behavior. Regulation instruments have caused inconvenience and resource waste to commuters, as many have to leave their vehicles home and some purchase more vehicles than necessary. A quota system deprives people's desire to buy and own vehicles. Parking fee does not affect how long and where the travel occurs. Ridesharing makes sense only for long distance commuting. Job-housing balance and spatial structure may have marginal effects only in the long run. Staggering work schedules may cause inconvenience and inefficiency. Congestion pricing, on the other hand, directly relates to where, when, and how long the travel occurs. It thus could directly affect people's commuting behavior.

Fifth, some Chinese characteristics could make China less difficult to implement congestion pricing. For example, privacy has been a major obstacle for implementing congestion pricing in western nations. However, Chinese seem to be less sensitive to privacy, probably due to the culture or a better trust to the government. Another Chinese characteristic is that car travelers in China basically include only middle or higher income people. Most urban residents still commute via public transit, bicycles, and even walk. With congestion pricing, toll will be collected from those who are relatively richer and revenue will be used to increase transportation facility such as adding more buses and expanding subways, directly benefiting the majority of Chinese commuters. Hence, the regressive nature of congestion charges, a main fairness concern in the western countries, would be much smaller in China. Furthermore, for many years, China collects a fee from every vehicle traveling in freeways. Therefore, charging a fee for using transportation facility, such as congestion pricing, is not a new concept.

Last, China has a better political structure of implementing congestion pricing. Unlike the USA case where many political cities live together in a metropolitan area, transportation or economic cities are basically the same as political cities in China. Hence, there are many fewer institutional or political barriers to overcome in transportation planning and implementations. Also, the Chinese government enjoys more resources for public project investment, including land and financial resources. In addition, like Singapore, China sees many more government-oriented projects. Certainly, congestion pricing can be a new government-led project, which will involve government land allocation, financial investment, fee collection, and revenue distribution.

5. Conclusions

Between 1990 and 2011, the number of private vehicles in China increased more than 1200 percent. In consequence, China has seen worsening traffic congestion in all major cities. Like almost all other countries, China has relied on supply-side and regulatory instruments to mitigate urban congestion, including expanding road capacity and forcing private vehicles to stay off roads. However, such instruments could be often ineffective and unsustainable. For example, forcing commuters to stay off roads causes inconvenience and resource waste. A quota system deprives people's desire to buy and own vehicles. Some demand-side policies may also have limited impacts. For instance, raising parking fee does not affect how long and where the travel occurs. Ridesharing makes sense only for long distance commuting. Job-housing balance and spatial structure may have marginal effects only in the long run. Staggering work schedules may cause inconvenience and inefficiency. It is important to propose some mechanism that could directly affect people's commuting behavior by making motorists become more aware of the true cost of driving and recover the full cost of urban commuting.

This paper has shown the existence of traffic externality in urban commuting and such an externality attracts more people to travel on the roads, causing more traffic. Congestion pricing is to charge a toll that equals the difference between the marginal social cost and the average private cost. The paper has proved that congestion pricing helps to internalize traffic externalities, reduce travel level, and generate social efficiency gain. Relative to other demand-side policy, congestion pricing directly affects commuting behavior, because the toll varies with time, location, and distance.

Using cases from Singapore, London, Stockholm, and the USA, the paper has presented international experiences of congestion pricing. Generally speaking, with implementation, the international experiences are quite positive, as evidenced by traffic reduction, time savings, air quality improvement, net revenue generation, road efficiency gain, and better public acceptability. For proposals that failed to be implemented, it was due to the lack of public support. But as the London and Stockholm experiences suggested, public perception about congestion pricing could be improved with implementation. Hence, congestion pricing may no-longer be a Western politician's nightmare. A possible way to increase public support is to provide a whole picture of congestion pricing, including the concept, the rationale, the fee determination, the revenue collection and distribution, and the side benefits such as safety improvement and air quality improvement. Congestion pricing asks commuters to internalize their externality by paying the full cost. It is basically a concept of who-use-who-pay or a pay-as-you-drive system.

For a number of reasons, this paper has argued that China should implement congestion pricing. First, congestion pricing is theoretically proven to help internalize travel externality, correct the market failure, reduce traffic volume, and produce net efficiency gain. Second, the successful international experiences have demonstrated that congestion pricing works in practice. Third, congestion pricing makes motorists become more aware of the true cost of driving and recover the full cost of urban commuting. Therefore, it helps current owners to use their vehicles more economically and potential owners to purchase vehicles more rationally. China saw a dramatic growth in vehicle ownership in recent years. It is urgent for China to send a correct price signal to its residents in their vehicle purchases and uses. Fourth, due to triple convergences and potential induced demand, supply-side policies have been proven ineffective in mitigating congestion. Regulatory instruments have caused inconvenience and resource waste to commuters. Some demand-side policies, such as raising parking fee, may not be able to affect how long and where the travel occurs. Last but not the least, some Chinese institutional and political characteristics could better facilitate China to implement congestion pricing, including the reality that most urban residents still commute via public transit but only the middle-upper class drives private vehicles, the less-concerned privacy issue, the current practice of collecting fee for using freeways, the more resources enjoyed by the government, and the more experience of government-led infrastructure projects.

To mitigate traffic congestion in major cities, China needs to apply the "one-hundred-cut" principle, using as many solutions as possible. But this paper particularly promotes demand-side policies in China, especially congestion pricing.

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