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Fare evasion in *proof-of-payment* transit systems: Deriving the optimum inspection level

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ABSTRACT

In *proof-of-payment* systems, fare evasion represents a crucial topic for public transport companies (PTCs) due to lost fare revenues, damaged corporate image, and increased levels of violence on public transport, which might also have negative economic repercussions on PTCs. Therefore, there is a need to establish the level of inspection (i.e. the number of inspectors) to tackle fare dodgers as a possible option. By building on previous models, this paper develops a formal economic framework to derive the optimum inspection level in a long time window, based on system-wide profit maximization when fare evasion exists. The framework takes into account: (i) the refined segmentation of passengers and potential fare evaders, (ii) the variability of perceived inspection level by passengers, and (iii) the fact that an inspector cannot fine every passenger caught evading. Its implementation is illustrated by using three years of real data from an Italian PTC. Based on 27,514 stop-level inspections and 10,586 on-board personal interviews, the results show that the optimum inspection level is 3.8%. Put differently, it is sufficient to check 38 passengers out of every 1000 to maximize profit in the presence of fare evasion. This outcome is very useful, because it improves the one obtained in previous formulations. Indeed, profit maximization is achieved with a lower number of inspectors, thus reducing inspection costs, which are relevant determinants in proficient PTCs. Finally, the framework is flexible and may be applied to public transport modes other than buses as long as *proof-of-payment* systems are in use.

1. Introduction

Fare evasion occurs when a passenger does not have a ticket or has the wrong one. Fare evasion causes damage due to lost fare revenues and corporate image (e.g. Bonfanti and Wagenknecht, 2010) as well as social inequity, aggravating the subsidization needs of public transport companies (PTCs) and forcing paying passengers to increase their expenditures in order to counter the financial effects of fare evasion (e.g. Abrate et al., 2008). It also reduces security levels because the actions employed to tackle it (e.g. increasing the number of inspectors) can trigger violence from fare evaders (e.g. Bijleveld, 2007; Del Castillo and Lindner, 1994; Sherman, 1990; Smith and Clarke, 2000). Fare evasion potentially affects different public transport systems, even though not in the same way and to the same extent (Kooreman, 1993). For some of these – air, sea transport, and so forth – it is almost impossible to avoid fare payment: access to the service is prevented at the beginning by

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several checking procedures. Conversely, in *proof-of-payment* systems, passengers are legally forced to purchase a ticket and to validate it before using the service, but they are not physically constrained to do so. Indeed, payment regularization does not occur immediately and this may have different effects depending on the control system used. For example, in massive systems (e.g. subways), payment regularization occurs before boarding by forcing passengers to pass through turnstiles, sometimes guarded by authorized staff or video cameras. In this way, despite fare evasion being a chronic problem, its value is limited to 1.3% in a large city like New York (Reddy et al., 2011). Thus, it seems to be a minor problem compared to collective transport systems. Indeed, in these latter systems (e.g. buses, trolleybuses, trams, etc.), payment regularization occurs once on-board via a voluntarily self-validation of the ticket, which makes it easier to fare dodge compared with other systems. In collective transport systems, a UITP bus Committee study found that fare evasion is more widespread and the average fare evasion rate is estimated at 4.2% (Bonfanti and Wagenknecht, 2010). In collective transport systems, fare evasion problems first emerged during the 1960s in Europe and soon after in the U.S. (Diebel, 1981). The progressive abandonment of conductors and their substitution with "honour" ticketing schemes, where a passenger is supposed to voluntarily self-cancel his or her ticket while respecting ticket-use limitations, is widely acknowledged to have aggravated the problem. The change in ticketing systems has resulted in significant operating savings for PTCs, besides further benefits in terms of technology adoption and vehicle design. These savings consist of travel time reductions compared to the on-board fare payment, which slows down the boarding of passengers, especially if they are required to pay cash; moreover, cash payments generate higher delays to transit operation compared to any other fare collection systems such as magnetic strips, contactless smart cards and off-board payments (Fernández et al., 2009; Tirachini, 2013; Tirachini and Hensher, 2011). On the other hand, the elimination of a continuous and systematic monitoring system has increased the likelihood of passengers evading fares, especially on short trips. Nevertheless, if the inspection is badly addressed, there is a chance that who usually pays the fare will imitate the evasion propensity, resulting in the phenomenon spinning out of control (Clarke et al., 2010). Generally speaking, fare evasion propensity can be conditioned both by passengers' internal attributes of the social-economic, psychological, and ethical facets (e.g. Bucciol et al., 2012) and by external attributes such as the number of inspectors, fares, and fine values (e.g. Bootheway, 2009; Boyd et al., 1989; Kooreman, 1993). Bijleveld (2007) reports that, in the Netherlands, fare evaders can be divided – largely – into three groups, each not purchasing a ticket for a different reason. The first group consists of accidental fare evaders, the second of calculator dodgers, and the third of chronic ones. Accidental fare evaders are those who involuntarily forget to buy a ticket. Calculator dodgers evaluate whether it is more expensive to buy a ticket every time or to pay a fine once. Chronic fare evaders habitually fare evade, irrespective of the level of network inspection and the amount of the fine. These users are hardly caught by inspectors and, in any case, it is not possible to recover revenues from them. In contrast to accidental and calculator evaders, chronic ones usually generate disturbances and violence on public transport.

To reduce the economic losses from fare evasion, PTCs usually support the *proof-of-payment* system with spot-checks on passengers, using teams of inspectors. The objective of spot-checks is to verify the tickets of all passengers, and if a passenger is caught without a valid ticket, he or she should be fined. To our knowledge, spots-checks are performed by a daily number of inspectors, organized in teams. Inspections occur alternatively on boarding, alighting, and on-board (Abrate et al., 2008; Horizon Research Corporation, 2002; Israel and Strathman, 2002). The inspection can be planned or not; it is frequent, but it is not continuous. Recently, the problem of scheduling inspection teams in terms of timing and places was formulated by employing optimization models in order to analyze the inspection in more formal ways (e.g. Matyášek, 2013; Thorlacius and Jens, 2009; Yin et al., 2012a, 2012b). However, before performing checks, a compulsory step is establishing the level of inspection on the network (i.e. the number of inspectors (X)). Indeed, in an exhaustive study of several large European cities, Hauber (1993) found that the frequent inspection of tickets was the most effective method for cutting fare evasion. Despite the availability of other options against fare evasion (e.g. increasing the fine), these seem to be less effective than the inspection level. Firstly, the literature on deterrence (e.g. Beyleveld, 1980; Clarke et al., 2010; Von Hirsch et al., 1999) has stressed that potential offenders pay greater attention to the certainty of being caught than to the severity of the punishment if caught (e.g. a high value of the fine). Secondly, Killias et al. (2009), in a field experiment on Zurich's suburban transport system, found that the fare evasion rate did not change despite increasing fines, while the increase of inspection levels led to a reduction in fare dodging. Third, Sasaki (2014) points out that in low income countries a free rider's income may be too low to pay for a high fine. Fourth, other options requiring investments in technology, such as the use of video monitoring systems, could lead to privacy issues when used for the detection of evaders, thus encountering possible obstacles during their application. However, this technological facility does not eliminate fare evasion and could be fairly expensive to install and maintain (Reddy et al., 2011). Thus a support inspection activity appears beneficial. Therefore, to summarize, the inspection can represent the most profound bridge between the PTC, which seeks a profitable service, and the evader, who seeks not to pay the fare. Two types of inspections can be considered, related to objective and subjective probabilities.

Established by the PTC, the objective probability of inspection – denoted by p – can be defined as the probability that a passenger has to be checked. It can be represented by a function of X and could be interpreted as the ratio between passengers who have had their tickets checked and all carried passengers in the same time window.

Perceived by the passenger, the subjective probability of inspection – denoted by p_i – can be defined as the probability that a passenger feels he or she will be checked. It can be represented by a function of X and could be interpreted as the ratio between the subjective frequency of the inspection and the subjective frequency of the trip in the same time window. Interestingly, if the distribution of p_i is represented by frequency diagrams and onto this distribution the probability density function is built, the area subtended by this function - up to a definite value, as shown in Section 2.2 - represents the