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Paratransit Services for Efficiency: Examining the Potential for Taxis to be Included in Subsidized Market*

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Abstract

This study examines the inefficiency of subsidized paratransit transportation services for the elderly. In the open-entry market, there is a possibility of an oversupply of vehicles and a deadweight loss. Our empirical results reveal that expanding paratransit vehicles reduced taxi usage with fewer public subsidies by 2.7%. To improve the efficiency of the paratransit transportation market, we propose using unoccupied taxis and regionally integrating paratransit services with smart dispatching algorithms. If taxis could provide the complementary services as dedicated paratransit vehicles, it is estimated that the taxi driver's annual income would increase by 4.2%.

Keywords: paratransit, taxis, transportation policy, elderly care policy
JEL classification: D61, H53, J18

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I. Introduction

With the increase in the number of people aged 65 years and older, the demand for paratransit services[1] has risen in many developed countries, and its operating costs have continually increased (Nelson et al., 2010; Kaufman et al., 2016; Hansson and Holmgren, 2018). Paratransit systems rely on operating subsidies because low fares, which encourage ridership, rarely cover operating costs (Karlafitis and Sinha, 1997; Mulley et al., 2012; Deakin et al., 2020). Considering the high cost of on-demand trips, it is important to estimate their performance and pursue practical measures that can increase the efficiency of paratransit operations (Hansson and Holmgren, 2018; Rahimi et al., 2018).

However, there are some serious challenges to overcome in paratransit service evaluation. First, the complex systems and overlapping jurisdictions of paratransit services make it difficult to identify the total cost of its services, which is essential efficiency metrics. Furthermore, policymakers exclusively focus on efficiency improvements under their jurisdiction and are reluctant to evaluate the paratransit market as a whole. Public transport managers perceive their charter to provide conventional public transport services cost-effectively, so they have not strategically thought about how to use paratransit services to achieve the overall welfare gains (Mulley et al., 2012). Therefore, only a few studies, mostly institutional analyses or case studies, have examined the entire paratransit market in terms of welfare.

This study focuses on paratransit services using wheelchair-accessible vehicles (WAVs) in Japan. Since it is difficult to identify the supply–demand curve and calculate the deadweight loss, we infer inefficiencies in the WAV market by measuring the degree of competition between taxis and non-commercial WAVs

[1] Paratransit refers to services providing transportation for people with disabilities who could not otherwise take fixed-route public transit services like buses and rail (Deakin et al., 2020). In this paper, demand responsive transit (DRT), special transport service (STS), and flexible transport service (FTS) are all referred to as “paratransit service.”

with white license plates (called WhiteWAVs)[2]. Most WhiteWAVs are owned by elderly care facilities and registered to transport elderly people to and from their homes and places of care. Under the Japanese system, user charges for WhiteWAV transportation are lower than those for taxis because of local government subsidies and Long-Term Care Insurance (LTCI) reimbursement[3]. However, WhiteWAVs and taxis provide similar door-to-door transportation services[4]. Therefore, taxis can also provide WhiteWAV transit, which is expected to mitigate the public burden and inefficiency of the WAV market.

Our empirical results using prefecture panel data indicate that the number of taxi passengers is estimated to have declined by 2.7% from 2010 to 2015. Given that the actual number of passengers decreased by 7.2% in five years, approximately one-third of the decrease in the number of taxi passengers can be explained by the increase in the number of WhiteWAVs. The 2.7% decrease in taxi passengers from 2010 to 2015 due to the increase in WhiteWAVs corresponds to a 4.2% decrease in the annual income of taxi drivers. Furthermore, the extent to which taxi demand decreases with the increase in WhiteWAVs is significantly related to population aging in the region and welfare spending. The results of these analyses were robustly confirmed by IV estimation, which considered prefectural fixed effects and reverse causality.

Assuming that the quality of taxi service had not declined during the sample period, the decrease in taxi use is interpreted as a result of users choosing cheaper subsidized WhiteWAVs, rather than a poor taxi service. Behind the choice of WhiteWAVs for the mobility-disabled elderly is a welfare policy that

[2] WAVs are classified into two categories: commercial vehicles with green license plates and non-commercial vehicles with white license plates. All taxis are commercial ones.

[3] Everyone aged 65 or older is eligible for benefits based on physical and mental disability under LTCI (Campbell and Ikegami, 2000; Tamiya et al., 2011).

[4] Although taxis equipped with wheelchair-accessible functionality (TaxiWAVs) are increasing, WhiteWAVs are also available to people who do not need wheelchair functions. Therefore, taxis and WhiteWAVs in this paper refer to transportation modes for the elderly, including those who do not necessarily need wheelchair function. In the following, TaxiWAV is used only when it is institutionally necessary to distinguish between TaxiWAV and a taxi, and a taxi is used uniformly otherwise.

subsidizes individual facilities to purchase WhiteWAVs and also covers most of these usage fees with LTCI. The government's "generous" welfare policy of allowing open entry to highly subsidized services without considering supply–demand balance and costs has possibly increased the WAV market's inefficiency.

To improve the WAV market's efficiency, we suggest using vacant taxis for paratransit transportation. Taxis can supplement the capacity of dedicated WhiteWAVs by offloading a portion of WhiteWAVs' peak demand. The proportion of taxis and WhiteWAVs should be determined by the regional demand for paratransit services, cost of each mode of transportation, and amount of available subsidy. In Europe and the US, taxis are used for subsidized paratransit transportation, and they report lower costs than paratransit services using only dedicated WAVs (Mulley et al., 2012; Deakin et al., 2020). The latest technological advancements, such as optimization algorithms, would technically contribute to coordination between cost savings and WAV market efficiency.

This study's contribution to the literature is threefold. First, this study provides specific numerical examples of the extent of competition between WhiteWAVs and taxis. Some previous studies, such as those by Rahimi and Gonzales (2015), Amirgholy and Gonzales (2016), and Turmo et al. (2018), also examined the effect of complementary use of taxis to offset the high cost of dedicated WAVs. Although these studies are elaborate and suggestive using empirical data, they have only analyzed specific regions. Few studies have used nationwide regional panel data to numerically measure the inefficiency of non-complementary taxi use as in this study. Second, we demonstrate the heterogeneity of the negative correlation between WhiteWAV supply and taxi demand by the region's degree of population aging and welfare spending, assuming that depopulated rural areas have fewer human and budgetary resources and require more flexible transport systems. This approach overcomes the limitations of case studies, making regional comparisons possible. Third, with the fundamental model of welfare economics in mind, we discuss the effectiveness of the WAV market. This approach can explain why vehicle supply increases and deadweight loss occurs in a subsidized WAV market. The persuasiveness of policy proposals supported by both theory and empirical analysis is enhanced.

The paper is structured as follows: Section 2 describes the welfare analysis in the subsidized WAV market. It also discusses factors of inefficiency in the accrual paratransit services. Section 3 provides a brief overview of data sources and measurements. Section 4 presents empirical evidence that the rapid increase in WhiteWAVs has reduced the demand for taxis. Section 5 explores the extent to which declining taxi usage corresponds to taxi driver wages. Section 6 discusses policy implications for increasing efficiency of WAV transportation. Section 7 concludes the paper.

II. WAV market

Welfare in the WAV market

According to the Portland Bureau of Transportation (2015), wheelchair mobility services are usually undersupplied due to high costs and low demand. Hence, subsidy policies that incentivize producers to increase supply are often adopted. However, the theoretical model predicts that the supply of WAVs will exceed the efficient level in the subsidized markets. In this section, we discuss subsidized WAV surplus and inefficiency with a welfare model in mind.

A subsidy drives a wedge, decreasing the price that consumers pay and increasing the price that producers receive, at the expense of the government. When the government wants to increase the number of WAVs and subsidizes their purchase and use, the producers receive a higher price instead of a competitive price, which increases the quantity of WAVs supplied and the producer surplus. Consumers now pay a lower price instead of a competitive price, which increases the quantity demanded and the consumer surplus.

However, the difference between the market surplus before and after the subsidy policy results in a deadweight loss on the WAV market, as the equilibrium quantity of WAV becomes excessively high. In a basic welfare model, the subsidy-heavy market becomes more inefficient because the oversupply and deadweight loss are proportional to the subsidy amount. In contrast, market efficiency can be improved by reducing subsidies and deadweight loss.

Inefficiencies in the actual WAV market

Using Japan as a case study, we examine the efficiency of the actual WAV market. It was initially expected that paratransit in Japan, such as wheelchair-accessible buses and taxis, could satisfy the transportation needs of the rapidly increasing mobility-challenged people. However, the government questioned whether existing taxis and buses could sufficiently handle growing transportation needs. To address this concern, elderly care facilities were allowed to have own WhiteWAV transportation services.

Figure 1 depicts the rapid growth of TaxiWAVs and WhiteWAVs and the aging population. In 1990, 14% of the population was aged 65 years and above. By 2015, the proportion of the population had increased to 28%. The total number of WAVs increased by more than 20 times during the same period[5], while the number of taxis decreased by 10.0%. The breakdown of WAVs indicates significant growth in WhiteWAVs, depicting that non-taxi operators, such as senior care facilities, meet most door-to-door transportation demands. The number of TaxiWAVs has increased from 2,050 in FY2000 to 16,612 in FY2014; however, TaxiWAVs constitute less than 10% of all WAVs.

[5] The *Annual Report on Government Measures for Persons with Disabilities* by the Cabinet Office indicated that the number of disabled people aged 18–64 decreased from 1998 to 2016, while the number of people with disabilities aged 65 and above gradually increased. Namely, the increased demand for WAV is not due to young disabled people but elderly people.

[Figure 1]

The following two relevant facts indicate that WhiteWAVs, which have grown more rapidly than the aging of the local population, may not operate efficiently. Appendix Figure 1 indicates that WhiteWAVs have increased more than the aging of the local population from 1990 to 2015. Appendix Figure 2 presents the intensive operating hours of WhiteWAVs in the morning and evening, with the majority of the day being empty.

No coordination between the welfare policy and the transportation policy

There are three types of WhiteWAV service: (i) paid transportation for welfare by municipalities and NPOs; (ii) local mutual aid transportation by volunteer drivers; and (iii) transportation of people who need nursing care services through institutional care providers. WhiteWAVs are most frequently used for the third service: transporting people to and from care facilities.

Both (i) and (ii) are under the jurisdiction of the national Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) and the local transportation or welfare department; (iii) is under the jurisdiction of the national Ministry of Health, Labour and Welfare (MHLW) and the local welfare department. Thus, transportation for the elderly is a complex issue between MLIT, which handles transportation policy, and MHLW, which handles welfare policy, as well as local governments that administer these policies. Because both MLIT and MHLW "respect" each other's jurisdiction, they seldom negotiate and achieve efficiency together [6]. The reluctance to coordinate between MLIT and MHLW may inefficiently affect the paratransit market.

[6] Van Wolferen (1989) stated that the Japanese bureaucratic system has complex overlapping hierarchies but no peak.

Note that under the transportation policy, many Japanese municipalities have implemented community bus services. However, these services require a substantial subsidy for low-density areas and are not popular among the elderly (Aini et al., 2019). Local governments have cut or reduced the community bus services on loss-making routes but less drastic changes have not had the effects of efficiency improvements.

The situation in Europe, Australia, and the US was similar to that in Japan until the 2000s. Administrative issues generated higher costs and impeded efficient paratransit services. However, these countries are trying to clarify the division of roles between administrative organizations and balance the convenience of mobility with cost savings (Mulley et al., 2012).

Difficulty in cost estimation

The social cost of WAVs arises from the subsidies. Karlafitis and Sinha (1997) argues that such paratransit subsidies may have encouraged productivity declines, a lack of innovation and initiative, and financial mismanagement of transit properties. To evaluate the extent of deadweight loss and inefficiency caused by the subsidies, one must calculate the total cost of the WAV market. Better approximations require estimation of the response of purchases to prices (Deaton, 2016).

However, it is practically challenging to calculate the overall cost of WAV services in Japan since there is no comprehensive information on the usage and pricing of a wide variety of WAV services. For example, LTCI, which is part of the welfare policy, subsidizes commuting services. Among 11 LTCI services[7], the "commuting for care" services, for which WhiteWAV transportation is essential, constituted three-quarters of "commuting services" in 2018. This transportation of

[7] Five kinds of "home-visit service," four kinds of "commuting service," "life support service," and "preventive care management."

elderly persons to care facilities is recorded together with care services at the facility and is positioned as a fringe service. Accordingly, the cost of the transportation service itself cannot be identified.

Under the transportation policy of MLIT, because taxis have not been considered public transport, subsidies often do not apply to taxicabs used by the elderly. Since the 2010s, an increasing number of municipalities have started to consider taxis as part of local public transportation, thereby subsidizing the use of taxis by the elderly (Aini et al., 2019). Each municipality determines the targets and amounts of such subsidies, but no national-level data exist on coverage or the share of WAV services among subsidies.

Nevertheless, the WAV market is possibly oversupplied. First, a subsidized market is assumed to be theoretically oversupplied. Particularly, distortions occur in capital-subsidy programs; recipients tend to use a higher ratio of capital to other inputs than would be optimal from a cost-cutting standpoint (Small and Verhoef, 2007). Second, the number of WAV vehicles in Japan can increase with open entry, where each nursing care service provider or taxi operator owns and operates WAVs. The reason is that an open-entry regime tends to provide too many vehicles when they are least needed (Dempsey, 1996). Moreover, since Japanese policymakers prioritize keeping user fees low over increases in municipal costs (Takeuchi et al., 2019), there are no incentives or regulations to address the supply–demand balance or efficiency of the total WAV market.

Mitigating market inefficiencies by cooperation with taxis

The US, Canada, and many EU countries have incorporated taxis into the WAV market because both dedicated WAV operators and TaxiWAVs provide the same type of door-to-door transportation service (Dempsey, 1996; Deakin et al., 2020). Several county- and city-level cases have reported that replacing some

WhiteWAV services with taxis, which need lower subsidies, could reduce public spending (Gonzales et al., 2019; Deakin et al., 2020).

However, perceived or actual competition between paratransit and other flexible modes of public transport, such as taxis and community transport, can create significant barriers to introducing integrated services (Mulley et al., 2012). Therefore, to promote and set the new efficient paratransit market, it is important to give estimates based on actual operational data on the benefits of the alliance between existing WAV operators and other transport services. At the regional level, case studies have been conducted by the Portland Bureau of Transportation (2015), Gonzales et al. (2019), Deakin et al. (2020), Irani et al. (2021), and so on. However, few studies have comprehensively analyzed the overall effectiveness of incorporating taxis into the WAV transportation market at the national level. As discussed in the previous section, the difficulty of estimating the total cost of WAV transport precludes direct and comprehensive evaluation.

In the next section, we measure the degree of competition between taxis and WhiteWAVs in the paratransit service in Japan, where there is little coordination between them. WhiteWAV, which provides taxi-like services but operates with more than 70% of its utilization fees subsidized by LTCI, is found to discourage taxi use, which is less publicly subsidized. We then interpret the extent to which taxi demand is reduced by the increase in WhiteWAVs as the room for taxis to substitute for WhiteWAVs in the WAV market.

Having the existing taxis satisfy some of the WAV demand is expected to cut the subsidy expenditures and increase market efficiency by reducing deadweight loss. Even when the WAV service is provided by taxis, as long as users can use the same level of service at the same cost as before, consumer surplus will not change (will not decrease). From the viewpoint of producer surplus, part of the surplus of care facilities that used to provide this service is transferred to taxi operators. However, if care workers who used to engage in transportation tasks at care facilities, which constantly suffer from workforce shortages, can concentrate on care work by outsourcing WAV transportation to taxis[8], the producer surplus in the care market will not decrease.

Note that since ride-hailing services were not permitted in Japan[9] (Altura et al., 2021), ride-hailing services have never impacted taxi demand[10]. However, using a ride-hailing paratransit service such as UberWAVs instead of TaxiWAVs is considered almost indifferent. This is because both taxi and ride-hailing WAVs provide the same service in that they offer door-to-door service with wheelchair-accessible functions in addition to their regular service[11]. In the following empirical analysis, the discussion is limited to taxis, but the argument is applicable to ride-hailing paratransit services.

III. Data

For the empirical analysis, we use the quinquennial prefectural panel data from 1990 to 2015. An aging society was widely recognized as a policy issue in Japan in the 1990s. Given that the number of WAV has also been increasing since the 1990s, it is reasonable to focus on 1990 through 2015.

In this study, since we focus on the extent to which an increase in WhiteWAVs competes with taxis, the most crucial explanatory variable is the number of WhiteWAVs, obtained from the Number of Vehicles by Type published by the Japan Automobile Inspection and Registration Information Association. From 1990 to 2015, the number of WhiteWAVs increased by 23.7-fold, from 4,717

[8] Care facility staff devote 1/4 of their working time to transportation tasks (Mitsubishi UFJ Research and Consulting, 2018).

[9] Labor movement resistance and the cautious stance of the MLIT on ride-hailing safety were factors that prevented ride-hailing from obtaining permission to operate (Altura et al., 2021).

[10] Berger et al. (2018) revealed that in the US, the spread of ride-hailing services reduced taxi-driver wages by about 10%. In China, ride-hailing helped lift the capacity utilization rate of taxis (Nie, 2017).

[11] In the US and Canada, UberWAVs are replacing a declining number of cabs and taking on many paratransit services (Deakin et al., 2020; Young and Farber, 2020; Hassanpur et al., 2021).

to 111,642. The dependent variables are two indicators of taxi demand—the number of passengers and corporate taxi revenue. The taxi data are obtained from the *Hire-Taxi Yearbook,* published by the Hire-Taxi Problem Study Group. We use the consumer price index to make the data real. Figure 2 shows that the number of passengers peaked in 1988 and fell by 52.1% in 2015; operating revenue peaked in 1990 and fell by 40.1% in 2015. However, the number of drivers fell by only 14.9% from 1990 to 2015.

[Figure 2]

Dempsey (1996) argued that taxi demand is a function of two major variables: the overall economic activity in the market (including population, employment, and income) and the relative price and quality of service of taxis vis-a-vis alternative modes of transport (automobiles and public transportation). We add these factors as confounders in the regression analysis. The initial fares for taxis by the prefecture are acquired from the Retail Price Survey, which were also converted into real values. The jobs-to-applicants ratio by prefectures is also added to the model to control for regional economic fluctuations. As an indicator of taxi policy change, we add a post-deregulation dummy to the model, which is given only to the 2005–2015 samples, based on the study by Aoki (2017), who stated that the principle of deregulation in 2002 has been maintained to date[12]. As for alternative modes of transport, we use the distances (in kilometers) of bullet trains, JR conventional lines, and private railways (including subways and monorails) from the Yearbook of Regional Transport by MLIT[13]. The numbers of registered transit cars (public buses) and registered private cars per 1,000 people are also included in the regression[14]. To control for other factors caused by

[12] The process and consequences of deregulation and reregulation of taxi services in Japan since the 2000s are similar to those in the US in the 1980s and 1990s (Teal and Berglund, 1987; Dempsey, 1996; Kawaguchi and Mizuno, 2011). However, while demand for taxis in the US had recovered by early 2010 (Schaller, 2015), when ride-hailing began, taxi usage in Japan remained stagnant.

[13] For prefectures with 0 route distances in any transportation, we replaced route distances with 1 kilometer. Table 1 shows the values before adding 1.

[14] They are available in the "Table of Vehicles Owned," published by the Japan Automobile Inspection and Registration Information Association.

population, three more explanatory variables, obtained from the Population Census, are added to the regression model: population and rate of aging (the percentage of the population aged 65 years or older) by prefecture, and overall rate of aging across Japan. Table 1 presents the descriptive statistics for the variables in 1990 and 2015.

[Table 1]

Before moving on to the regression analysis, we would like to discuss the possibility of the local population changing over time. This is a concern when using prefectural panel data. In a recession, for example, taxi drivers might have moved to urban areas with a higher demand for taxis. If that is the case, it is impossible to distinguish if the demand for taxis changed due to an increase in WhiteWAVs or the supply of taxis through the movement of taxi drivers. To confirm this, we needed information on the movements of taxi drivers. However, the Basic Survey of Wage Structure (BSWS), the only survey that includes individual attributes of taxi drivers, provides only the drivers' place of employment at the time of the survey. Therefore, we examined the movements of the "broad occupational categories: transportation and machinery drivers," including taxi drivers, from the Population Census, albeit the data are crude. In the 2010 and 2015 surveys, the percentage of workers moving from other prefectures since the previous survey among all transportation and machinery drivers was no more than 3.4% and 3.2%, respectively. Therefore, it is unlikely that taxi drivers moving between prefectures significantly impacted the supply of taxis during the period analyzed in this study.

IV. Empirical analysis of taxi usage and WAVs

Basic model

In this section, we relate the number of WhiteWAVs registered to changes in the number of taxi passengers and operating revenues to explore its linkage systematically by using prefectural panel data analysis from 1990 to 2015. Specifically, even after controlling for factors that affect demand for taxis, we attempt to ascertain that the increase in the number of WhiteWAVs decreased the demand for taxis[15]. The estimated specification is as follows:

$$\ln Y_{pt} = \beta_1\left(\ln WAV_{pt}\right) + \left(Taxi\_DMD_{pt}\right)\Gamma + \delta(Taxi\_DMD_t) + \gamma_p + \varepsilon_{pt} \qquad (1)$$

where p represents prefectures, and t reflects the year. The left-hand-side variable, $\ln Y_{pt}$, is the logged number of taxi passengers or operating revenue. Our key independent variable is the logged number of WhiteWAVs, $\ln WAV_{pt}$. $Taxi\_DMD_{pt}$ is a vector of prefecture-level controls that include factors affecting the taxi demand explained in the data section: alternative modes of transportation, the initial taxi fare, economic trends, and taxi regulations. The prefecture-fixed effect is represented by γ_p. By including prefecture-fixed effects into the model, we control for factors affecting taxi demand specific to each region, and we can identify the effect of the increase in WhiteWAVs in each prefecture from the variation within the same prefecture. All regressions utilize weighted least squares with weights based on prefecture populations. The standard errors are clustered at the prefecture level, considering the heterogeneity of the residuals and serial correlation.

We use regional differences in WhiteWAVs to estimate the parameter of β_1 by statistically testing the relation between the number of WhiteWAVs and taxi demand. β_1 is interpreted as elasticity because the dependent variables, number of passengers, and operating revenue, and the number of WhiteWAVs are logarithmic. Regression results are presented in Table 2. Each of the two taxi management indicators is reported with two different specifications. Columns 1 and 4 present results without control variables other than the prefecture-fixed

[15] Previous studies unanimously revealed that the number of taxi services in Japan has been demand-driven rather than supply-driven (Aoki, 2017; Goto, 2017).

effects. Columns 2 and 5 present results with control variables, including alternative modes of transportation, the initial taxi fare, economic trends, and taxi regulations. Three population-related explanatory variables are added to columns 3 and 6 to differentiate the impact of WhiteWAVs from that of other factors resulting from aging and demographic factors: 1) the population by prefecture, 2) rate of aging (the proportion of the population aged 65 or older) by prefecture, and 3) proportion of the population aged 65 or older at the national level for each year.

[Table 2]

The top row of the table indicates the coefficients for the number of WhiteWAVs across specifications. In all six cases, coefficients are significantly negative. In columns 3 and 6, the inclusion of demographic variables slightly reduces the magnitude of the coefficients on the number of WhiteWAVs. This implies that the relation between the number of WhiteWAVs and the taxi managerial indices depends on the age structure of the population in each region. Nevertheless, the magnitude implied by the coefficients on WAV is substantial; a 10% increase in WhiteWAVs is associated with a 0.9% reduction in the number of taxi passengers and a 1.3% decrease in operating revenue. Given the actual increase in WhiteWAVs between 2010 and 2015, it is calculated that the number of taxi passengers decreased by 2.7%[16]. This corresponds to an annual decrease of 8.2 million passengers. When compared with the actual decrease in passengers (22.3 million per year) from 2010 to 2015, the increase in WhiteWAVs can account for about one-third of the decrease.

Robustness check

[16] Between 2010 and 2015, WhiteWAVs increased by 29.6%, from 86,124 to 111,642. For this period, the number of taxi passengers decreased by 41,483,725.

Given the relatively limited set of available covariates, omitted variables may be a concern in the last regressions. Factors such as taxi accessibility, residents' health status, accessibility to health care, and household budget constraints may also affect the demand for taxis. We thus include additional variables to the previous model: the logged number of taxi offices per thousand population, the logged number of taxis per thousand population, the logged number of outpatient visits to hospitals per thousand population, the logged number of hospitals per thousand population, and the logged real personal income per capita[17]. All these factors could increase the use of taxis.

Table 3 investigates the sensitivity of the WhiteWAV coefficients to a range of alternative specifications. We consider the specifications with the full set of controls in Table 2 as a baseline. The WhiteWAV coefficients from those regressions are reported in columns 1 and 8 of Table 3. Each column in the table represents a different specification, and the sensitivity of the results to a change in taxi supply is examined. The effect of including the logged number of taxi offices per thousand population on the logged number of passengers (Panel A) reduces the estimated number of passengers, whereas including the logged number of taxis per thousand population increases the WhiteWAV coefficient for the category. Alternatively, adding two kinds of healthcare indices (Column 4) did not significantly change the estimated impact of WhiteWAVs. Regression using real personal income per capita in Column 5 yields a coefficient similar to, but slightly larger than, the baseline coefficient. Including all of these variables leads to slightly higher estimates in Column 6, suggesting once again that WhiteWAVs substantially impact taxi demand.

[Table 3]

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[17] The numbers of taxi offices and taxis are derived from the *Hire-Taxi Yearbook*, whereas the numbers of outpatient visits and hospitals are derived from the Patient Survey by MHLW. Information on household disposable income is obtained from the Comprehensive Survey of Living Conditions by MHLW.

The results do not substantially differ in Panel B of the table, where the dependent variable is operating revenues. Controlling for taxi supply and health care factors somewhat increases the estimated effect of WhiteWAVs on operating revenues (Column 9–11). It does not change their significance. Including real personal income per capita leads to coefficients greater than the estimates used as a baseline (Column 12). Finally, Column 13 has all the variables, and the number of WhiteWAVs is still significantly linked with lower operating revenue.

So far, our study has assumed that the increase in the number of WhiteWAVs is an exogenous factor affecting the taxi service in each prefecture. However, the number of WhiteWAVs in some regions may have increased because of the reduction in taxi services. To address this concern, we tried to handle the reverse causality by using prefectural welfare expenses for the elderly as an instrumental variable for the number of WhiteWAVs. For the welfare expenses for the elderly to be appropriate as an instrumental variable for the number of WhiteWAVs, the change in welfare expenses for the elderly must be related to the purchase of WhiteWAVs (the first condition) and must not be directly related to taxi demand (the second condition).

Given that the prefectural government's welfare expenses for the elderly are spent on subsidies for constructing and maintaining elderly care facilities, the first requirement has been met [18]. It is common for elderly care facilities constructed with these subsidies to provide both care services and transportation between the house and the facility. As discussed in Section 2.2, many of these facilities have WhiteWAVs to transport the elderly. However, in the *Annual Statistics on Local Public Finance*, there is no data on the purchase of WhiteWAVs in each prefecture. Instead, we assumed that the welfare expenses for the elderly per population are an indicator of the prefecture's welfare

[18] Information about the welfare expenses for the elderly in the prefecture can be obtained from the *Annual Statistics on Local Public Finance*. Note that welfare expenses for the elderly are also used for medical expenses for the elderly.

generosity toward the elderly. The larger the expenses, the more WhiteWAVs are assumed to be introduced to the region. The correlation coefficient between the logged welfare expenses for the elderly per thousand population in the previous year and the logged number of WhiteWAVs is 0.637, indicating a strong positive correlation between the two variables [19].

The second condition that the elderly welfare expenses are not directly related to taxi demand is equally plausible. As discussed in Section 2.2, while many local governments subsidize public transportation services such as buses and trains for the elderly, few local governments provide taxi vouchers for mobility-challenged individuals, including the elderly. Therefore, we can assume that welfare expenses for the elderly are an exogenous variable in demand for taxis and do not directly affect the demand for taxis. If the number of WhiteWAVs increased as a result of the development of regional welfare policy, then we can identify the causal relationship between WhiteWAVs and taxi demand by considering the variation in welfare expenses for the elderly per population—a proxy for the development of welfare policy.

When welfare expenses for the elderly are used as an instrument variable (Column 7 of Table 3), the effects of β_1 are negatively significant at the 1% level for both cases in which passengers and operating revenue are dependent variables, although the estimates slightly fluctuate erratically and the standard errors more than triple. Accordingly, we conclude that the increase in the number of WhiteWAVs suppressed the demand for taxis, not a reverse causal relationship.

Analysis by region

Sections 4.1 and 4.2 examined the effects of the increase in WhiteWAVs on the number of passengers and operating revenue of taxis, assuming a

[19] Ogasawara (2002) also found a positive correlation in Japan between regional aging rates and per capita welfare costs for the elderly, with variations across prefectures.

constant percentage of the population aged 65 years and above across the country. This assumption implies that the effect of the increase in the number of WhiteWAVs on the taxi indices is the same between areas with aged and unaged population. However, the environment and business practices for taxis vary greatly between urban and rural areas (Skok and Kobayashi, 2007; Fukumoto et al., 2017). Since the 1990s, the per capita welfare expenditures for the elderly in prefectures with higher aging ratios (more rural areas) have been consistently 24.5% higher than in prefectures with low aging ratios (more urban areas) (in 2015). In contrast, transportation-related expenditures are greater in regions with densely populated cities[20]. The prevalence of WAVs is also expected to differ between urban and rural areas, which have different speeds and levels of population aging[21]. These differences suggest non-negligible regional differences in the relation between WhiteWAVs and taxis. In fact, since more rapidly aging areas have experienced a greater downturn in taxi demand (Appendix Figure 3), it would be reasonable to examine the regression analysis by dividing it into subgroups.

Thus, we assume that the effect of the number of WhiteWAVs on taxi demand is heterogeneous and depends on the degree of aging in the region. Prefectures are divided into two groups according to some indicators of aging from 1990 to 2015. The basic model is then modified by adding an interaction between the ratio of elderly people in each prefecture and the number of WhiteWAVs. Moreover, by including a quadratic term for the number of WhiteWAVs, we consider the potential for a non-linear relation between the number of WhiteWAVs and the number of passengers/amount of operating revenue for taxis.

Figure 3 presents the interaction term coefficients for the cases where the ratio of elderly people in each prefecture is assumed to be 10% or 30%. When

[20] https://www.mlit.go.jp/common/001007541.pdf
[21] Karlaftis and Sinha (1997) and Mulley et al. (2012) reported that in the US, there are large differences in the services offered by and the operating environments of rural and urban paratransit systems.

the ratio of elderly people is low (10%), an increase in WhiteWAVs decreases taxi passengers and operating revenue modestly. Alternatively, when the ratio of elderly people is high (30%), an increase in the number of WhiteWAVs has a greater impact on the number of passengers and operating revenue of taxis. Given the assumption that the elderly ratio in Japan will increase for the foreseeable future, this result supports that the demand for taxis may decrease at a higher rate in the near future as the number of WhiteWAVs increases.

[Figure 3]

Table 4 presents the coefficients of the number of WhiteWAVs across regional subgroups. We use three indicators of regional aging from 1990 to 2015: the average aging rate, elderly growth rate, and average expense for the elderly. For example, a prefecture whose elderly rate was higher than average between 1990 and 2015 is classified as a high elderly group. The same holds for classifying the other two indicators. Panel A shows the results when the dependent variable is the logged number of passengers, whereas Panel B shows the results when the dependent variable is the logged number of operating revenues. The estimation method is fixed effects instrumental variables (FEIV) estimation, corresponding to columns 7 and 14 in Table 3, considering a bias due to reverse causality.

[Table 4]

In all the six cases in Panel A, the coefficient is negative, although the coefficient for the region with the lower elderly rate, Column 2, is not significant. This implies that an increase in WhiteWAVs is associated with a decline in the number of taxi passengers. Point estimates are slightly larger in areas with high elderly rates and high expenses for the elderly, which is consistent with Appendix Figure 3. However, the impact on the number of passengers is less severe in areas with higher elderly growth rates. In Panel B, where the dependent variable is the logged operating revenues, the results for the number of passengers are not substantially different. The more generous the local budget for the elderly, the greater the observed decrease in taxi demand. This result indicates that the enhancement of public elderly care services has negatively impacted the taxi industry. Since welfare-related spending is preferentially generous in Japan at present, it is possible that WhiteWAVs will become more prevalent in rural areas with high aging populations and an increasing reliance on welfare policies and that this may significantly impact the demand for taxis.

V. Drivers' wage elasticity of taxi demand

In this section, we explore the extent to which declining taxi usage corresponds to taxi drivers' wages. Since most taxi drivers' wages are on a commission-based pay system, the fluctuation in drivers' wages directly reflects the change in taxi demand. Thus, we derive drivers' wage elasticity of taxi demand from estimating the extent to which taxi drivers' wages would increase if taxis were to take on the part of WAV transportation. This estimated wage increase is then interpreted as an incremental increase in the surplus of taxi workers. If the WhiteWAV driver is dedicated, then the substitution of the WhiteWAV driver for the taxi driver in the WAV market means a decrease in WhiteWAV drivers' surplus. However, as explained in Section 2.2, care facility staff are concurrently working as WhiteWAV drivers. Outsourcing a portion of WhiteWAVs' transportation operations would allow care workers to focus on their primary responsibilities. Thus, we can assume that care facility workers' total workload and treatment remain unchanged.

A simple fixed effect estimate could be biased because the decrease in taxi usage is partly driven by changes in both supply and demand. FEIV mitigates this simultaneity bias by instrumenting the changes in taxi demand with changes in WhiteWAVs. As found in detail in Section 4, the increase in WhiteWAVs as welfare policy is exogenous to taxi demand. Accordingly, we can assume that the welfare policy causes a change in taxi demand and taxi drivers' wages through increasing WhiteWAV services.

To capture the demand-driven component of taxi usage, we instrument the logged number of taxi passengers and the logged operating revenue with a WhiteWAV variable. This instrument is motivated by the fact that the decline in taxi usage in prefectures is caused by the increase in WhiteWAVs, a demand shock in the taxi industry. In addition, WhiteWAV is an independently generated variable that is not directly related to taxi drivers' wages. The additional identifying assumption is that demand shocks caused by WhiteWAVs are uncorrelated across prefectures and that there are no substantial increasing returns to scale in welfare policies, such as more construction of elderly care facilities. As long as our instrument is valid, our estimates will correctly identify the effects of decreased taxi usage on drivers' wages.

Panel A in Table 5 presents the results of FEIV estimation when the logarithm of the number of taxi passengers is used as the endogenous variable. Panel B reports the cases in which the explanatory variable is the logged operating revenue. In all specifications, the dependent variable is the real wage rate for taxi drivers at the prefectural level, which we aggregated from the BSWS. The covariates used to explain the prefectural average wages for taxi drivers are identical to those used in the taxi demand regressions in Section 4. The first column of results contains variables discussed in previous studies and prefecture-fixed effects, whereas the second column adds indicators of taxi availability, health care, and household income per capita. As in Section 4, we also present the results of splitting for elderly rates (columns 3–4), elderly growth rates (columns 5–6), and expenses for the elderly (columns 7–8).

[Table 5]

Table 5 indicates that taxi usage (the number of passengers and the operating revenues) coefficients are positive and statistically significant for all specifications except one. Including additional covariates and splitting the sample do not impact the sign of the coefficients of taxi usage. In all cases, decreases in taxi use are associated with decreases in taxi drivers' wages, with the point estimate ranging from 0.95 to 2.66. The coefficients of the number of passengers are typically larger than those of the operating revenues. In addition, the fact that most drivers' wage elasticity is greater than one implies that wages declined more than the decrease in taxi usage. The results of the first stage of estimation reveal that the logged number of WhiteWAVs does not have a weak IV problem and that the increase in WhiteWAVs affects wages through the demand for taxis.

For groups divided by the average elderly ratio between 1990 and 2015 and by the growth rate of the elderly during that period, the estimated impacts on drivers' wages are more elastic and significantly larger in areas with a low average elderly ratio or a low growth rate in the elderly ratio. This may be due to the fact that urban prefectures with a low ratio of elderly people are more likely to have elastic commission-based wages. We also analyze taxi drivers' wages by expenses for the elderly. The point estimate on the logged number of passengers' coefficient in columns 7–8 of Panel A is larger in magnitude in the prefecture group with higher expenses for the elderly. This is consistent with the regression result of the logged number for the operating revenue (Panel B). Specifically, the wage decrease caused by lower demand for taxis was twice or thrice greater in regions with higher expenses for the elderly.

Finally, we conclude our empirical analysis by showing how estimated wage elasticities correspond to the changes in taxi drivers' wages. Although estimates vary widely, we observe that the estimates of the wage elasticity range from 0.841 to 2.661 in Table 5. For example, in an analysis that includes all regions (where wage elasticity is 1.554), the 2.7% decrease in the number of taxi passengers from 2010 to 2015 due to the increase in WhiteWAVs corresponds to a 4.2% decrease in the annual income of taxi drivers. Similarly, the increase in WhiteWAVs reduced the annual income of taxicab drivers by 9.4% in areas with higher spending on welfare policies and by 3.5% in areas with lower spending on welfare policies. These figures could also be interpreted as an incremental increase in income if taxi drivers had supplied WAV services instead. These increments appear large enough for taxi drivers, whose incomes have declined since the 1990s[22].

VI. Policy implications

In the last two sections, we estimated that the expansion of WhiteWAVs caused a 2.7% decrease in taxi passenger volume from 2010 to 2015. This decrease is equivalent to about 4% of a taxi driver's annual income. In the paratransit market in Japan, due to the increase in WhiteWAV transportation, whose fares are kept low by large subsidies from LTCI, the demand for taxis without fare subsidies has slowed down, resulting in many vacant hours. Thus, it is thought that open entry, generous subsidies for WhiteWAVs, and vacant hours for taxis have created an oversupply in the WAV market. The decrease in taxi demand caused by the increase in WhiteWAVs can be interpreted as the portion where taxis with less public subsidy could provide paratransit transportation in the slack WAV market. Such a situation where the government spends substantial subsidies on WhiteWAVs when cost-saving taxis are available results in inefficiency in the WAV market.

The inefficiency of the WAV market differs from place to place within a country. According to our study, in rural areas where the paratransit market is saturated and local governments continue to spend heavily on welfare policies despite a declining elderly population, the competition between taxis and WhiteWAVs is greater than those in other areas. Our results are consistent from an economic perspective; a saturated market with open entry makes the market more competitive, resulting in lower marginal benefits for suppliers. These results can be paraphrased as room for improvement in the efficiency of paratransit services, particularly in rural areas.

[22] The BSWS reports that a taxi driver’s annual total income was 74% of the mean total income wages of male workers in all industries in 1980 and fell to 57% in 2015.

Implementation of paratransit does not occur in an organizational vacuum, and long-standing public transport industry attitudes, perceptions, and cultural conditioning frequently impede the introduction of new forms of service (Mulley et al., 2012). In Japan, there was a lack of coordination between MLIT and MHLW, and the position of taxis in the public transportation system was unclear. Such inefficiencies exist in areas where economic theory and ideology collisions cannot be resolved solely from an economic perspective but require policy mediation.

To improve the efficiency of the WAV market, we propose establishing integrated mobility coordinators for WhiteWAVs and TaxiWAVs. Mulley et al. (2012) provided evidence that since taxis for paratransit services could utilize their existing vehicles and booking capabilities, they offered significant reductions in operating costs. Moreover, the use of non-dedicated WAVs, such as taxis, can complement the capacity to provide dedicated WAVs by taking some of the peak load off the dedicated WAVs, thereby enabling dedicated WAVs to keep serving other types of demand during non-peak hours (Gupta et al., 2010). In addition to load leveling, the benefits of intensive use of vehicles are substantial: lower cost per passenger (since depreciation and operating costs are spread over many more occupants) and more rapid turnover of vehicles, resulting in the accelerated adoption of cleaner vehicles (Shaheen, 2018).

Many studies, including those by Shaheen et al. (2017), Rahimi et al. (2018), Gonzales et al. (2019), and Deakin et al. (2020), have reported that incorporating taxis into public paratransit systems by applying subsidies generates benefits, such as cost reduction for local paratransit services in the US. In the Netherlands, Sweden, the UK, and the US, the public transport authorities have already utilized taxis to optimize the deployment of the dedicated WAV fleet (Gupta et al., 2010; Nelson et al., 2010; Mulley et al., 2012; Hansson and Holmgren, 2017). In these countries, the number of paratransit services supplemented by TaxiWAVs has increased, and their costs are considerably cheaper than those for a corresponding exclusive taxi ride. It would also be effective in Japan to incorporate taxis into the LTCI welfare transportation system to streamline the current individual transportation by elderly care facilities.

If taxis can lessen the fiscal burden on the public sector by providing paratransit services of the same quality as WhiteWAVs, the deadweight loss of the WAV market will be reduced[23]. This could lead to a Pareto-improving win–win situation where both taxi drivers' wages and care facility workers' time to concentrate on care jobs increase. In addition, WhiteWAVs and taxis can achieve economies of scale by further streamlining the WAV market, such as reducing wait times. Especially in countries such as Japan, where the population is declining and labor shortages are becoming severe in many fields, labor-saving investments must be prioritized by policymakers. Improving the WAV market's efficacy leads to a more efficient use of labor resources.

With the advent of a new era of communication capabilities, we believe there is room for improvement in technical challenges. The challenges of integrating paratransit services could be overcome by employing smart dispatching algorithms that account for traffic volume, real-time vehicle location, trip cancellations, and so on. However, we should note that the current integrated paratransit mobility coordinators could become obsolete as the declining cost of autonomous vehicles threatens incumbent services and the use of shared automated vehicles increases (Daduna, 2020; Milakis and Van Wee, 2020). Not only taxi drivers but also paratransit drivers may be rendered superfluous. However, demand for existing services will persist for the foreseeable future, as a study shows that the elderly are resistant to automated driving (Sharma and Mishra, 2022). In such a transitional period, policies that use existing resources more efficiently will be needed more than policies that rely on substantial subsidies to maintain traditional operating services.

[23] The concession schemes should also be incorporated to minimize adverse incentives due to open entries. The use of concession schemes can reduce the adverse impacts of subsidies as inefficient operations in terms of cost-efficiency reduce the probability of winning the concession (Small and Verhoef, 2007).

VII. Conclusion

This study highlighted the inefficiency of the WAV market, which has expanded with the aging of the population. WAV transportation, which is unprofitable because of the low number of users despite the higher cost of providing mobility aid, tends to be underprovided. Thus, policymakers typically encourage service supply by granting subsidies. However, in the open-entry WAV market, where subsidies are provided while the overall cost of the paratransit system is not controlled, there is a high possibility of an oversupply of vehicles and a large deadweight loss. In this study, using the case of WAV transportation in Japan, where coordination between paratransit policies for the elderly is not enough, we demonstrated that when one player (WhiteWAVs) is heavily subsidized in an open-entry system, demand for the competitive player (taxi) is reduced. Subsidized WhtieWAVs with significant vacant hours outside of peak hours and low-demand TaxiWAVs with stagnating utilization rates have created inefficiency in the WAV market.

If regional panel data with the number and/or ridership of WAVs, taxi outcomes, and government spending indicators are available, similar analyses could be conducted for other countries. Future studies will need to use more direct and credible indices of the WAV market to precisely estimate the supply–demand curve, service costs, and degree of oversupply in the WAV market. An evaluation of the WAV market using more direct measures may either support the robustness of our analysis or expose imperfections in our study. A meta-analysis of the results of the country-by-country analysis could allow for international comparisons and comprehensive assessments of efficiency in each country’s WAV market. In any event, an accumulation of reliable empirical evidence in the future would lead the market for paratransit transportation to a higher social well-being.

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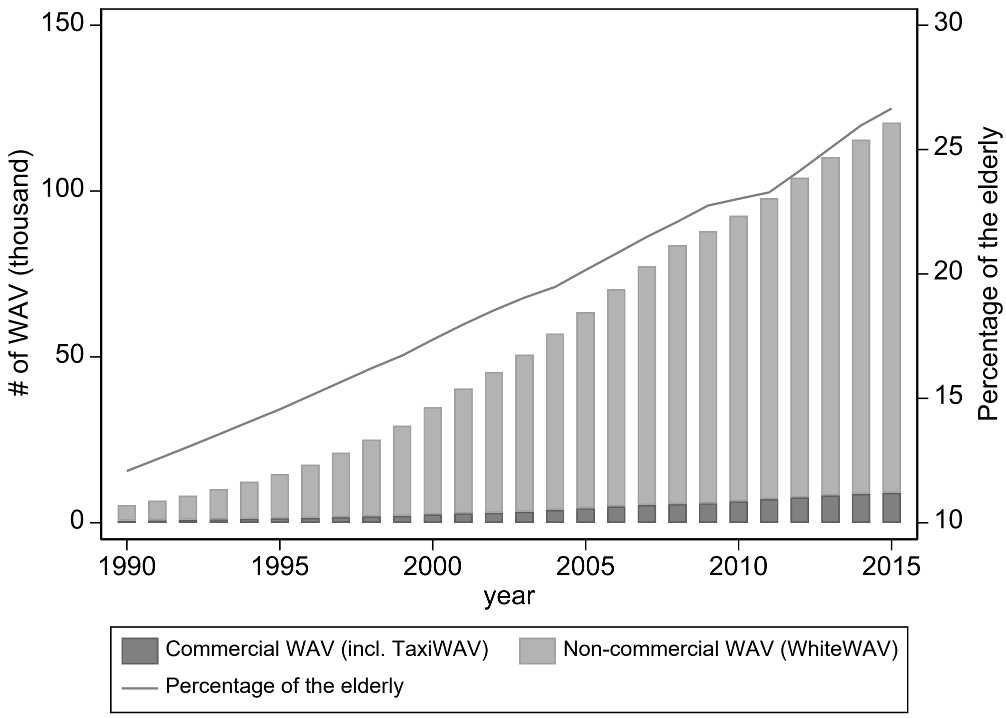


Figure 1. Aging population and rapid increase in WAV

Data Source: Population Census (1990–2015, Ministry of Internal Affairs and Communications) and Automobile Inspection and Registration Information Association (1990–2015).

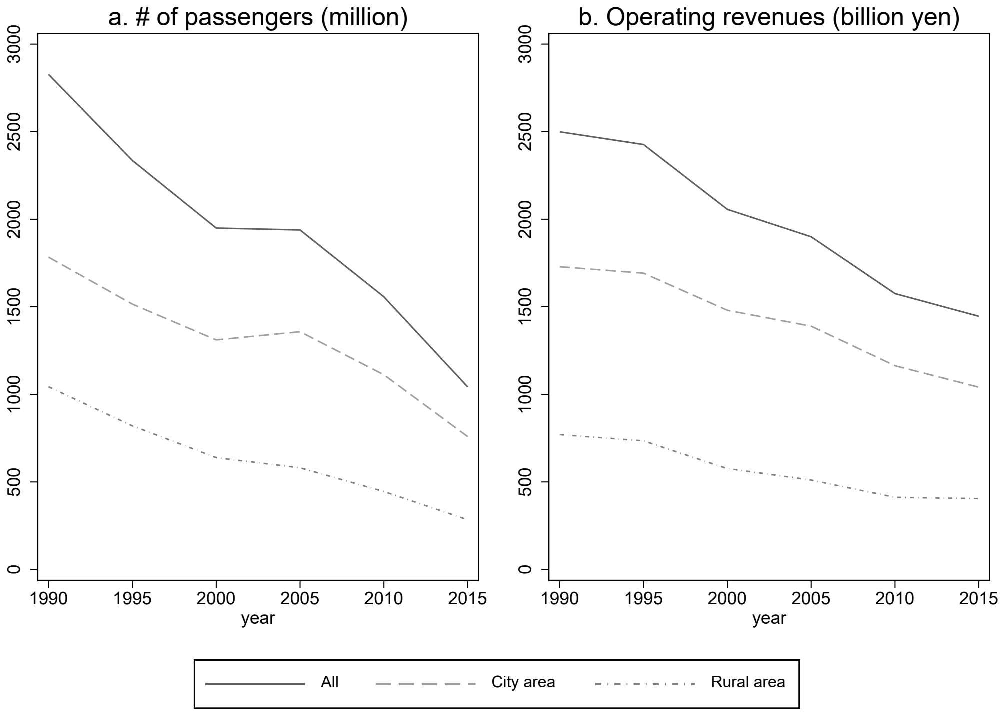


Figure 2. Operating indicators for the taxi industry by area

Data Source: Hire-Taxi Yearbook (1990–2015).

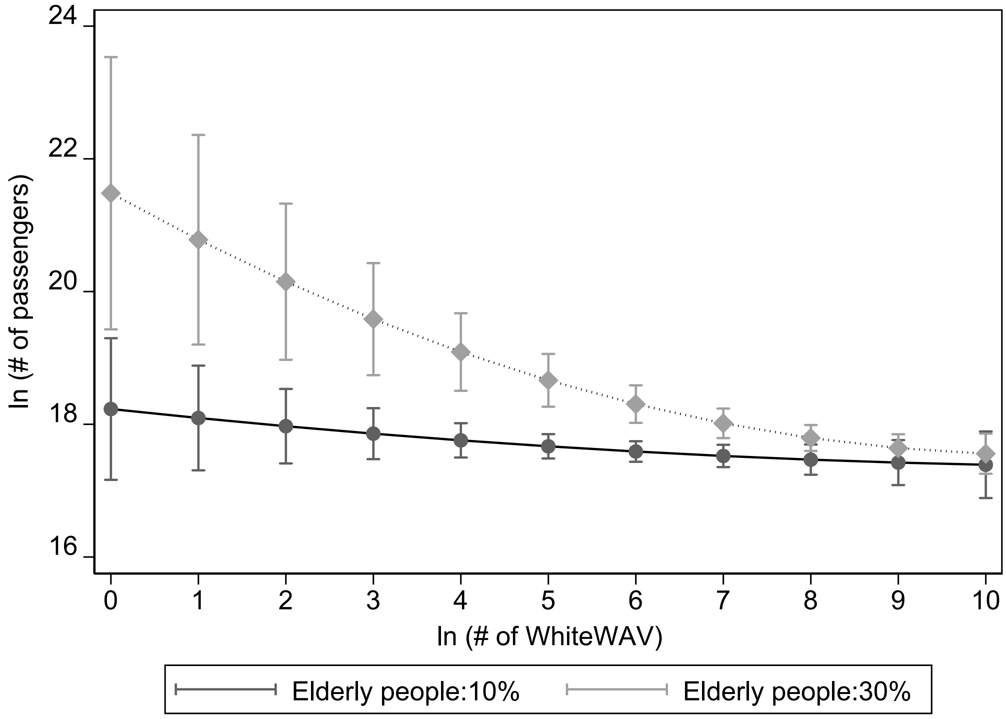


Figure 3a. Linear prediction (number of passengers)

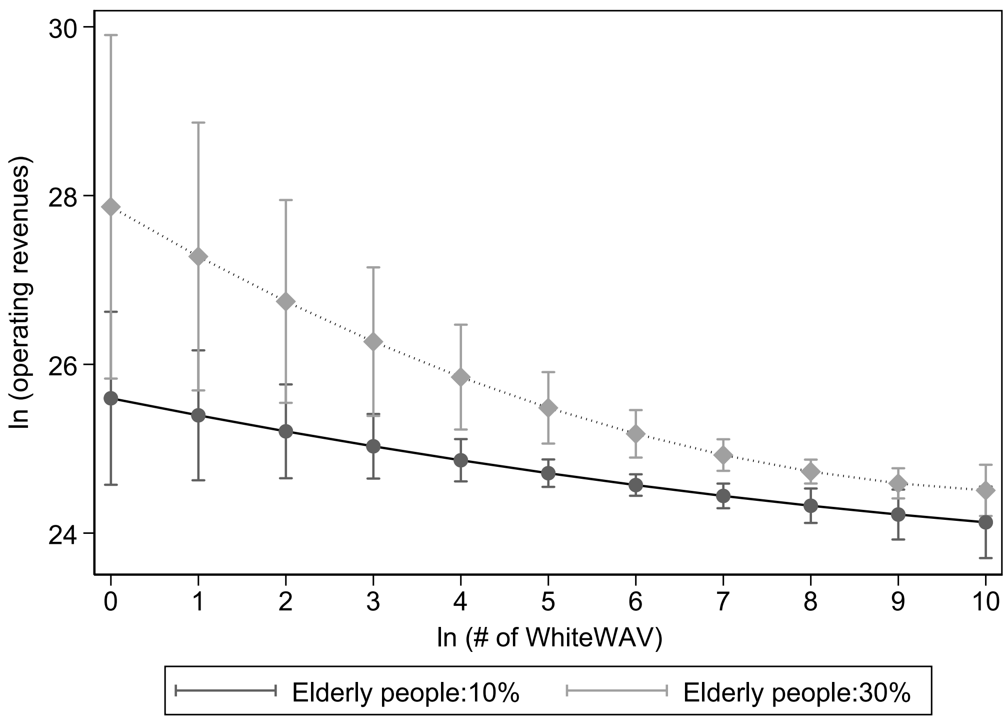


Figure 3b. Linear prediction (operating revenue)

TABLE 1

Descriptive statistics

	Year	*Obs.*	*Ave.*	*SD*	*Min*	*Max*
Number of taxis	1990	47	4,521	5,547	771	35,594
	2015	47	4,072	5,071	707	30,907
Number of taxis offices	1990	47	153	80	30	367
	2015	47	339	284	58	1,296
Yearly mileage (million km)	1990	47	370	546	56	3,440
	2015	47	199	347	28	2,210
Number of yearly passengers (million)	1990	47	60	77	10	454
	2015	47	31	51	4	319
Real yearly operating revenue (million yen)	1990	47	58,000	103,000	7,970	676,000
	2015	47	32,300	64,900	3,800	428,000
Real initial taxi fare (yen)	1990	47	486	36	390	521
	2015	47	628	76	465	730
Number of WhiteWAV per 1000 residents	1990	47	270	35	205	357
	2015	47	548	96	228	683
Real hourly wage (yen)	1990	47	1,400	285	961	2,291
	2015	47	1,165	203	811	1,675
Monthly working hours	1990	47	227	14	202	266
	2015	47	176	16	121	209
Population (ten thousand)	1990	47	263	242	62	1,186
	2015	47	270	273	57	1,352
Population ratio of over 65 years old (%)	1990	47	14	2.4	8	18
	2015	47	28	2.8	19	34
Real elderly welfare expenses per 1000 residents (yen)	1990	47	6,732	2,145	2,840	11,872
	2015	47	26,002	4,735	16,425	36,250
Number of outpatient visits to hospitals per 1,000 residents	1990	47	4,938	964	3,293	7,745
	2015	47	3,994	654	2,909	6,136
Number of hospitals per 1,000 residents	1990	47	0.74	0.13	0.49	1.01
	2015	47	0.89	0.13	0.62	1.19
Rail length of bullet train (km)	1990	47	43	58	0	183
	2015	47	55	62	0	186
Rail length of JR (km)	1990	47	383	368	0	2,586
	2015	47	370	355	0	2,500
Rail length of other private railways (km)	1990	47	146	143	0	568
	2015	47	159	160	0	732
Number of buses per 1000 residents	1990	47	2.43	1.45	0.38	7.94
	2015	47	2.29	1.37	0.39	8.11
Job opening-to-application ratio	1990	47	1.54	0.57	0.48	2.62
	2015	47	1.17	0.22	0.84	1.75

TABLE 2

Panel-data estimates of the relationship between WhiteWAV and taxi usage

Variable	ln (# of passengers)			ln (operating revenue)		
	(1)	(2)	(3)	(4)	(5)	(6)
ln (# of WhiteWAV)	0.208***	−0.117***	−0.089**	−0.185***	−0.143***	−0.127***
	(0.019)	(0.028)	(0.034)	(0.015)	(0.031)	(0.025)
Population over 65 rate (national)			−0.065***			−0.065***
			(0.009)			(0.009)
Population over 65 rate (prefecture)			2.960***			3.123***
			(0.937)			(0.921)
ln (# of population)			2.529***			2.679***
			(0.340)			(0.337)
ln (bullet trains km)		−0.022**	0.012		−0.038***	−0.003
		(0.010)	(0.011)		(0.011)	(0.009)
ln (JR conventional lines km)		0.305**	0.346***		−0.120	−0.070
		(0.133)	(0.108)		(0.215)	(0.063)
ln (private railways km)		0.032	−0.008		0.037*	−0.004
		(0.025)	(0.018)		(0.022)	(0.012)
ln (registered private cars)		−0.697***	−0.105		−0.378***	0.247***
		(0.087)	(0.104)		(0.123)	(0.067)
ln (registered transit cars)		0.010	−0.026		0.013	−0.023
		(0.026)	(0.019)		(0.026)	(0.017)
ln (initial taxi fare)		0.265	0.104		0.267*	0.107
		(0.164)	(0.085)		(0.156)	(0.069)
Jobs-to-applicants ratio		−0.016	0.101***		−0.058***	0.060***
		(0.015)	(0.019)		(0.017)	(0.014)
Post-deregulation (2005–2015)		−0.006	0.054***		−0.025	0.036**
		(0.023)	(0.016)		(0.021)	(0.017)
Prefecture-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	282	282	282	282	282	282
R2	0.7756	0.8467	0.9299	0.7882	0.8297	0.9411

Notes: The dependent variable is the log in the taxi demand named at the top of each pair of columns. The first column in each pair presents results from specifications in which the only additional covariates are prefecture-fixed effects. The second column presents using the variables pointed out in previous studies. The third column presents results using the full specification. The data set is comprised of quinquennial prefecture-level observations for the period 1990–2015. The two variables, the national over-65 population ratio and the institutional change dummy, use national-level values. Estimation is performed using weighted least squares estimates with weights determined by prefecture population. Standard errors are in parentheses and adjusted for clusters in prefecture. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level.

TABLE 3 *Sensitivity of WhiteWAV coefficients to alternative specifications*

Variable	(1) FE	(2) FE	(3) FE	(4) FE	(5) FE	(6) FE	(7) FEIV
	Panel A: ln (# of passengers)						
ln (# of WhiteWAV)	−0.089** (0.034)	−0.082*** (0.030)	−0.104*** (0.034)	−0.085** (0.035)	−0.100*** (0.027)	−0.105*** (0.031)	−0.368*** (0.115)
ln (# of taxi offices per 1,000 residents)		0.021 (0.039)				0.011 (0.030)	−0.007 (0.044)
ln (# of taxis per 1,000 residents)			0.670*** (0.104)			0.668*** (0.113)	0.727*** (0.101)
ln (# of outpatient visits to hospitals per 1,000 residents)				0.078 (0.197)		0.110 (0.178)	−0.058 (0.114)
ln (# of hospitals per 1,000 residents)				−0.181 (0.323)		−0.208 (0.272)	0.288 (0.252)
ln (real personal income per capita)					0.300** (0.129)	0.253*** (0.094)	0.137* (0.076)
1st stage							
ln (elderly welfare expenses per 1000 residents) (t−1)							0.336*** (0.079)
F value							680.97
Prefecture-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	282	282	282	282	281	281	281
R2	0.9299	0.9301	0.9468	0.9303	0.9346	0.9516	0.9452

Variable	(1) FE	(2) FE	(3) FE	(4) FE	(5) FE	(6) FE	(7) FEIV
	Panel B: ln (operating revenue)						
ln (# of WhiteWAV)	−0.127*** (0.025)	−0.127*** (0.025)	−0.140*** (0.031)	−0.130*** (0.025)	−0.132*** (0.022)	−0.153*** (0.032)	−0.289*** (0.088)
ln (# of taxi offices per 1,000 residents)		0.000 (0.026)				−0.019 (0.029)	−0.006 (0.034)
ln (# of taxis per 1,000 residents)			0.560*** (0.113)			0.558*** (0.104)	0.561*** (0.077)
ln (# of outpatient visits to hospitals per 1,000 residents)				−0.001 (0.119)		−0.009 (0.111)	−0.043 (0.087)
ln (# of hospitals per 1,000 residents)				0.191 (0.252)		0.164 (0.176)	0.321* (0.193)
ln (real personal income per capita)					0.163* (0.091)	0.143** (0.067)	0.106* (0.058)
1st stage							
ln (elderly welfare expenses per 1000 residents) (t−1)							0.336*** (0.079)
F value							680.97
Prefecture-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	282	282	282	282	281	281	281
R2	0.9411	0.9411	0.9562	0.9415	0.9431	0.9586	0.9561

Notes: Results in this table are variations on the specifications reported in columns (3) and (6) of Table 2. Columns (1) and (8) of the current table are baseline specifications that are presented in Table 2. All specifications are estimated using quinquennial, prefecture-level panel data of the years 1990–2015. The instrumental variable of the number of WhiteWAVs is the logged welfare expenses per thousand population in the previous year. The number of observations in specifications including real personal income per capita is 281, since the sample of Hyogo prefecture affected by the Hanshin earthquake is missing in 1995. Standard errors are in parentheses and adjusted for clusters in prefecture. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level.

TABLE 4

WhiteWAV Coefficients for regional subgroups

Panel A	*Dep. Var.: ln (# of passengers)*					
	(1)	(2)	(3)	(4)	(5)	(6)
Est. mh.: FEIV	High elderly rate	Low elderly rate	High elderly growth rate	Low elderly growth rate	High expenses for the elderly	Low expenses for the elderly
ln (# of WhiteWAV)	−0.237* (0.134)	−0.440 (0.301)	−0.335* (0.176)	−0.357*** (0.137)	−0.709* (0.380)	−0.149** (0.066)
Number of observations	138	144	138	144	120	162

Panel B	*Dep. Var.: ln (operating revenue)*					
	(7)	(8)	(9)	(10)	(11)	(12)
Est. mh.: FEIV	High elderly rate	Low elderly rate	High elderly growth rate	Low elderly growth rate	High expenses for the elderly	Low expenses for the elderly
ln (# of WhiteWAV)	−0.176** (0.089)	−0.238 (0.213)	−0.246** (0.122)	−0.358*** (0.128)	−0.647** (0.308)	−0.151** (0.068)
Number of observations	138	144	138	144	120	162

Notes: Results in this table are variations on the specifications reported in columns (7) and (14) of Table 3. Panel A of the current table are results of number of passengers. Panel B of the current table presents the results of operating revenue. All specifications are estimated using quinquennial, prefecture-level panel data of the years 1990–2015. The instrumental variable of the number of WhiteWAVs is the logged welfare expenses per thousand population in the previous year. Standard errors are in parentheses and adjusted for clusters in prefecture. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level.

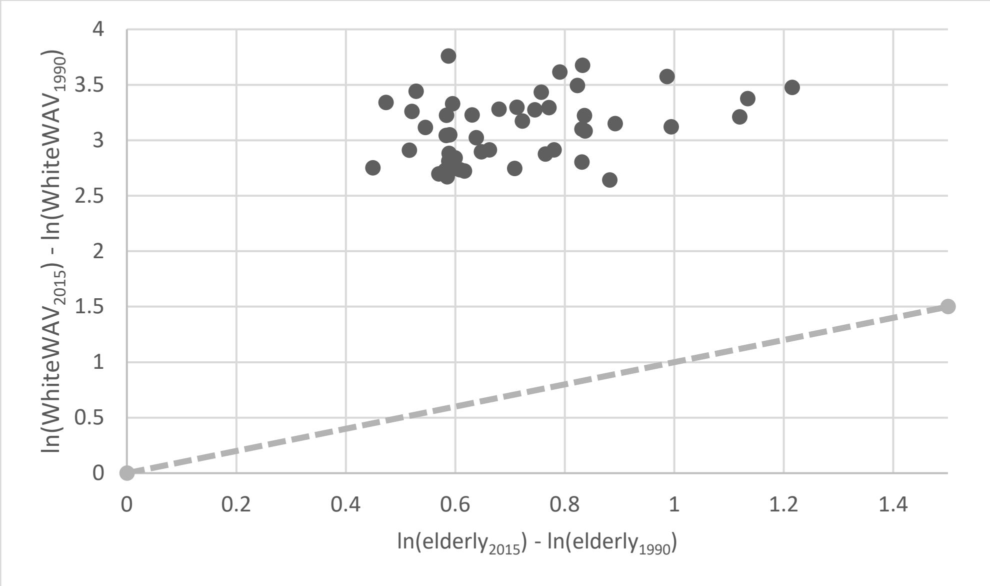
TABLE 5

The relationship between taxi usage and driver's wages

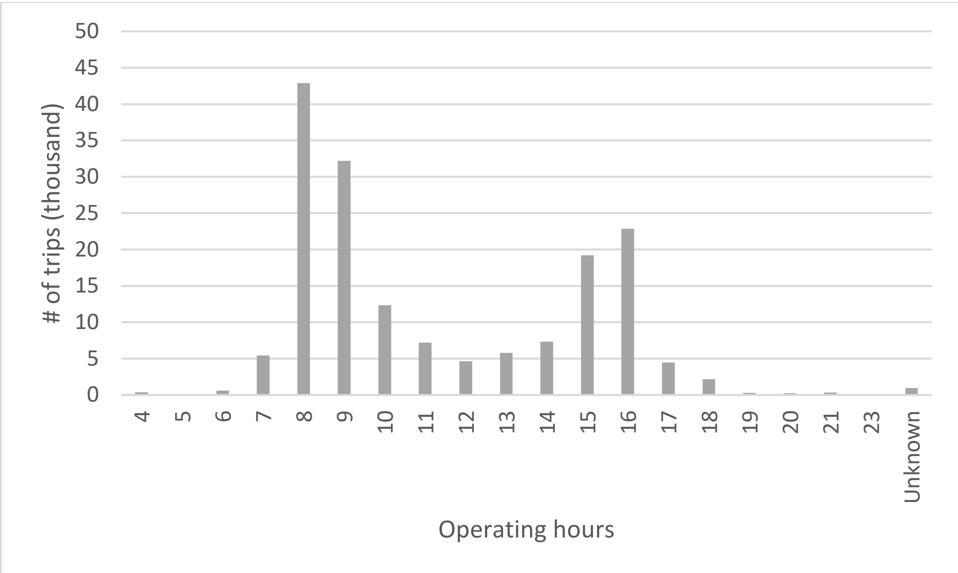
Panel A	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var.: driver's wage	All	All	High elderly rate	Low elderly rate	High elderly growth rate	Low elderly growth rate	High expenses for the elderly	Low expenses for the elderly
	FEIV	FEIV	FEIV	FEIV	FEIV	FEIV	FEIV	FEIV
ln (# of passengers)	1.403***	1.554***	1.781	1.970**	0.986**	2.661**	2.237*	0.841*
	(0.395)	(0.442)	(1.133)	(0.801)	(0.431)	(1.207)	(1.151)	(0.507)
1st stage								
ln (# of WhiteWAV)	−0.125***	−0.110***	−0.069	−0.112***	−0.172***	−0.070**	−0.086*	−0.112***
	(0.029)	(0.027)	(0.042)	(0.039)	(0.054)	(0.030)	(0.044)	(0.035)
F value	336.23	321.25	214.14	132.39	123.37	233.81	161.17	170.29
Taxi supply, health care, income	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	282	281	138	143	131	150	156	125

Panel B	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var.: driver's wage	All	All	High elderly rate	Low elderly rate	High elderly growth rate	Low elderly growth rate	High expenses for the elderly	Low expenses for the elderly
	FEIV	FEIV	FEIV	FEIV	FEIV	FEIV	FEIV	FEIV
ln (operating revenue)	1.315***	1.317***	1.360**	1.485***	0.948***	1.775***	1.622***	0.981*
	(0.291)	(0.280)	(0.536)	(0.433)	(0.327)	(0.519)	(0.452)	(0.585)
1st stage								
ln (# of WhiteWAV)	−0.133***	−0.130***	−0.091***	−0.149***	−0.179***	−0.105***	−0.118***	−0.096***
	(0.023)	(0.022)	(0.030)	(0.032)	(0.038)	(0.028)	(0.031)	(0.034)
F value	381.13	348.25	309.26	152.77	193.27	186.83	253.64	113.39
Taxi supply, health care, income	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	282	281	138	143	131	150	156	125

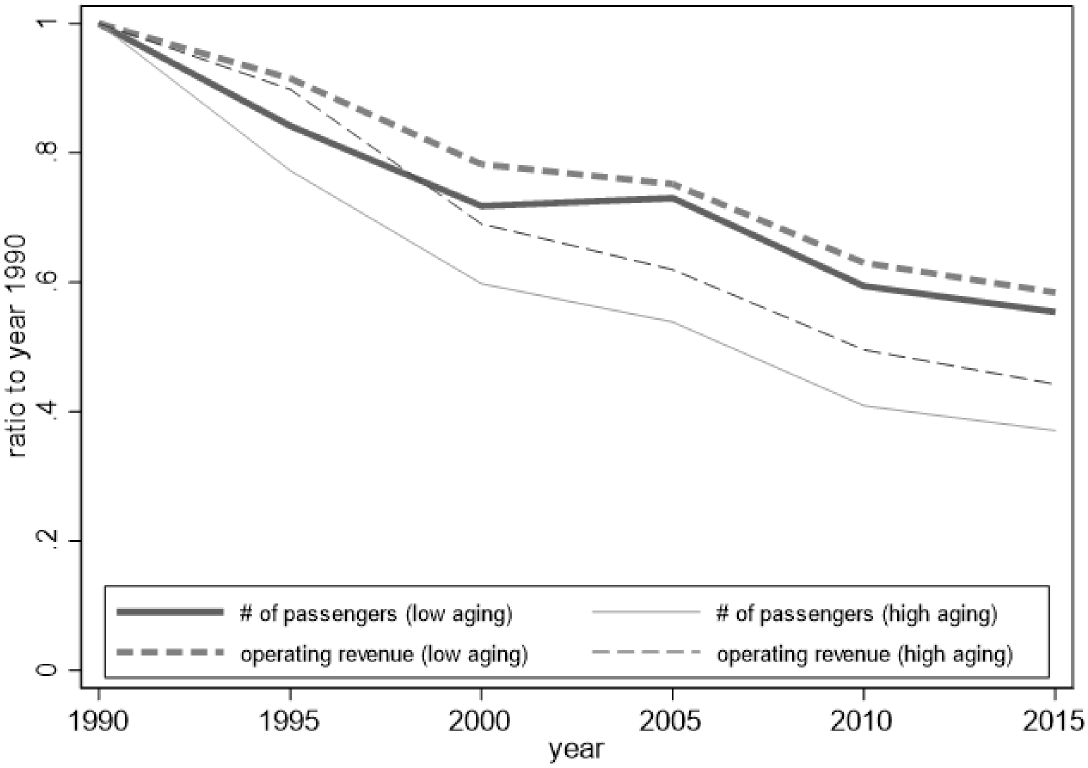
Notes: Results in the table are coefficient from FEIV estimation, using the logged number of WhiteWAV as an instrument variable. For columns 3–8, the prefectures are broken by elderly rate, elderly growth rate, and welfare expense for the elderly by average instead of using overall sample. Dependent variables are the logged taxi driver's wage. The top row of the table presents results from the second stage of FEIV estimation, with specifications in which the key independent variable is the logged number of passengers (Panel A) or the logged operating revenues (Panel B). The covariates are identical to those in Table 3. The data of Hyogo prefecture in 1995 is not available because of Hanshin-Awaji earthquake. Standard errors are in parentheses and adjusted for clusters in prefecture. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level.



Appendix Figure 1. Increase in WhiteWAVs and elderly population
Data Source: Automobile Inspection and Registration Information Association.



Appendix Figure 2. Number of trips where the origin or destination is medical or social welfare facilities
Data Source: Road Traffic Census (2005, Ministry of Land, Infrastructure, Transport, and Tourism).



Appendix Figure 3. Passenger count and the operating revenue by aging level
Data Source: Japanese Population Census (1990–2015, Ministry of Internal Affairs and Communications) and Automobile Inspection and Registration Information Association (1990–2015).