Urban Transportation Infrastructure and Poverty Reduction: Delhi Metro's Impact on the Cycle Rickshaw Rental Market

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Takashi Kurosaki[a]

Abstract

Based on a primary survey of cycle rickshaw pullers and rickshaw owners in Delhi, India, this paper estimates the causal impact of the opening and extension of Delhi Metro on the rental rates of cycle rickshaws. The cycle rickshaw rental market provides employment opportunities for unskilled, assetless workers who have migrated from rural areas because of poverty. A change in this market is thus expected to affect urban and rural poverty. Controlling for unobservable area characteristics using house tax information, we identify the causal impact using the variation in timing when Metro stations opened over the past decade. The regression results indicate that of the 1.6 percentage point increase in rental rates per km associated with a reduction in distance to a Metro station, approximately 1.0 point is attributable to the causal effect. Thus, Delhi Metro has increased the demand for cycle rickshaw services, which is a pro-poor consequence of the infrastructural investment.

Keywords: urban poverty, migration, infrastructure, informal sector, India
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[a] Institute of Economic Research, Hitotsubashi University, 2-1 Naka, Kunitachi, Tokyo 186-8603, Japan. E-mail: kurosaki@ier.hit-u.ac.jp. The author is grateful to Tahir Andrabi, Asit Banerji, Yoko Kijima, S.N. Mishra, Teiji Sakata, Prakarsh Singh, Mineo Takada, and the participants of the 2011 Meeting of the Japanese Association for South Asian Studies, the 2012 Meeting of the Japanese Economic Association, and the 2012 PacDev Conference for their useful comments on the earlier version of this paper. The funding from JSPS Grant-in-Aid for Scientific Research (22223003) is highly acknowledged.

1. Introduction

Since the early 2000s, the importance of infrastructure has grown in development economics (Bourguignon and Pleskovic, 2007). Infrastructure is now regarded as a prerequisite for sustained economic growth in developing countries, which is the key to poverty reduction. It is therefore crucial for reducing poverty in the long run at the macro level through sustaining and accelerating aggregate growth rates. At the micro level, infrastructure such as rural roads also plays an important role in reducing poverty by improving the poor's access to various markets and thus increasing their incomes (Estache, 2007).

Despite the clear importance of infrastructure, identifying its causal impact on poverty reduction is difficult, mostly because each infrastructural investment is strategic. This makes random assignment almost impossible and leaves little room for exogenous variation in project placement. Faced with this difficulty, Duflo and Pande (2007) investigate the productivity and distributional effects of large irrigation dams in India using river gradients as instrumental variables. Their estimation results show that rural poverty declined in downstream districts but increased in the districts close to dams, suggesting that neither markets nor state institutions can alleviate the adverse distributional impacts of dam construction.

Following this seminal work, studies that estimate the economic impacts of large infrastructure projects have grown. For example, Jensen (2007) evaluates how mobile phone networks in India affect the efficiency of fishermen's marketing decisions, Dinkelman (2011) estimates the impact of electrification on employment in South Africa, and Shinkai et al. (2010) examine the impact of irrigation investment on household poverty dynamics in Sri Lanka. In a study that is closer to the present paper in terms of the infrastructure chosen for analysis, Donaldson (2010) estimates the causal impact of railway expansion in the Indian subcontinent on market development. He applies three methods to cope with the endogenous railroad assignment: placebo specifications using unrealized railroad plans, instrumental variables specifications using rainfall shortages, and a bounds check.

The present paper contributes to this growing literature by estimating the causal impact of the opening and extension of Delhi Metro in India on the rental rate of cycle rickshaws. Delhi Metro is a rapid transit system that has served the National Capital Region of India since 2002, when the first section was opened. In India, as in other developing countries, modern and formal transport systems such as Delhi Metro coexist alongside traditional and informal transport systems, such as cycle rickshaws. The cycle rickshaw rental market provides employment opportunities for unskilled, assetless workers who have migrated from rural areas because of poverty (Deshingkar et al., 2006; Kurosaki et al., 2007; 2012). A change in this market is thus expected to affect both urban and rural poverty. By assessing the change in the demand for cycle rickshaw rental services since the creation of Delhi Metro, we can characterize the influence of such modern infrastructural investment.

This study is also related to another development literature on the informal sector in cities and rural–urban migration (Williamson, 1988) because cycle rickshaw pulling in Indian cities is dominated by migrants from villages. As originally modeled by Todaro (1969), individuals migrate if their expected earnings from migration are higher than what they would earn by staying. These expected earnings after migration depend on the probability of finding a job in the formal sector and the earnings differentials between formal and informal jobs in cities.

Cycle rickshaw pulling is a typical informal sector job because the government regulations rarely function. In this sector, a new migrant who does not own a cycle rickshaw can rent one from a contractor who owns surplus rickshaws. Another benefit of renting rather than owning a cycle rickshaw is that migrant rickshaw pullers can return to their villages during the peak farming period without worrying about the security of their asset. Seasonal and/or temporary migration is thus more in line with the rickshaw rental market. Several new studies in development economics have been conducted on seasonal/temporary migration (e.g., Shonchoy, 2011; Dustmann and Mestres, 2010, and references therein). By examining how the introduction of Delhi Metro has affected the informal cycle rickshaw sector, we can deepen our understanding of the informal transport sector, poverty reduction in urban areas, and rural–urban migration.

In the present analysis, we first show that rickshaw rental rates in areas close to a Metro station are higher compared with areas away from one. This comparison is, however, unlikely to provide a causal estimate of the impact of Metro stations since areas close to them are likely to differ along other dimensions, such as potential demand for transport services. In order to address this problem and to isolate the causal impact, we control for unobservable area characteristics by using information on house tax and the timing of the opening of a Metro station. The regression results indicate that the causal effect is still positive, although smaller than it first seems. We also show that daily earnings of a cycle rickshaw puller are not affected by the distance to a Metro station, while rickshaw pullers operating in areas closer to a Metro station work less hours per day than other pullers. These results indicate that the major welfare gain to each rickshaw puller from the increased demand is in more leisure time rather than in higher earnings per day. In other words, the first contribution of this paper is to identify a causal impact of an urban infrastructural project on poverty reduction in a developing country. The second contribution is to specify a microeconomic route through which a modern urban infrastructural project contributes to poverty reduction.

The remainder of the paper is organized as follows. Section 2 describes the research background and data used in this study. Section 3 explains the empirical strategy. Section 4 provides the results of the regression analysis. Section 5 concludes.

2. Data and Background

2.1 Urban Transport in Delhi

Since India began economic liberalization policies in the early 1990s, Delhi has seen a huge growth in the number of private and personal automobiles, such as cars, jeeps, motorcycles, and scooters. Public transport such as taxis, buses, and auto-rickshaws has, however, lagged behind (Kurosaki et al., 2007). In the meantime, the coverage of Delhi Metro is continuing to expand. Its first section opened in December 2002 and by the end of 2010, it was recognized as one of the largest Metro networks in the world (Ramachandran, 2012). Figure 1 shows the expansion of Delhi Metro in terms of its number of stations.

Such developments in modern modes of transport have not, however, displaced traditional modes such as cycle rickshaws, handcarts, and tongas. The city has retained a demand for these traditional modes. In particular, cycle rickshaw pullers often transport people in residential areas of the city as well as on its outskirts. It is even possible that the demand for short-distance transport from a Metro station to individual houses or stores will increase once citizens become accustomed to traveling in an air-conditioned Metro coach. Such demand is more likely to be facilitated by cycle rickshaws, because auto-rickshaws rarely service short-distance travel requests.

For regulatory purposes, cycle rickshaws fall within the jurisdiction of the Municipal Corporation of Delhi (MCD).[1] According to MCD statistics, the number of cycle rickshaws in Delhi increased rapidly during the late 1990s, from a little over 46,000 in 1995/96 to over 70,000 in 1999/2000; however, the statistics show erratic trends since then, possibly because of the MCD's failure to keep correct records (Kurosaki et al., 2007).

The use of cycle rickshaws is regulated by the Cycle Rickshaw Bye-Laws of 1960 framed under the Delhi Municipal Corporation Act of 1957 (66 of 1957) and its subsequent amendments. The cycle rickshaw sector must abide by the following three main rules (MCD, 2008):

(1) No person shall keep or ply for hire a cycle rickshaw in Delhi unless he himself is the owner thereof and holds a license granted in that behalf by the MCD.

(2) No person will be granted more than one such license (Provided further that commissioner may grant more than one license to a widow or a handicapped subject to a maximum of five licenses).

(3) No person shall drive a rickshaw for hire unless he holds a driving license granted in that behalf by the commissioner.

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[1] The National Capital Territory (NCT) of Delhi is divided into three areas: MCD; the city centre area covered by the New Delhi Municipal Council, where the union Government has its seat; and the area under the Delhi Cantonment Board. Cycle rickshaws are not permitted to trade in the latter two. However, the population residing in the latter two areas represents less than 3% of the total NCT population.

Thus, two licenses are necessary: one for the owner of the rickshaw and the other for its driver (e.g., a driving license). However, in reality, a migrant rickshaw puller neither knows nor cares about the formal system of rickshaw transport in Delhi described above. All he does is to go to an entity called an owner-contractor (*Thekedar*), usually through an acquaintance, rent a cycle rickshaw, use it, return it, and pay the rent to the contractor on time. If caught for an infringement of law, he points this out to his contractor who, in turn, deals with the concerned MCD or police official. Despite this critical role played by *Thekedars*, they are not recognized as a legal entity and as such carry on their businesses in contravention of the MCD bye-laws. The MCD, the regulatory authority for rickshaw transport, knows only the number of rickshaw licenses it has issued. According to the latest information reported in the first column of Table 1, the total number of cycle rickshaw licenses issued in Delhi is approximately 84,000. However, it is a common perception that there are many times more rickshaws than the number licensed (Kurosaki et al., 2007).

These MCD regulations were attacked in courts by several NGO groups who made the plea that the regulations were discriminatory because no such cap on motor vehicles exists and against the fundamental right of property rights. In April 2012, the Supreme Court of India upheld the plea, implying that any individual can own as many rickshaws as they can afford to purchase and the holder of a driving license need not be the owner of a rickshaw. The court then directed the MCD to prepare a comprehensive plan to streamline cycle rickshaw operations in Delhi. By the timing of this writing, however, no concrete reforms have been implemented and the uncertain policy situation is likely to continue for some time to come (Kurosaki et al., 2012).

2.2 Primary Survey in 2010/11

On the basis of an earlier pilot survey of rickshaw pullers in a north-east district of Delhi (Kurosaki et al., 2007), we surveyed cycle rickshaw pullers and *Thekedars* in order to draw a representative picture of the current rickshaw sector in Delhi (Kurosaki et al., 2012). The survey was conducted in December 2010−February 2011, using structured questionnaires in Hindi. In the survey, we collected information on a number of factors: the social characteristics of rickshaw pullers and owner-contractors, their migration statuses, the forward and backward linkages regarding migration, the economic situations of migrants in their places of origin, earnings and living conditions in Delhi, rickshaw rental contracts, debt and credit situations, the licensing of rickshaws, opinions on treatment by police and MCD officials, microfinance facilities, and the impact of Delhi Metro on rickshaw transport.

Given the absence of a formal register of the population of rickshaw pullers and *Thekedars*, drawing a representative sample was a challenging task. To overcome this problem, we adopted an areal approach following Minten et al. (2010), who surveyed informal street vendors in Delhi. In the areal approach, the administrative tiers in Delhi are used as the sampling framework. The first tier is termed a zone. There are 12 zones in the MCD, out of which 11 have licensed rickshaw pullers. The present survey thus covered these 11 zones of the MCD (the excluded zone was the south zone). In each zone, two wards, and then from each ward, five colonies were randomly selected for the survey. A colony is a term used by the MCD to indicate a residential area.

In order to sample rickshaw pullers in the sample colonies, the field investigator first carried out a census survey to find out how many focal points (in this case, rickshaw stands) were in the colony and how many rickshaw pullers were in each stand. The researcher then selected two focal points randomly, and finally selected six rickshaw pullers randomly from the census list of rickshaw pullers in the selected focal point. This provided a sample of 12 rickshaw pullers in each selected colony, 60 (12 × 5) in each selected ward, and 120 (60 × 2) in each selected zone, resulting in a total sample of 1,320 rickshaw pullers (120 × 11).

By combining the list of all colonies and wards in each zone obtained from the MCD with our sample data, we calculated the sampling probability, from which we estimated the population of rickshaw pullers in MCD areas. The estimate obtained is reported in the middle columns of Table 1. The point estimate for the total population of approximately 104,000 is larger than the number of licenses issued but smaller than indicated by common perception. Conceptually, we estimated the total number of rickshaw pullers working on the survey day, which may be smaller than the actual number of potential rickshaw pullers.[2]

In order to sample *Thekedars*, we selected six contractors from each selected ward in a zone, resulting in a sample of 132 contractors across the 11 zones. The number of rickshaws owned by the sampled *Thekedars* ranged from six to 500, with an average of 55.5 (standard deviation 58.7). From each respondent, information on the number of *Thekedars* in the colony or ward in which he operates was collected. From this, we estimated the population of rickshaws owned by *Thekedars*. Conceptually, the total number of cycle rickshaws owned by them was closer to the total number of potential rickshaw pullers and larger than the number of rickshaw pullers actually working on the survey day. The point estimate for the total population was approximately 440,000 (last column of Table 1), which is much larger than the other two estimates. However, because of the small sample size, this estimate may be imprecise.

2.3 Characteristics of Sample Rickshaw Pullers

As shown in Table 2, more than 98% of sample rickshaw pullers have their permanent address outside Delhi. In this broader sense, the majority of cycle rickshaw pullers in Delhi are

[2] Another reason for this underestimation may be that we missed smaller focal points in the census survey (Kurosaki et al, 2012).

migrants. We can instead adopt a stricter definition of a migrant rickshaw puller by classifying a puller as a migrant by meeting all four of the following criteria: permanent address outside Delhi; no ration card for the Public Distribution System in Delhi; not registered for election in Delhi; and sends remittance to his family in his home village. Under this strict definition, 68.2% of sample rickshaw pullers in our sample are migrants.

The largest origin state for migrant rickshaw pullers is Bihar. This is consistent with the result based on the 64th National Sample Survey that the state of Bihar accounts for the largest number of temporary and seasonal migrants in India (Keshri and Bhagat, 2012). Because of network-based migration (Kurosaki et al., 2012), migrants from one district tend to concentrate on one zone. In Table 2, the null hypothesis of independence between origin places and current zones of residence is rejected at the 0.1% level. Thus, the tendency for migrants to be spatially concentrated according to their origin places is statistically significant.

Table 3 shows the socio-economic statuses of sample rickshaw pullers.[3] First, their education levels are low. Approximately 45% of them are illiterate, while only 6.2% went to secondary school or more. Second, the shares of scheduled castes (SC), schedules tribes (ST), and Muslims are above average. These two characteristics imply that cycle rickshaw pullers are from the lower stratum of Indian society. Regarding the ages of rickshaw pullers, the majority are in their twenties or thirties. Among elder rickshaw pullers, the percentage of illiterate persons is higher than it is among younger pullers.

Of the 1,320 sampled rickshaw pullers, 91% (1,205) use a rental rickshaw owned by a *Thekedar*. In all cases, the contract is a fixed rental per day, paid every day when the rickshaw is returned. To avoid the rickshaw puller disappearing with the rickshaw, the majority of *Thekedars* use a surety man as a substitute for collateral. The rental rate ranges between Rs. 25 and Rs. 60 per day, with an average of Rs. 37.6 and median of Rs. 40 per day.[4] Figure 2 plots rickshaw rental rates against the distance from the rickshaw stand to the nearest Metro station. The maximum distance to the nearest Metro station in our sample is 15 km. The figure shows a negative correlation, suggesting that rickshaw rental rates tend to be higher when rickshaws are rented close to Metro stations.

In our survey, several sample rickshaw pullers and *Thekedars* attributed higher rental rates to the higher demand for rickshaw pulling services driven by the opening and extension of Delhi Metro. As shown in Table 4, approximately 42% of *Thekedars* replied that the opening of Delhi Metro had increased demand and 58% replied that demand is expected to increase as Delhi Metro is further extended. More than 60% of *Thekedars* replied that this increased demand did and will accelerate the migration inflow of rickshaw pullers into Delhi. Among

[3] See Kurosaki et al. (2012) for details of the socio-economic characteristics of sample rickshaw pullers and *Thekedars*.
[4] "Rs" refers to the Indian rupees. At the time of our survey, US$1 was approximately equal to Rs. 45.1.

rickshaw pullers, more than 70% replied that they prefer to work near a Metro station because either there are more customers there or each customer pays a higher amount for the service (Table 5). These figures imply that the opening and extension of Delhi Metro has benefitted cycle rickshaws. Nevertheless, we need to interpret them with care because they are subjective in nature.

3. Empirical Strategy

Because the rental rates described in section 2 are considered precise after cross-checking with *Thekedars*, we focus on the impact of Delhi Metro on the rickshaw rental rate in this paper.[5] If we observe an increase in rental rates induced by Delhi Metro, we can conclude that the demand for cycle rickshaw services has increased because of the expansion of Delhi Metro, under the assumption that very few other changes in the supply side of the rickshaw rental business have occurred over the past decade. Our informal discussions with sample *Thekedars* indeed confirmed this assumption. We also examine the primary data of 132 *Thekedars* and find that neither the entry timing nor the business expansion since the entry is correlated with the opening timing of the nearest Metro station.[6]

The negative correlation shown in Figure 2 could reflect the mixture of the causal effect of Metro stations and the selection effect of their endogenous placement. In other words, the regression curve shown in the figure is unlikely to provide a causal estimate of the impact of the opening of Metro stations because colonies and rickshaw stands close to stations are likely to differ along other dimensions, such as potential demand for transport services.

To address this problem, we control for unobservable area characteristics in three ways. First, because a zone is the basic administrative unit within the MCD, each has characteristics that reflect its differences in urban policy as well as areal development. Therefore, we control such unobservable characteristics by zone fixed effects.

Second, within a zone, residential areas are diverse, ranging from luxurious residential areas for the middle class to (quasi-)slums. Such diversity is expected to affect both the demand and the supply of rickshaw rental services. To proxy for this diversity, we use the information on house tax categories. In order to calculate the house tax incurred by homeowners, the MCD assigns a category to each colony. There is no variation in the tax rate within a colony since it is

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[5] To infer the impact of Delhi Metro on each rickshaw puller's welfare, we also run regressions with the dependent variable replaced by a rickshaw puller's daily earnings (net of the rental fee and maintenance costs) and daily working hours. The measures are based on subjective responses regarding "average" earnings (working hours) per day, as reported by sample rickshaw pullers.

[6] The distribution of the entry year was fairly smooth, uncorrelated with the opening of Metro stations. The business expansion was measured by the growth of the number of rickshaws owned by each *Thekedar* from the business establishment year to the survey date. After controlling for the firm vintage effect, the exposure length with the Metro station was not correlated with the business expansion measure. The regression results are available on request.

usually a homogeneous residential area. Eight categories that range from "A" (most luxurious area) to "H" (least luxurious) are published on the MCD website.[7] Our sample of rickshaw pullers operate in colonies classified in seven of these eight categories (no sample was taken from colonies classified as "H"). Thus, we include fixed effects for these seven categories. Using these two sets of fixed effects should minimize the bias due to endogenous placement.

Third, to control for a possibility that even after controlling for these fixed effects, the selection on unobservables may dilute our estimate, we use the information when Metro stations opened, as shown in Figure 1. The unobservable impact of the endogenous placement of a Metro station on rental rates should be similar regardless of whether our survey was carried out a sufficient period after the Metro station opened or immediately after. However, the causal impact of the Metro station opening should have been fully realized for a station that opened well before our survey was carried out, but not for a recently opened Metro station. Therefore, if our control using these two sets of fixed effects successfully eliminates the selection effect, the coefficient on the distance to a Metro station (both new and old) should be zero, while that on the distance to an older Metro station should remain negative. Allowing the coefficient on the distance to differ according to the age of the nearest Metro station enables us to examine the appropriateness of our fixed effects specification strategy. In other words, the coefficient on the distance to a Metro station (both new and old) serves as a placebo test.

4. Regression Results

4.1 Impact on Cycle Rickshaw Rental Rates

The main regression results are reported in Table 6. The columns named "model 1" and "model 3" show the bivariate regression results. The coefficients on the distance to the nearest Metro station are negative and statistically significant, confirming the casual observation of the scatter plot (Figure 2). Therefore, rental rates in colonies close to a Metro station are higher than they are in colonies further away from one. According to the results in model 1, the rental rate increases by Rs. 0.58 as the distance is reduced by 1 km. According to the results in model 3, the rental rate increases by 1.6% as the distance is reduced by 1 km (or a 5.05% increase as the distance is reduced by one standard deviation).

This comparison is, however, unlikely to provide a causal estimate of the impact of the opening of Metro stations because areas close to a Metro station could be different along other dimensions. To eliminate selection effects from these estimates, we control for unobservable area characteristics using zone fixed effects and house tax classification fixed effects and by distinguishing new and old Metro stations. After adding these correlates (see the columns

[7] The list of colonies distinguished by their house tax categories was obtained from the MCD website (http://www.mcdonline.gov.in/), accessed on July 22, 2010.

named “model 2” and “model 4” in Table 6), the coefficients on the distance to the nearest Metro station that opened by January 2010 (*distance***D_old*) reduce but remain statistically significant. By contrast, with these fixed effects, the coefficients on the distance to the nearest Metro station regardless of its opening timing (a placebo effect) become insignificant. Thus, the placebo test is passed and the coefficients on *distance***D_old* are likely to identify the causal impact of the opening of Metro stations on the rickshaw rental market.

The results in model 2 indicate that the rental rate increases by Rs. 0.31 as the distance is reduced by 1 km and the results in model 4 indicate that the rental rate increases by 0.97% as the distance is reduced by 1 km. The magnitude of the causal impact is thus smaller than the total impact of causal and selection effects. Positive selection effects confirm the expectation that areas near to a Metro station have unobservable characteristics that raise the demand for rickshaw rental services (presumably because the demand for rickshaw plying services is high).

In model 5, we include rickshaw pullers’ characteristics such as age, education, religion, and caste background. In Table 6, only those additional variables that have significant coefficients are reported. We find that Muslim and illiterate rickshaw pullers tend to rent a rickshaw at a higher price, suggesting (a) their tendency to rent better rickshaws, (b) the existence of discrimination against them, or (c) their lower bargaining power. Whatever the reason, the important point from the results in model 5 is that the addition of these characteristics does not affect the coefficients on the distance to a Metro station. Rental rates are higher by 1.0% (significant at the 5% level) as the distance to an old Metro station is reduced by 1 km, while they are not affected by the distance to a Metro station in general (without distinguishing new or old).

The results reported in Table 6 are robust to alterations such as changes in threshold month in order to separate new and old Metro stations, the weighting that reflects the sampling structure, the addition of survey date fixed effects to control for daily demand fluctuations such as rainfall, and the addition of survey investigator fixed effects to control for the measurement error specific to investigators. The coefficients on *distance***D_old* and *distance* in models 2, 4, and 5 under the alternate specifications remained very similar to those reported in Table 6 and the additional fixed effects were jointly insignificant. These robustness check results are available on request.

4.2 Impact on a Rickshaw Puller’s Daily Earnings and Working Hours

Given that there occurred very few changes in the supply side of the cycle rickshaw rental market associated with the opening of a Metro station, the regression results shown in the previous subsection indicate that demand for rickshaw rental services increased as the Metro service expanded. The natural interpretation of this increased demand for rickshaw rental services is an increased demand for rickshaw plying services. In other words, the regression results in Table 6 provide objective evidence for the claim in the first panel of Table 4 (several sampled *Thekedars* thought that the demand for rickshaw pulling services was an increasing function of extended Metro services).

In order to assess the impact of Delhi Metro on each rickshaw puller's welfare in a more direct way, this subsection reports the regression results with the dependent variable replaced by a puller's daily net earnings. The results are reported in Table 7. In specifications in models 2, 4, and 5, the coefficients associated with the distance to the old and nearest Metro station (*distance***D_old*) were all insignificant, indicating the absence of an impact of Metro opening on rickshaw pullers' net earnings. This lack of impact was confirmed robustly using similar alterations.

However, the results in Table 7 do not imply that the welfare of rickshaw pullers is not affected by the distance to the nearest Metro station. As Table 8 shows, rickshaw pullers operating in areas closer to a Metro station work significantly less hours per day than other pullers. Per-day working hours are lower by 0.154 hours or 9.25 minutes (model 2) or by 1.54 % (model 4) as the distance to an old Metro station is reduced by 1 km. The significant partial correlation between per-day working hours and the distance to an old Metro station was confirmed robustly using similar alterations.

Because of the decline in working hours per day (Table 8), the daily earnings of rickshaw pullers closer to an old Metro station were not affected by the distance to it (Table 7). Considering the hard work of rickshaw pulling, an income effect on rickshaw pullers' labor supply to reduce working hours in response to high demand makes perfect sense.[8]

Our results thus suggest that Delhi Metro created more employment opportunity for the migrant population in the form of cycle rickshaw pulling (similar earnings per day from reduced hours of working), although we have to be careful in drawing a firm conclusion due to potential measurement error in per-day earnings and working hours. Furthermore, the increased rental rates imply that each *Thekedar* earned more as a result of the enhanced demand, for which we are quite confident that measurement error is not serious. Nevertheless, because *Thekedars* are generally not wealthy people (Kurosaki et al., 2012), the majority of whom belong to the lower middle class, we can conclude that the overall impact of the Metro expansion on the cycle rickshaw sector can be seen to have been advantageous to poorer Indian

[8] The behavior of reducing taxi labor supply when there is high demand for taxi service is irrational from the standard neoclassical viewpoint if the demand increase is *temporary* (such as daily demand fluctuations). Whether or not New York City taxi drivers behave in this way has been thoroughly investigated in the literature (see e.g., Crawford and Meng, 2011, and references therein). In the current case of cycle-rickshaw-taxi drivers, the demand increase due to the opening of a Metro station is more *permanent* than the NYC taxi case. Therefore, the behavior of reducing taxi labor supply in response to high taxi demand is rational.

residents.

5. Conclusion

This paper estimated the causal impact of the opening and further extension of Delhi Metro on the cycle rickshaw sector, based on a primary survey of cycle rickshaw pullers and rickshaw owners in Delhi. We identified this causal effect by controlling for unobservable area characteristics, using the information on house tax and the timing when different Metro stations opened over the past decade. The regression results indicated that out of the 1.6 percentage point increase in the rental rate per km associated with a reduction in the distance to a Metro station, approximately 1.0 point could be attributable to the causal effect of the Metro expansion. In addition, the regression results suggested that the rickshaw pullers operating in places near a Metro station were able to earn from significantly lower work hours an amount similar to other rickshaw pullers. Since the cycle rickshaw rental market provides employment opportunities for unskilled, assetless workers who have migrated from rural areas because of poverty, the presented results suggest that a modern transport infrastructure such as Delhi Metro could contribute to the urban poverty reduction through the following route. It first increases the demand for traditional transport services such as cycle rickshaws, which results in higher per-capita earnings by rickshaw owners, more rickshaw pullers working in the city, and lower work hours of each rickshaw puller per day with similar levels of earnings. In this sense, the opening and extension of Delhi Metro could be termed as a pro-poor infrastructural investment.

One caveat of the analysis described in this paper is its partial equilibrium nature. New migrants induced to work as cycle rickshaw pullers in Delhi may have had other employment opportunities if Delhi Metro had not increased the demand for cycle rickshaw pulling services. Furthermore, other competing transport services could have responded to this increased demand. Providing further support to the findings shown in this paper by incorporating general equilibrium effects (e.g., at the urban transport sector level as a whole) is left to further research. Analyzing the dynamic changes in rickshaw puling more rigorously is another avenue for future research, for which another survey of the sector in question is under preparation.

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Table 1. Estimated number of cycle rickshaws in Delhi

Zone name	Number of licenses issued	Estimated number of rickshaw pullers based on the areal approach				Estimated number of rickshaws owned by *Thekedars*
		Number	Standard error	95% confidence interval		
				Lower bound	Upper bound	
City	2,429	5,490	678	3,957	7,023	25,443
Central	1,959	4,998	374	4,153	5,843	15,662
South	0	0	0	0	0	0
Karol Bagh	1,980	4,064	330	3,318	4,810	15,668
Sadar Paharganj	2,000	2,089	187	1,666	2,513	9,598
West	14,000	22,370	1,366	19,280	25,460	104,154
Civil Lines	10,000	5,115	293	4,452	5,777	36,238
Shahdara (N)	17,109	12,712	1,675	8,923	16,501	76,494
Shahdara (S)	16,615	11,400	1,463	8,090	14,710	63,648
Rohini	7,854	9,610	1,019	7,304	11,915	49,112
Narela	3,197	6,671	347	5,885	7,457	6,469
Najafgarh	7,234	19,760	1,654	16,018	23,503	39,475
Total	84,377	104,279	3,421	97,491	111,068	441,960

Source: Kurosaki et al. (2012), Table 2.3. The original information for the number of licenses issued was directly collected from MCD offices. All other numbers were estimated using the primary data mentioned in the text.

Table 2. Distribution of sample rickshaw pullers by their permanent addresses and MCD zones

	Total	{column %}	Top two zones (if *n* >4)					
			Zone name	*n*	(%)	Zone name	*n*	(%)
Bihar$	688	{52.12}	Rohini	91	(13.2)	Najafgarh	77	(11.2)
Bihar-Banka	41	{3.11}	Civil Lines	14	(34.1)	West	11	(26.8)
Bihar-Begusarai	40	{3.03}	West	18	(45.0)	Sadar Paharganj	8	(20.0)
Bihar-Darbhanga	100	{7.58}	Rohini	29	(29.0)	Civil Lines	20	(20.0)
Bihar-Madhubani	49	{3.71}	Sadar Paharganj	12	(24.5)	Civil Lines	11	(22.4)
Bihar-Muzaffarpur	44	{3.33}	Najafgarh	9	(20.5)	Rohini/Shahdara(S)	8	(18.2)
Bihar-Samastipur	93	{7.05}	Najafgarh	25	(26.9)	West	23	(24.7)
Bihar-others	321	{24.32}	Central	42	(13.1)	Rohini	38	(11.8)
Delhi	18	{1.36}	Civil Lines	6	(33.3)			
Madhya Pradesh	48	{3.64}	Karol Bagh	26	(54.2)	Civil Lines	5	(10.4)
Other states*	15	{1.14}						
Rajasthan	11	{0.83}						
UP	499	{37.80}	Shahdara(N)	76	(15.2)	Shahdara(S)	69	(13.8)
UP-Budaun	49	{3.71}	Shahdara(N)	10	(20.4)	City/Narela	10	(20.4)
UP-Gonda	43	{3.26}	Sadar Paharganj	18	(41.9)	Central	9	(20.9)
UP-Shahjahanpur	64	{4.85}	Karol Bagh	33	(51.6)	Shahdara(N)	11	(17.2)
UP-others	343	{25.98}	Shahdara(S)	56	(16.3)	Shahdara(N)	53	(15.5)
West Bengal	41	{3.11}	City	16	(39.0)	Central	14	(34.1)
Total	1,320	{100.00}						

Notes:

The null hypothesis of independence: $chi^2(150) = 991.95$, p -value = 0.000.

$"Bihar" includes nine rickshaw pullers whose permanent addresses are in Jharkhand.

*"Other states" = Assam (1), Haryana (5), Himachal Pradesh (1), Nepal (5), and Punjab (3).

Source: Compiled by the author from primary data on sample rickshaw pullers. The source is the same for the following tables and figures.

Table 3. Socio-economic statuses of sample rickshaw pullers

	Education					{column %}	*p* -value
	Illiterate	Primary (5 yrs)	Middle (8 yrs)	Secondary & more	Total		
Total	596	502	140	82	1,320	{100.00}	
(row %)	(45.15)	(38.03)	(10.61)	(6.21)	(100.00)		
By community group							0.000
SC (Scheduled Castes)	83	78	39	14	214	{16.21}	0.001
	(38.79)	(36.45)	(18.22)	(6.54)	(100.00)		
ST (Scheduled Tribes)	61	32	13	9	115	{8.71}	0.123
	(53.04)	(27.83)	(11.30)	(7.83)	(100.00)		
Hindu OBC (Other Backward Classes)	260	232	65	44	601	{45.53}	0.362
	(43.26)	(38.60)	(10.82)	(7.32)	(100.00)		
Other Hindu	60	63	11	10	144	{10.91}	0.347
	(41.67)	(43.75)	(7.64)	(6.94)	(100.00)		
Muslim	131	97	12	4	244	{18.48}	0.000
	(53.69)	(39.75)	(4.92)	(1.64)	(100.00)		
Other religion	1	0	0	1	2	{0.15}	0.067
	(50.00)	(0.00)	(0.00)	(50.00)	(100.00)		
By age group (min=16, max=70)							0.001
Teens	24	20	4	6	54	{4.09}	0.434
	(44.44)	(37.04)	(7.41)	(11.11)	(100.00)		
20-29	178	203	47	25	453	{34.32}	0.003
	(39.29)	(44.81)	(10.38)	(5.52)	(100.00)		
30-39	216	160	59	26	461	{34.92}	0.107
	(46.85)	(34.71)	(12.80)	(5.64)	(100.00)		
40-49	116	80	24	24	244	{18.48}	0.029
	(47.54)	(32.79)	(9.84)	(9.84)	(100.00)		
50+	62	39	6	1	108	{8.18}	0.007
	(57.41)	(36.11)	(5.56)	(0.93)	(100.00)		

Notes:

"*p* -value" reports the probability value of chi-squared test statistics for the null hypothesis that row and column distributions are independent. When the index takes more than two categories, the first row reports the test of the indicator variable, while the next rows report the test for a dummy variable taking one for each category.

Table 4. Delhi Metro's impact according to *Thekedars* ' opinions

	How did the opening of Delhi Metro affect the rickshaw sector?		How will the further extension of Delhi Metro affect the sector?	
Demand for rickshaw pulling service				
Increase	56	(42.42)	77	(58.33)
No change	64	(48.48)	33	(25.00)
Decrease	12	(9.09)	6	(4.55)
Do not know	0	(0.00)	16	(12.12)
Total	132	(100.00)	132	(100.00)
Inflow of rickshaw pullers from outside				
Increase	81	(61.36)	88	(66.67)
No increase	24	(18.18)	11	(8.33)
Decrease	0	(0.00)	0	(0.00)
Do not know	27	(20.45)	33	(25.00)
Total	132	(100.00)	132	(100.00)

Note: Percentage of the total is reported in parentheses.

Table 5. Question to rickshaw pullers: Do you prefer to work near a Metro station? If yes, why?

	Number	%
Yes	946	(71.67)
More customers near a Metro station	610	(46.21)
Customers pay higher amount	336	(25.45)
Other	0	(0.00)
There is no Metro station near here	99	(7.50)
No	275	(20.83)
Total	1,320	(100.00)

Table 6. Correlates of cycle rickshaw rental rates in Delhi

	Dep.var = *rental*		Dep.var = ln(*rental*)		
	model 1	model 2	model 3	model 4	model 5
distance	-0.5781***	0.2304	-0.0158***	0.0070	0.0073
	[0.0372]	[0.1652]	[0.0010]	[0.0047]	[0.0047]
*distance*D_old*		-0.3110**		-0.0097**	-0.0104**
		[0.1475]		[0.0042]	[0.0042]
Muslim dummy					0.0255***
					[0.0084]
Illiterate dummy					0.0202***
					[0.0067]
Zone fixed effects	No	Yes	No	Yes	Yes
House tax classification fixed effects	No	Yes	No	Yes	Yes
Rickshaw puller's characteristics	No	No	No	No	Yes
R-squared	0.100	0.450	0.109	0.454	0.464
F-statistics	241.8***	92.6***	240.2***	104.9***	84.4***

Notes: The number of observations is 1,205. Statistically significant at * p <0.1, ** p <0.05, and *** p <0.01. Heteroskedasticity-robust standard errors are reported in brackets.

In model 5, five additional dummy variables for Muslim, Illiterate, SC, ST, and Bihari are added. Coefficients on SC, ST, and Bihari were insignificant so that they are not reported here.

Statistics (mean, s.d., min, and max) of variables used in the regression analysis: *rental* [in Rs.] (37.58, 5.84, 25, 60), ln(*rental*) (3.615, 0.153, 3.22, 4.09), *distance* [in km] (3.056, 3.199, 0, 15). Mean of dummy variables: *D_old* [dummy variable for Metro station opened by January 2010] = 0.774, *Muslim dummy* = 0.193, *Illiterate dummy* = 0.445.

Table 7. Correlates of a rickshaw puller's daily net earnings in Delhi

	Dep.var = *earning*		Dep.var = ln(*earning*)		
	model 1	model 2	model 3	model 4	model 5
distance	0.4435	1.8355	0.0058***	0.0097	0.0104
	[0.4573]	[1.9314]	[0.0021]	[0.0092]	[0.0095]
*distance*D_old*		-1.1274		-0.0064	-0.0079
		[1.7392]		[0.0083]	[0.0085]
Zone fixed effects	No	Yes	No	Yes	Yes
House tax classification fixed effects	No	Yes	No	Yes	Yes
Rickshaw puller's characteristics	No	No	No	No	Yes
R-squared	0.001	0.089	0.004	0.110	0.130
F-statistics	0.941	7.510***	7.588***	7.414***	7.457***

Notes: The number of observations is 1,320. Statistically significant at * p<0.1, ** p<0.05, and *** p<0.01. Heteroskedasticity-robust standard errors are reported in brackets.

Statistics (mean, s.d., min, and max) of the dependent variables used in the regression analysis: *earning* [in Rs.] (222.3, 68.1, 70, 460), ln(*earning*) (5.356, 0.311, 4.248, 6.131).

Table8. Correlates of a rickshaw puller's daily hours of work in Delhi

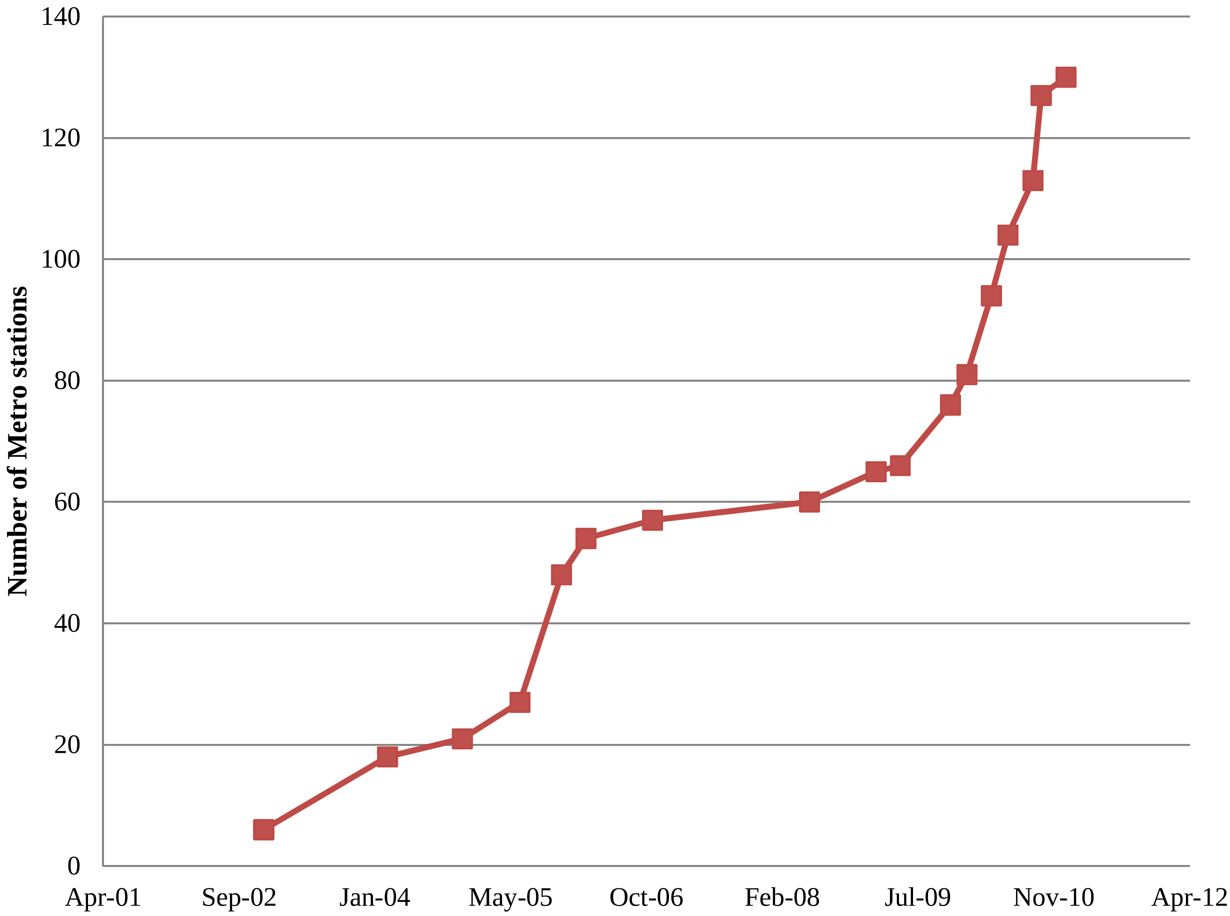
	Dep.var = *workhrs*		Dep.var = ln(*workhrs*)		
	model 1	model 2	model 3	model 4	model 5
distance	-0.0196	-0.1101	-0.0006	-0.0098	-0.0091
	[0.0157]	[0.0806]	[0.0017]	[0.0085]	[0.0085]
*distance*D_old*		0.1542**		0.0154**	0.0145*
		[0.0729]		[0.0077]	[0.0078]
Zone fixed effects	No	Yes	No	Yes	Yes
House tax classification fixed effects	No	Yes	No	Yes	Yes
Rickshaw puller's characteristics	No	No	No	No	Yes
R-squared	0.001	0.162	0.000	0.146	0.150
F-statistics	1.56	13.59***	0.125	13.17***	10.76***

Notes: The number of observations is 1,320. Statistically significant at * p<0.1, ** p<0.05, and *** p<0.01. Heteroskedasticity-robust standard errors are reported in brackets.

The dependent variable *workhrs* was calculated by {(the hours of work in a typical day)*(the number of days worked in the last 15 days)/15}.

Statistics (mean, s.d., min, and max) of the dependent variables used in the regression analysis: *workhrs* [in hrs] (9.73, 2.20, 3.6, 16), ln(*workhrs)* (2.249, 0.231, 1.281, 2.773).

Figure 1. Expansion of Delhi Metro until January 2011



Source: Compiled by the author from data obtained from Delhi Metro's webpage (http://www.delhimetrorail.com/, accessed on April 18, 2011)

Figure 2. Distribution of rickshaw rental rates among sample rickshaw pullers