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Are Ride-Hailing Services and Public Transport Complements or Substitutes?

Evidence from the Opening of Jakarta's MRT System

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Abstract

Motorbike-based ride-hailing services are widespread in many of the most congested cities in the developing world. These services often predate the construction of modern public mass rapid transit systems. Ride-hailing services may complement such investments by providing important first and last mile connectivity. However, it has also been argued that they undermine the viability of mass rapid transit systems as people prefer to use ride-hailing services given their convenience and low prices. This paper applies an event study research design to proprietary, high-frequency data from one of Indonesia's largest ride-hailing services, Gojek. The findings show that the opening of stations on Jakarta's first mass rapid transit line led to large increases in ride-hailing activity in the immediate vicinities of the stations. This was accompanied by a significant decline in the average distance of ride-hailing trips to and from the station locations. These findings are consistent with ride-hailing services complementing public transport by providing first and last mile connectivity to the newly opened mass rapid transit system. Interestingly, this holds for both commuting and non-commuting trips and is strongest for mass rapid transit station locations that were not already served by Jakarta's bus rapid transit system.

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1. Introduction

Motorbike-based ride-hailing services have grown exponentially in many of the heavily congested cities in the developing world. While this growth has expanded the mobility options of urban residents, it has also prompted fears that the convenience and low prices of these services are undermining the viability of public transport investments, with potentially negative repercussions for traffic congestion, greenhouse gas emissions, local air pollution levels, and, through these, the health and productivity of a city's residents. Against this, however, it has also been argued that, far from being substitutes for public transport, ride-hailing services may, in fact, be complements due to the first- and last-mile connectivity that they provide. A trip from, say, the workplace to home that involves public transport for the main portion of the trip plus use of a ride-hailing service for the first and/or last mile of the trip may offer a more convenient, less costly, and/or less polluting transportation option than was hitherto available.[1]

In this paper, we empirically investigate whether ride-hailing services and public transport are substitutes or complements in such a developing country city context. In particular, we examine the impacts of the staggered opening of Jakarta's mass rapid transit (MRT) system on the use of ride-hailing services in the immediate neighborhoods of newly opened MRT stations. In doing so, we take advantage of (anonymized) spatially very fine-grained daily ride-hailing activity data from *Gojek*, which, together with *Grab*, dominates the Indonesian ride-hailing market, as well as daily tap-in and tap-out data from Jakarta MRT.

Jakarta officially opened its first MRT line, which consists of 13 stations, on March 24, 2019. This opening, however, was staggered in the sense that it was immediately preceded by a 12-day limited public trial during which no charge was made for use of the metro, but ridership was capped. This was followed by a further one-week period during which users could continue to ride the MRT for free. On April 1, 2019 fares were introduced, but still at a 50 percent discount. On May 13, 2019 full fares started to be charged. Using an event study research design, we examine how this staggered opening of Jakarta's first MRT line impacted *Gojek* activity – defined as the sum of the number of trips originating (pick-ups) and terminating (drop-offs), as well as the average distance of those trips, within 50 and 100-meter radii of the newly opened MRT stations – relative to that in a set of control locations. These control locations consist of both planned, but not yet opened, station locations on the next phase of Jakarta's MRT system, as well as locations on the newly opened MRT line in-between the actual stations.

Overall, we find strong evidence in favor of the complementarity hypothesis. Relative to the control locations, the opening of Jakarta's MRT system had a large, positive impact on the number of ride-hailing

[1] See Gendron-Carrier *et al.* (2022) for evidence of beneficial effects of the opening of mass rapid transit systems on both local levels of air pollution and health for initially highly polluted cities. Heger *et al*. (2019) provide similar evidence for the extension of Cairo's metro line in the Arab Republic of Egypt.

trips in the neighborhoods of the newly opened stations that, moreover, steadily increased over time. Moreover, the number of daily *Gojek* pick-ups and drop-offs at the newly opened MRT stations and the total number of tap-outs (i.e., exits from) and tap-ins (i.e., entries into) the MRT system are positively associated. To be more specific, the number of ride-hailing trips starting or ending within 50 meters of a newly opened MRT station increased by 86 percent (0.62 log points) between the start of the MRT system's public trial and 20 days later, when fares came into effect. After about two months, this effect had leveled-off to around a 215 percent (1.15 log points) increase. At the same time, the average distance of ride-hailing trips to and from station locations significantly decreased: by 16 percent (0.18 log points) in the first 20 days of the MRT being operational, leveling off at a 23 percent (0.26 log points) decrease after about two months following the MRT system's opening.

Taken together, these results provide strong evidence that ride-hailing services provide important first- and last-mile connectivity to the newly opened MRT system. In further analyses, we find this result to hold for trips on regular weekdays, weekends and public holidays, as well as rush- and non-rush hour trips alike. This suggests that the complementarity hypothesis holds for both commuting and non-commuting trips. Last but not least, we see a more pronounced impact of the opening of the MRT system on ride-hailing activity in the vicinity of MRT station locations that were not already served by Jakarta's bus rapid transit (BRT) system. For these locations, the opening of the MRT increased mass public transportation options at the extensive margin. By contrast, for locations that were already served by the BRT, the opening of the MRT "only" increased transportation options at the intensive margin, explaining the weaker response of ride-hailing activity to the opening of the MRT near those stations.

Our paper contributes to a rapidly expanding literature investigating whether ride-hailing services and public transportation are substitutes or complements. In one of the first papers to tackle this question, Hall, Palsson and Price (2018) examine the effect of the arrival of *Uber-X* into US metropolitan areas on public ridership volumes using a diff-in-diff research design. They find *Uber-X* to be a complement for the average transit agency, but with considerable heterogeneity across metro areas with *Uber* most strongly complementing small transit agencies in large cities. By contrast, also using US data, Graehler *et al.* (2019), Erhardt *et al.* (2021), and Diao *et al.* (2021) find ride-hailing to be a substitute for public transport. Meanwhile, Nelson and Sadowsky (2018), Babar and Burtch (2020), and Cairncross *et al.* (2021) find mixed or statistically insignificant results.

Our paper differs from these papers in two important respects. First, rather than focusing on a developed country in which the existence of mass transit systems pre-dates ride-hailing, we focus on a large, heavily congested, developing country city, Jakarta, for which the existence, and widespread use of, ride-hailing pre-dates the opening of its MRT system. Second, our paper differs in its event-study research design, identifying the impacts of the opening of Jakarta's MRT system on ride-hailing activity using plausibly exogenous variation, exploiting the very fine spatial and temporal resolution of our data on daily ride-hailing activity and MRT travel, provided by *Gojek* and Jakarta MRT, respectively.

In its research design and the nature of its data, our paper more closely resembles Rao (2016) and Gonzalez-Navarro *et al*. (2021). Rao (2016) examines the impact of the opening of London's "night tube" service in August 2016 on *Uber* journeys starting within 200 meters of a "night tube" station.[2] He finds a 22 percent increase in *Uber* journeys on nights when the night tube is operational, with a decrease in pick-ups around central London stations accompanied by a large increase in station pick-ups outside central London. Gonzalez-Navarro *et al.* (2021) consider a similar question to ours. Instead of focusing on a single public transport project, they use data on the opening of new metro stations from 35 different cities[3] and use a "ring-based" empirical design that compares monthly *Uber* ridership within 100-meter distance bands before and after a transit station opens relative to the next further out distance band up to a maximum distance of 1,100 – 1,200 meters. They estimate that a new metro station opening increases *Uber* ridership up to 300 meters of the station by 53 percent in the 6 months after its opening. This is accompanied by a 1.26 km decrease in average *Uber* trip distance to/from the stations.

While similar in spirit, our paper differs from Gonzalez-Navarro *et al.* (2021) in three important ways. *First*, we use a different research design that identifies the effect of the opening of the MRT system by comparing *Gojek* activity before and after the opening of the MRT in the immediate neighborhoods of the newly opened stations to that in (different sets of) control locations. As we discuss in section 5.4, our results are however robust to using a "ring-based" empirical design instead.[4]

Second, we focus on one public transport project in a specific developing country city. Gonzalez-Navarro *et al.*'s sample consists mostly of cities in developed economies, often with well-developed (rapid) public transit options before the entry of ride-hailing services. Our focus instead is on a heavily congested city in a developing country context, where fewer people own their own transport, ride-hailing services are primarily motorbike-based, and (much) fewer rapid public transit options are available. Although our limited scope may raise questions about the external validity of our findings, they are arguably more relevant for other cities in the developing world, where the use of motor-bike based ride hailing services is widespread and mass rapid public transport options are still few.

[2] Rao (2016) is not a formally published paper, but a blog account of internal research performed by *Uber* on the impacts of the opening of London's "night tube."
[3] Gonzalez-Navarro *et al.*'s sample does not include Jakarta as *Uber* is not present in the Indonesian market.
[4] See Pollmann (2023) for a discussion of the different assumptions underlying ours and the "ring-based" method.

Third, the extremely rich *Gojek* data allows us to provide much more fine-grained, and, therefore, in-depth, evidence on the complementarity versus substitution hypothesis. Notably, **1)** we show the effect(s) of the opening of the MRT on a *daily*, as opposed to a monthly, basis, allowing us to show how they evolve throughout each phase of Jakarta MRT's staggered opening; **2)** we document how the MRT opening affects both rush- and non-rush hour ride-hailing activity, as well as regular weekday, and weekend and public holiday ride-hailing activity; **3)** we show that results differ for station locations at which there was no previous alternative BRT stop; and **4)** the data on daily tap-ins and tap-outs into each of the newly opened MRT stations allow us to show that daily *Gojek* ride volume and the actual use of the MRT system are positively associated, thereby alleviating concerns that the increased ride-hailing volume might be associated with, for example, the opening of new urban amenities around the MRT stations rather than the use of the MRT system itself.

Last, but certainly not least, our study complements several more qualitative studies that provide survey-based evidence on either ride-hailing customers' (Irawan *et al.*, 2020), or public transport users' (Saffan and Rizki, 2018; Sunitiyoso *et al*, 2022) commuting behavior to better understand the role of ride-hailing services in public transport trips in Jakarta. Also, we contribute to a literature that is specifically focused on evaluating the impacts of various transportation policies for Jakarta. Gaduh, Gračner, and Rothenberg (2022) evaluate the impacts of Jakarta's BRT system, the *TransJakarta*, on vehicle ownership, travel times and commuting flows. Kreindler *et al.* (2023) add to this by showing how the recent expansions of the BRT network affected bus ridership and overall commuting flows. Meanwhile, Hanna, Kreindler, and Olken (2017) identify the effect of Jakarta's so-called "3-in-1" high occupancy vehicle policy, aimed to reduce congestion, on travel speeds in the city.

The remainder of the paper is structured as follows. Section 2 provides an overview of Jakarta's MRT system. Section 3 describes our event study design, which leverages the highly spatially and temporally granular data that we describe in Section 4. Section 5 presents our results. Finally, Section 6 concludes.

2. Overview of Jakarta's MRT System

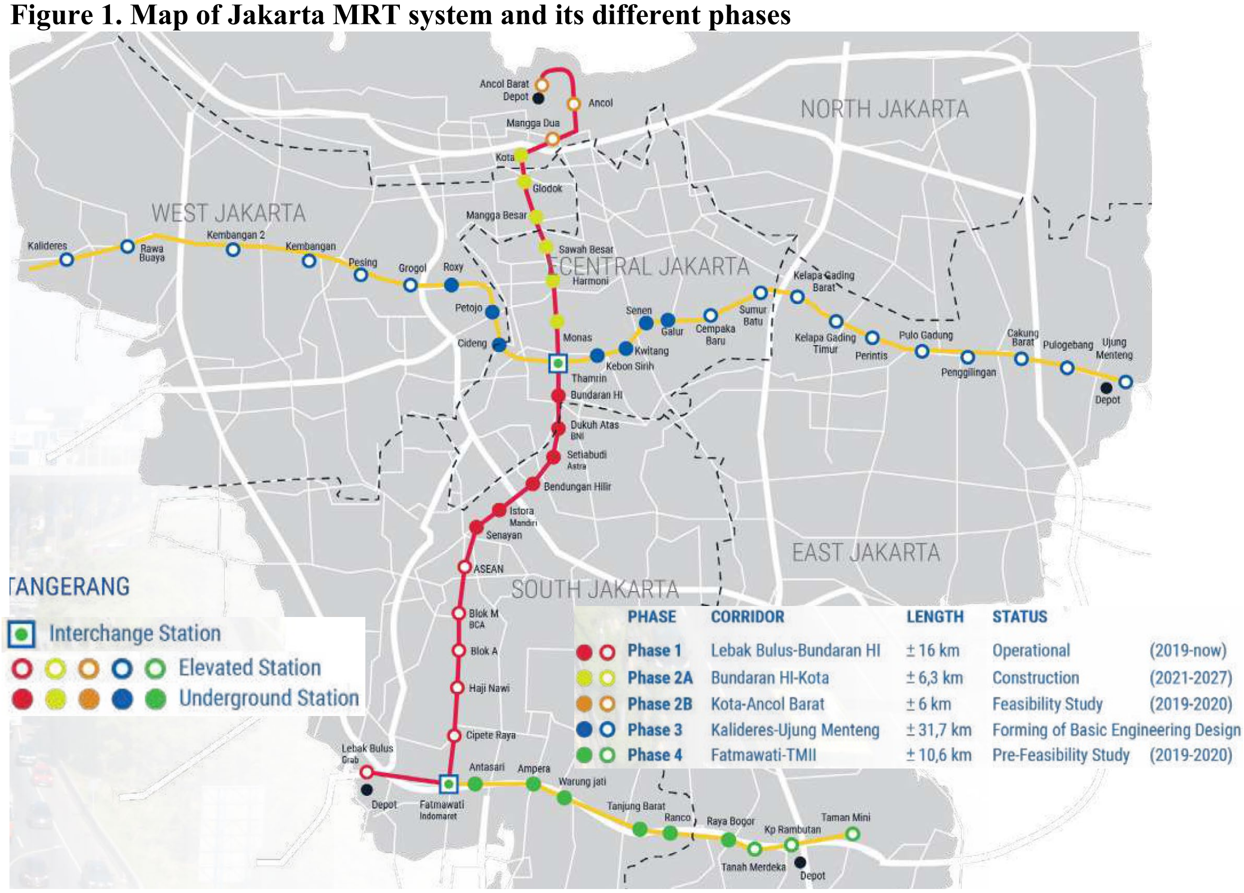
Jakarta is Indonesia's largest city. In 2016 it had a population of 10 million in the "city proper", and of 31 million in the wider metropolitan area, also known as Jabodetabek.[5] It is also consistently rated one of the 10 most congested cities in the world (Roberts, Gil Sander, and Tiwari, 2019). Around 3.2 million (or 11 percent) of Jabodetabek's inhabitants are commuters (BPS, 2020). Most of them (63.3 percent) use their own motorbike for travel, followed by "public" transport (26.9 percent) (BPS, 2020). The latter

[5] Jakarta's "city proper" corresponds to the district of DKI (*Daerah Khusus Ibukota*) Jakarta.

predominantly consists of conventional (mini-) bus, BRT, and ride-hailing services; with the latter accounting for about a third of total "public" transport activity (JICA, 2019).

Against this backdrop, the Jakarta MRT is a mass-rapid transportation system that was developed with the intention to help ease traffic congestion and improve mobility within Jakarta. After already being proposed in the late 1980s, it was only in 1999 that a basic design of the MRT system was officially laid out (JICA, 2001). Its first phase was to be the construction of a North-South line connecting Jakarta's central business districts with residential areas to the south (South Tangerang and Depok), the city's most congested commuting corridor. The Indonesian Ministry of Transport finally approved the Phase 1 plan in September 2010,[6] after which it took a further three years for construction to start in October 2013.

Figure 1. Map of Jakarta MRT system and its different phases



Source: adapted from PT MRT Jakarta

Upon its completion, Phase 1 of the MRT became officially operational on 24 March 2019. It complements the city's BRT system, the *TransJakarta*, which opened in January 2004 and is one of the world's largest

[6] Ministerial Regulation No. 15 year 2010 on National Intermodal Transportation Blueprint 2010-2030.

BRT systems (see also Gaduh, Gračner, and Rothenberg, 2022; Kreindler *et al*, 2023). The MRT currently consists of 13 stations stretching from the southern to the northern part of Jakarta along a 16 km line of track (shown as the solid red line connecting the stations indicated by solid and hollow red markers in Figure 1). We focus on these 13 stations in this paper.

Beyond the Phase 1 line, the Phase 2A line of Jakarta's MRT is currently under construction, extending the current line for around 6.3 km further north (the solid red line connecting the stations with yellow markers in Figure 1). On top of this, other plans such as Phase 2B (a further line branch of Phase 2A) and Phases 3 and 4 (both East-West lines) also exist, although construction of these lines has yet to begin.

Prior to the official opening of the 13 stations on the Phase 1 line on 24 March 2019, the system underwent a limited 12-day public trial, which commenced on 12 March 2019. During this period, the MRT system operated on all 13 stations between 8 am and 4 pm, with a total of 98 trips per day and a 10-minute headway interval between the arrival of each train. The number of passengers was limited to 4,000 on the first day, and then gradually increased each day by 2,000, reaching 28,800 on the final trial day. Throughout the trial period, no fares were charged to use the MRT.[7]

Following the MRT's official inauguration, on 24 March 2019, the system commenced with its normal operating hours from 5 am to midnight, with 285 trips per day, and it switched to different headway intervals for on peak and off-peak hours. During peak hours (5 – 9 am and 5 – 7 pm), trains arrive every five minutes, while, in off-peak hours, they run every 10 minutes. Weekends and public holidays are classified as entirely off-peak.[8] In the first week following the MRT's official inauguration, passengers continued to travel free without any cap on passenger numbers. Passenger fares were introduced on 1 April 2019, but still at a 50 percent discount. It was only on 13 May 2019 that full fares started to be charged. They range from IDR 3,000 to IDR 14,000 depending on distance traveled (roughly between US$ 0.21 and US$ 1), with IDR 1,000 fare increases for each station passed. Six months after fares were introduced, an average 90,000 daily trips were made using the MRT. For comparison, Jakarta's much more extensive BRT system (13 lines and 228 stops) attracts around 900,000 passengers per day (Sunitiyoso *et al.,* 2022).

3. Event-Study Design

The phased opening of the Jakarta MRT system provides an ideal setting to study whether ride-hailing is a complement or substitute for public transport, not least because the timing of the opening is plausibly exogenous to underlying ride-hailing trends. The Indonesian Ministry of Transport approved the Phase 1

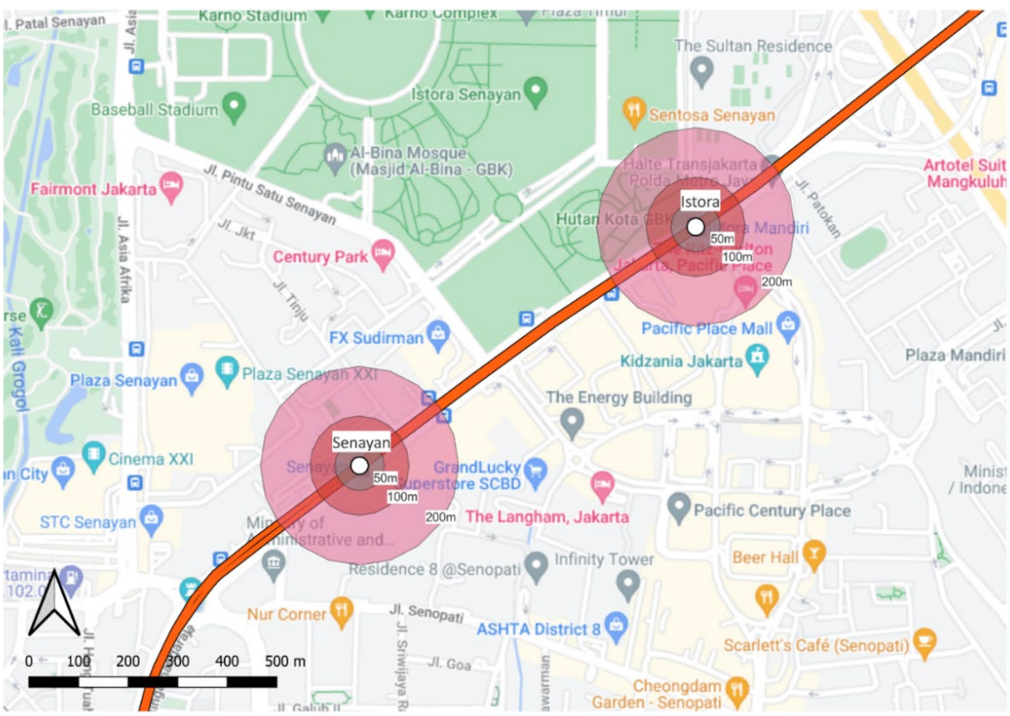
[7] https://megapolitan.kompas.com/read/2019/03/12/10084401/uji-coba-operasi-mrt-jakarta-untuk-publik-dimulai-hari-ini.
[8] https://finance.detik.com/infrastruktur/d-4489109/mulai-mei-2019-headway-kereta-mrt-jadi-5-menit-saat-jam-sibuk.

plan in September 2010 and its construction began in October 2013, predating the arrival of ride-hailing services in Indonesia by five and two years, respectively.[9]

We employ an event study design, estimating the impact of the opening of the MRT on demand for ride-hailing services by comparing, in our baseline results, the aggregate number of ride-hailing trips (defined as the sum of pick-ups and drop-offs) in the immediate neighborhoods of the Phase 1 MRT station locations with those in a set of control locations before and after the opening of the MRT. Importantly, our daily data allow us to estimate treatment effects that vary by day, or even by time-of day (i.e., rush-hour vs non-rush-hour). This allows us to provide evidence on whether effects differ between the trial and full operating periods, between the first week of the full operating period (when no fares were charged) and subsequent days after fares were introduced, first at a 50 percent discount and then at full rates from May 13, 2019 onwards.

We define each treatment location as a circle with a radius of 50 m, 100 m or 200 m whose center is defined by the coordinates (latitude and longitude) of the station location as returned by Google Maps. Figure 2 illustrates this for the Istora and Senayan stations.

Figure 2. Defining the immediate vicinity of a station

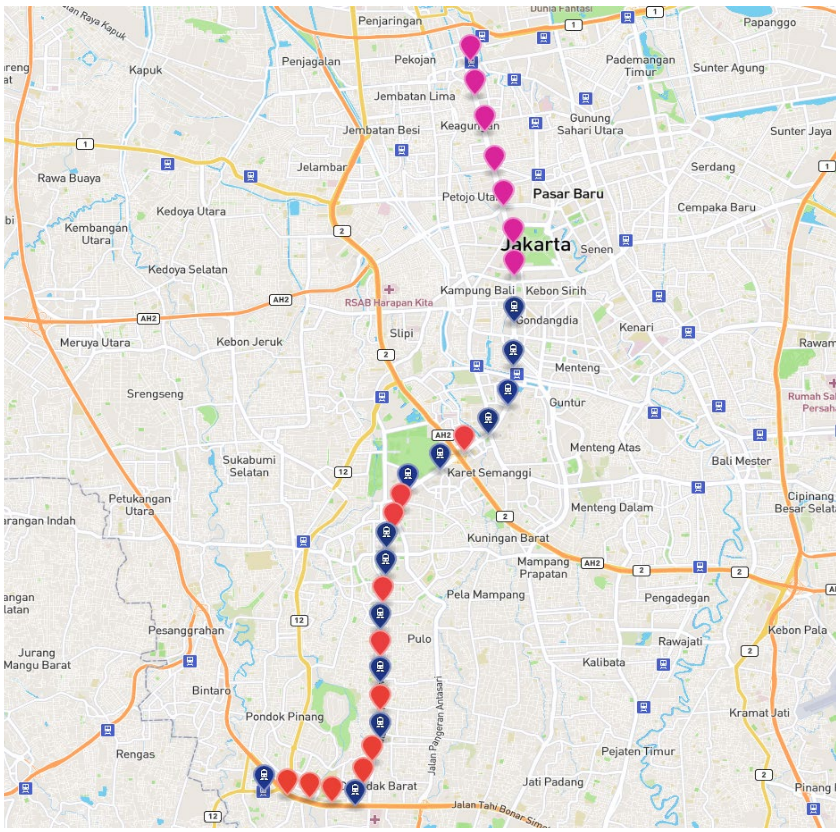


Source: Authors using Google Maps, illustrating the vicinity (50 m, 100 m and 200 m) of Senayan and Istora MRT Stations on the Phase 1 line. The thick orange line marks the route of the MRT.

[9] As noted below, although *Gojek* was established in 2010, it initially operated through a more traditional call center-based model with a limited fleet, only launching its app-based system in 2015.

Crucial to our research design is the selection of control locations. We consider two sets of control locations, in each case defining these as circles of fixed radius of 50 m, 100 m or 200 m to mirror our definition of the treatment locations. The first set are centered on the locations of the yet to open Phase 2A stations on which construction began in 2021. This control set consists of seven locations along the alignment of the extension of the current Phase 1 line (the purple markers in Figure 3). Since they will serve as future MRT stations, there is an active intent to treat for these locations.

Figure 3. Treatment locations and the two types of control location



Source: Authors using Google Maps.
Notes: Blue markers indicate the locations of the actual Phase 1 stations; purple markers those of planned, but not yet opened, stations on the Phase 2A line; and red markers the intermediate locations along the Phase 1 line in-between the locations of the opened stations.

Meanwhile, the second set of control locations consists of 11 locations along the current Phase 1 line which are intermediate between operating MRT stations (the red markers in Figure 3). We selected these locations so that their centroids are equidistantly spaced at least 400 m apart, both from each other and from the centroid of any current station location so that none of the locations overlap.[10, 11] One advantage of this set of control locations is that they are arguably more likely to share similar neighborhood characteristics to the treatment locations than the planned Phase 2A locations owing to their greater physical proximity to the actually opened stations. But even though the boundary of these “in-between” locations is at least 300 m (200 m) away from that of the nearest treated location when using 50 m (100 m) radii to define locations, this does come at the possible risk of contamination bias. The “in-between” locations might also be “treated” by the opening of the MRT. People living in these control locations might now e.g., start taking a shorter *Gojek* ride to/from the newly opened nearby MRT station, possibly instead of the longer ride that they took before to their final destination. Alternatively, they might no longer take a *Gojek* ride to get to their final destination, and instead now walk to the newly opened MRT station and use the MRT to get to their final destination.

Our main results for the volume of ride-hailing trips always consider *both sets of control location*s. In contrast, to avoid contamination bias, we show our main results on average trip distance using *only the planned locations* as control locations.[12] Of course, our results hinge on the validity of our choice of control locations. It is therefore very important to note at this point, that our findings do not depend on using only either one of our two sets of control locations, or both of them together. Neither the volume nor the average distance of *Gojek* trips to/from both our sets of control locations do not show much change following the opening of the MRT (see e.g., Figure 4 below), so that our findings our first and foremost driven by the changes in *Gojek* activity near the newly opened stations.

On top of this, in robustness checks (see Section 5.4), we show that our results are also robust to using an entirely different set of control locations inspired by a “ring-based” empirical design such as also adopted in Gonzalez-Navarro *et al.* (2021). And, we additionally perform two “placebo tests” that each lends strong support to the validity of our two different sets of control locations. First, we show no impact of the opening

[10] For example, if two stations are 1,000 m apart along the alignment of the MRT line, there will be one possible control location between these stations, but two possible control locations if the stations are 1,200 m apart. We make sure that the centroids of the control locations are spaced evenly between the two stations that they fall in-between. Thus, for stations that are 1,300 meters apart, there will be two possible control locations, the centroids of each of which are spaced 433 m apart, as well as 433 m from their nearest respective MRT stations.
[11] We use 400 m as 200 m is the maximum radius that we use to define locations (see results in Annex B).
[12] We do this in our baseline average distance results only, given that, in contrast to the total number of *Gojek* pick-ups and drop-offs, the average distance traveled on *Gojek* trips to/from our control locations might also be impacted by the opening of the MRT if people who were using *Gojek* before, to get to their final destination or another type of public transport station located further away, now switch to taking a *Gojek* to/from a newly opened MRT station and get to/from their final destination by MRT. This would leave the number of *Gojek* trips to/from these control locations unchanged, whereas it would still affect the average distance traveled.

of the Jakarta MRT on ride-hailing activity in the vicinity of our, still-to-be-opened, Phase 2A station control locations relative to the intermediate Phase 1 control locations. Second, we apply a "ring-based" method to our control locations only and find no differential impact of the opening of the MRT on locations closest to these control locations.

In our event study design, we take 12 March 2019, i.e., the date on which the limited public trial period of the Jakarta MRT commenced (see Section 2 above), as our baseline event date for which we set *k = 0*. Next, we estimate the effect of the opening of the MRT for each daily time window, *k = {-90, -89 ,…, +89, +90}* up to 90 days before and after 12 March 2019:

$$[1] \qquad y_{it} = \sum_{k=-90}^{90} \beta_k \cdot D_t^k \cdot T_i + \alpha_i + \gamma_t + \varepsilon_{it}$$

where y_{it} is the log number of ride-hailing trips originating and terminating at location *i* (i.e., the sum of drop-offs and pick-ups at location *i*) on date *t*. D_t^k is a dummy variable that equals one if date *t* lies *k* days from 12 March 2019, and zero otherwise, and T_i is a dummy variable that equals one if location *i* is a treatment location (i.e. a station location on the Phase 1 line) and zero otherwise. α_i and γ_t are location and date-specific fixed effects respectively. The location fixed effects control for time-invariant location characteristics, such as fixed neighborhood amenities, which may be correlated with both ride-hailing activity and treatment status. The date-specific fixed effects control for contemporaneous shocks that are common across all locations. This includes, for example, whether the date falls on a weekend or is a public holiday, as well as weather-related shocks that may affect ride-hailing activity. ε_{it} is the error term.

Our main parameters of interest are the β_k's. They tell us whether, and if so how, for each day in our sample period separately, ride hailing activity near the newly opened MRT stations relative to that in the control locations differs from that on 12 March 2019, the day on which the limited public trial of the Jakarta MRT commenced. Prior to 12 March 2019, we therefore expect β_k =0. In fact, our ability to estimate treatment effects prior to the opening of the MRT allows us to assess the crucial assumption underlying our estimates that ride-hailing activity did not show differential trends in treated and control locations before the MRT was opened. In the period after the opening of the MRT, we expect $\beta_k > 0$ if the MRT and ride-hailing are complements and $\beta_k < 0$ if they are substitutes. Furthermore, our daily estimates also allow us to look for patterns in the estimated β_k coefficients that would, for example, be consistent with people gradually adjusting their behavior following the opening of the MRT, or to look for differences in the effect between the limited public trial period, the fully operational, but continued fare free, period between 24 March 2019 and 1 April 2019, the period between 1 April 2019 and 13 May 2019 during which fares where charged at a 50 percent discount, and following the introduction of full fares on 13 May 2019. We estimate equation [1] clustering standard errors by location.

4. Data

The ride-hailing data that we use to implement our event study design comes from *Gojek*, which, along with *Grab*, is Indonesia's biggest ride-hailing company. These two companies each control about half of the ride-hailing market in Indonesia that for the largest part consists of two-wheeled ride-hailing services on motorbike. *Gojek* is an Indonesian-owned firm that started in 2010 with a fleet of 20 drivers connected to a call-center, but it was only after the launch of its mobile phone application in January 2015 that the company experienced exponential growth.[13] It now has a fleet of over 1 million drivers and, as of November 2019, *Gojek* had an estimated 29.2 million monthly active users in Indonesia.[14]

The ride-hailing data from *Gojek* has a daily frequency and covers the period from 1 September 2018 to 1 November 2019, which encompasses the staggered opening of the Phase 1 MRT line that took place between 12 March and 13 May 2019. For each day, we have information on the number of, as well as the average distance-traveled on, *Gojek* trips originating from (pick-ups) and terminating at (drop-offs) both our treatment and (both sets of) control locations as defined using circles of 50 m and 100 m radii.[15] The data further provide a breakdown between rush and non-rush hour trips, where rush hour trips are defined by *Gojek* as pick-ups and drop-offs that take place between either 5 – 8 am (morning rush hours) or 4 – 8 pm (evening rush hours).[16] In total, our data contains information on more than 17 million ride-hailing journeys between September 1, 2018 and November 1, 2019.

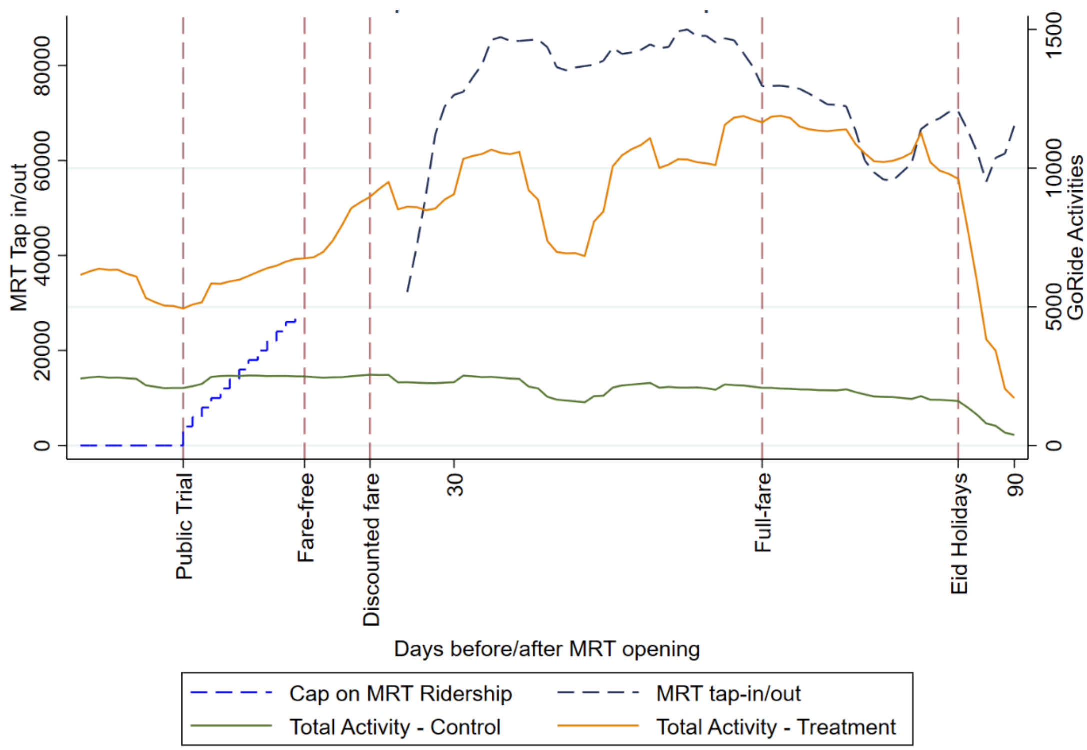
Meanwhile, our data on daily tap-ins and tap-outs into the MRT system at each individual newly opened MRT station comes from PT Mass Rapid Transit Jakarta. It covers the period from 1 April 2019 onwards, which is the date on which discounted fares started to be charged and therefore tracking of tap-ins and tap-outs started.

A preliminary glance of our data is provided in Figure 4, which plots the 7-day moving average of the sum of *Gojek* pick-ups and drop-offs within 50 m of all actual Phase 1 MRT stations, and similarly for our control locations. In addition, the figure also plots the 7-day moving average of the combined total number

[13] The app is a "lifestyle app" which offers a wide-range of other products alongside *Gojek*'s ride-hailing service. The ride-hailing service is now referred to as *GoRide*, but, for ease of exposition and to avoid confusion, we refer to the ride-hailing service as *Gojek* throughout this paper.
[14] After our sample period, *Gojek* completed a merger with *Tokopedia* in May 2021, with both becoming subsidiaries of a new company, *GoTo*.
[15] We also have data on the volume of *Gojek* trips (drop-offs plus pick-ups) for treatment and control locations as defined using circles of 200 m radius. We unfortunately lack data on average trip distance for these 200m radius circles. Moreover, we are unable to distinguish between rush and non-rush hour trips for these circles.
[16] These hours differ slightly from the regular weekday peak hours of the MRT system, which are 5 – 9 am and 5 – 7 pm.

of tap-ins and tap-outs at all opened Phase 1 MRT stations.[17] Following the opening of the MRT on 12 March 2019, the total number of *Gojek* trips near the newly opened stations increases gradually, whereas it stays flat for our control locations. Also, the total number MRT tap-ins and tap-outs, available from April 1 onwards, co-moves more strongly with *Gojek* trips within 50 m of the newly opened stations than that within 50 m of our control locations.[18] At the individual, newly opened, station level, where, importantly, the daily number of MRT tap-ins need not necessarily equal the daily number of MRT tap-outs, the raw correlation between daily MRT tap-ins (tap-outs) and the daily number of *Gojek* drop-offs (pick-ups) within 50 m of an MRT station is 0.59 (0.55).

Figure 4. MRT tap-in/tap-outs, and volume of Gojek trips within 50 m of control and treatment-locations



Source: Authors using ride-hailing data from *Gojek* and MRT tap-in/tap-out data from PT Mass Rapid Transit Jakarta. *Note:* For illustration purposes, data are plotted as 7-day moving averages. MRT tap-in and tap-out data is not available prior to 1 April 2019, when fares on the system became effective, explaining why the figure only plots MRT tap-ins/outs, as of 4 April, the first day for which we can calculate this 7-day moving average, as well as for the period before 12 March 2019 when the MRT was not yet open and thus the number of tap-ins/outs was simply zero. For the period between the public trial and the start of the fare-free period, we do not have info on the actual number of people using the MRT, but instead plot, in blue, the cap in place on the number of passengers during that period, starting at 4,000 on 12 March, and then increasing by 2,000 per day, to reach 28,000 on 24 March.

[17] Given the system's operating hours, the total number of daily MRT tap-ins necessarily equals the total number of tap-outs. For individual stations, these numbers need not necessarily be identical.
[18] The sharper drop in *Gojek* activity following the start of the Eid-Holidays (June 2 – June 7, 2019) can be explained by *Gojek* drivers also working less (or not at all) during this period – whereas the MRT remained operational.

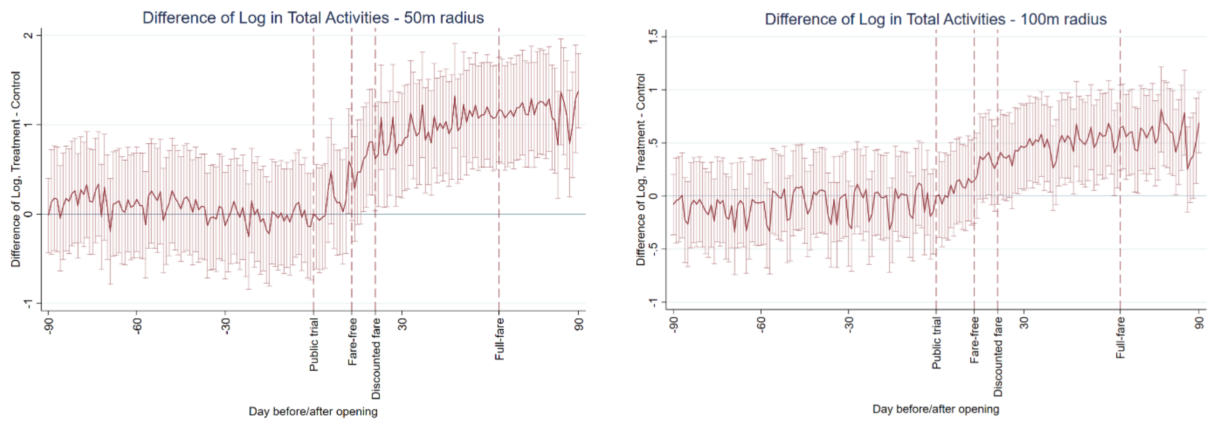
5. Results

5.1. Baseline results

The volume of ride-hailing trips

Figure 5 presents our baseline results in which the control group is defined to include both the yet to open Phase 2A station locations and the intermediate locations along the operational Phase 1 North-South line. Part (a) of the figure is based on both the treatment and control locations being defined using 50 m radius circles, while part (b) is based on 100 m radius circles.

Figure 5. The opening of the MRT: total volume of ride-hailing trips



(a) 50 m radius **(b) 100 m radius**

Note: Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (i.e., number of time-location observations): 13,071.

Prior to the opening of the MRT, we find, conditional on the location and date-specific fixed effects, no significant difference in *Gojek* trip volume between the treatment and control locations irrespective of whether we define these locations as 50 m or 100 m radius circles. All $\hat{\beta}_k$ for this period are statistically insignificant at the five percent level, as indicated by the confidence intervals plotted alongside the estimated coefficients. Importantly, this is consistent with the parallel trend assumption that underlies our estimates: prior to the MRT's introduction, the MRT station locations did not experience systematically different trends in ride-hailing activity compared to our control locations.

However, following the commencement of the limited public trial, we see that the $\hat{\beta}_k$s become increasingly positive as the trial period advances and the cap on MRT ridership numbers is gradually increased. This trend further continues following the system's full opening on 24 March 2019, which marks the lifting of the cap on MRT ridership and the switch to a full operating schedule. For the 50 m radius locations, by the time (discounted) fares are introduced on 1 April 2019, the estimated increase in ride-hailing trip volume because of the opening of the MRT system has reached 0.62 log points (86 percent), which is statistically significant at the 5 percent level (figure 5(a)). Following this, the estimated impact of the opening of the MRT system on ride-hailing trip volume gradually increases further and is always statistically significant at the 5 percent level. It levels-off at around a 1.15 log point increase (216 percent) about two months after the start of the public trial, with no discernable effect of the introduction of full fares on 13 May 2019.[19] This pattern is consistent with a process of travelers experiencing positive learning of using ride-hailing services in combination with the newly opened MRT system and the dissemination of news of these positive learning experiences to other travelers. This effect levels off after about two months, when the volume of *Gojek* trips near the newly opened MRT station appears to have reached a new steady state.

Results are qualitatively very similar for the 100 m radius locations in figure 5(b). However, the estimated positive impacts of the opening of the MRT on ride-hailing trip volume are much smaller – an estimated 0.37 log point increase (45 percent) by the time fares are introduced on 1 April 2019, leveling-off at an estimated 0.51 log point increase (66.5 percent) two months after the opening of the MRT. Moreover, they tend to be less precisely estimated. These smaller, less precisely estimated effects for larger defined locations are as we might expect – the larger are the areas of the neighborhoods that we define around MRT stations, the smaller is the proportion of ride-hailing trips to and from those neighborhoods that are likely to be associated with MRT use, i.e., the noisier the data becomes. Further increasing the radius to 200 m, our estimated effects become smaller still (see Annex B).[20]

The average distance traveled on ride-hailing trips

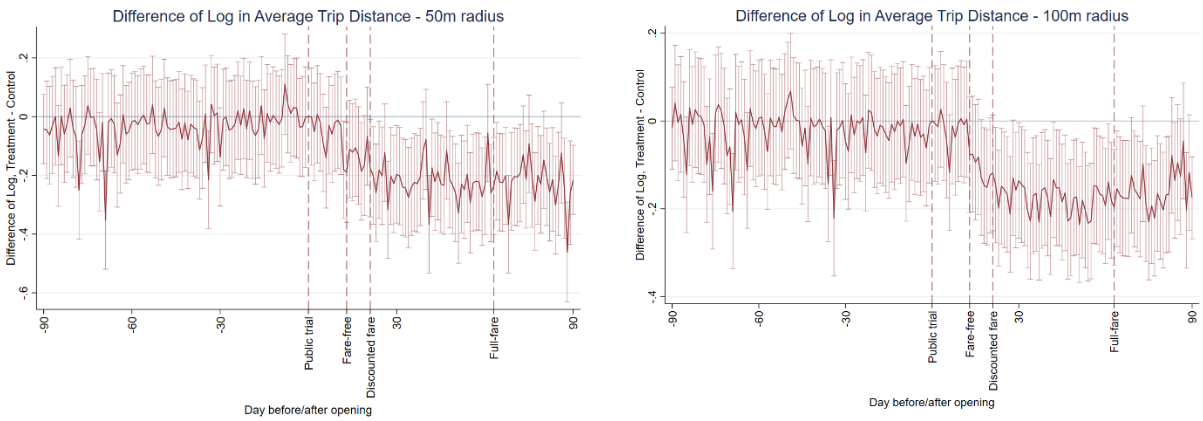
The impacts of the opening of the Jakarta MRT on the average distance of *Gojek* trips originating and terminating at the Phase 1 station locations is shown in Figure 6, again using either 50 m or 100 m radius circles to define locations. To minimize potential contamination bias, we exclude the "in-between" locations along the Phase 1 line from the control group (see our discussion in Section 3, and footnote 12). The estimated increase in the volume of ride-hailing trips in Figure 5 is mirrored by a (statistically) significant decline in the estimated average distance of those trips. The estimated size of this decline is increasing throughout the MRT system's free trial period and levels-off about 1.5 weeks after the

[19] Annex C presents results for the estimated daily impacts of the opening of the MRT on ride-hailing activity for the full-period for which we have data – i.e., 12 March – 1 April 2019. They show some further, much more modest, increases in the impact on the volume of ride-hailing trips beyond 90 days following the start of the limited public trial.

[20] With the caveat that, due to lack of data availability on average trip distance for our locations defined as 200 m circles, we can only claim this for total *Gojek* trip volume.

introduction of fares – a month earlier than we saw when considering the volume of ride-hailing trips. One month after the start of the public trial, the average trip that starts or ends within 50 m (100 m) from a newly opened MRT station location is 4.4 km (4.58 km), which is 1.4 km (1.1 km) shorter than before the MRT become operational. This is equivalent to a 23 (16) percent decline in average trip distance.

Figure 6. The opening of the MRT: average distance traveled on ride-hailing trips



(a) 50 m radius **(b) 100 m radius**

Note: Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Control locations include planned station locations only. Sample size (i.e., number of time-location observations): 8,433.

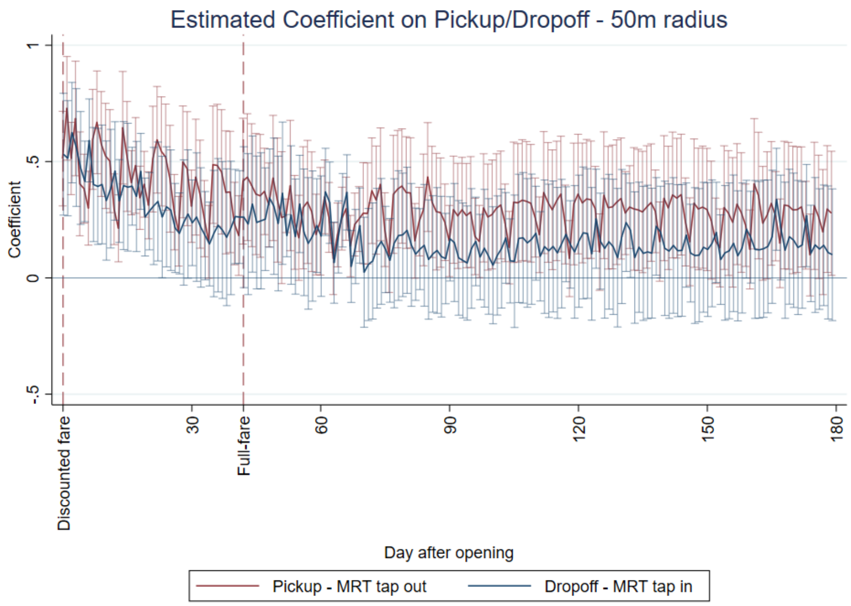
Combining these results with the strong increase in the volume of ride-hailing trips in the vicinity of the newly opened MRT stations triggered by the opening of the MRT (see Figure 5), tells us that the origins and/or destinations of these new trips are located much closer to the MRT station locations. In fact, assuming that all pre-existing trips neither changed nor disappeared as a result of the opening of the MRT, our coefficients imply that the average distance traveled on all new trips triggered by the MRT's opening is about 3.8 km, 35 percent (1.9 km) shorter than that of pre-existing trips.[21] This distance is strikingly similar to the 4.2 km and 3.6 km that survey participants in Saffan and Rizki (2018) report for their first- respectively last-mile motorbike based ride-hailing trips to/from commuter rail (KRL) stations in Jakarta. But it is important to note that this decline in average trip distance is more than made up for by the increase in the number of *Gojek* trips: based on our estimates, the *total kilometers traveled* on *Gojek* trips starting or

[21] One can calculate this by multiplying the estimated percentage change in average distance by (1 + (100 / the estimated percentage change in the number of Gojek trips)).

ending within 50 m of the newly opened MRT stations had increased by 144 percent (0.89 log point) two months after the opening of the MRT.[22]

Finally, Figure 7 shows that we also find a clearly positive association between the daily number of *Gojek* trips starting and ending within 50 m of the newly opened MRT stations, and the daily number of tap-outs and tap-ins from the MRT system respectively.

Figure 7. Relationships between tap-ins into (tap-outs from) the MRT system and *Gojek* drop-offs (pick-ups) at the same station location



Note: The red (blue) estimates are based on estimating a fixed effects regression of the ln number of *Gojek* pickups (drop-offs) on the total number of MRT tap-outs (tap-ins) including day- and station-specific fixed effects. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. The sample includes our 13 opened MRT stations only, and runs from 1 April 2019, the first day for which we have MRT tap-in/out data available, to 1 November 2019. Sample size: 2,795.

This association is strongest following the introduction of fares on 1 April 2019, when use of the MRT most rapidly increased (see Figure 4). During this period each 1 percent in-/decrease in daily MRT tap-ins/outs is associated with a 0.3-0.5 percent in-/decrease in the daily number of *Gojek* drop-offs/pickups. In the months thereafter, when the total number of MRT users stabilizes, it then becomes slightly weaker, leveling off at a 1 percent increase/decrease in daily MRT tap-ins/outs being associated with a 0.12-0.25 percent

[22] This can easily be calculated by summing the estimated log point changes in the total number of trips and in the average trip distance.

increase/decrease in the daily number of *Gojek* drop-offs/pickups.[23] These results provide additional confidence that the increase in ride-hailing activity near the newly opened MRT stations is the result of people actually using ride-hailing services to connect to the MRT system, rather than, for example, taking ride-hailing trips to/from the possibly newly opened shops, restaurants, and other urban amenities in the immediate neighborhoods of MRT stations.[24]

Summing up the results presented in Figures 5 to 7, we find a strong (local) complementary relationship between the use of ride-hailing services and Jakarta's newly opened, first, MRT system. Ride-hailing services provide important first- and last-mile connectivity.[25] In doing so, they also help to extend the potential spatial reach of the newly opened MRT system to attract customers, especially for those that cannot afford their own vehicle, live in places without reliable public transport alternatives, and/or for whom walking to the newly opened station is not an option (either because of safety or distance considerations).[26]

5.2. Work versus non-work related commuting

About 80 percent of all commutes in Jakarta are work-related (BPS, 2020). To probe the extent to which our baseline results are driven by work-related commuting versus other trip types for leisure or study purposes, we extend our baseline analysis to distinguish between trips that are more and less likely to be work-related. Specifically, we only consider regular weekdays (Monday – Friday), excluding weekdays that are public holidays, and compare results when focusing on rush hour trips *versus* non-rush hour trips. Rush hour trips are defined as pick-ups and drop-offs between the hours of 5 – 8 am (morning rush hours)

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[23] A small note on the insignificance of the daily association between daily station-level *Gojek* drop-offs and MRT tap-ins is in order here. Estimating day-specific associations is quite demanding, easily resulting in the wide daily confidence intervals that we see in the figure. The estimated daily association between *Gojek* drop-offs and MRT tap-ins is very stable after about a month following the introduction of fares. Allowing it to differ only every 3 days or every week, giving us more degrees of freedom, yields exactly the same estimated associations, *but turns them statistically significant*.

[24] Sunitiyoso et al. (2022) report that 25 percent (32 percent) of their surveyed public transit users in Jakarta (BRT, Commuter Line (KRL), or MRT) use ride-hailing services for their first-mile (last-mile) connectivity. Given that *Gojek* shares the ride-hailing market with *Grab*, our estimated associations between MRT tap-ins/outs and *Gojek* drop-offs/pickup, once the initial dust of the opening of the new MRT stations has settled (and commuting patterns have reached their new steady state), are in line with these survey findings.

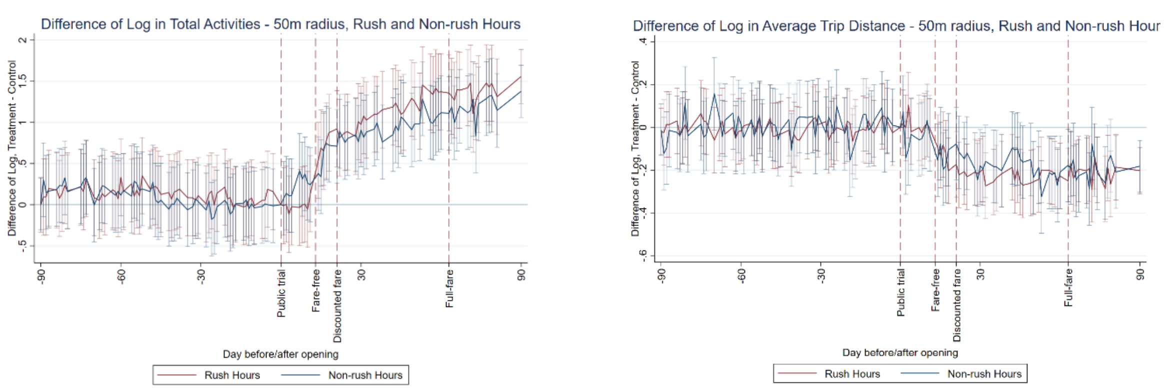
[25] In robustness tests reported in Annex A, we also estimate the impacts of the opening of the MRT on pick-up and drop-off activity separately. Impacts on pick-up and drop-off activity are quantitatively similar, suggesting that ride-hailing services are being used by passengers to provide both first- and last-mile connectivity to the MRT.

[26] Sunitiyoso *et al.* (2022) report the average walking distance of first-/last-mile trips to be 820 m for Jakarta's public transport users, against an average 3.6 km for two-wheeled ride-hailing services. Trahjono, Kusuma and Septiawan (2020) add to this by reporting that 46 percent, 60 percent and 82 percent of their surveyed commuters are not willing to walk more than 300 m, 500 m and 1km, respectively, to/from a public transport stop.

and 4 – 8 pm (evening rush hours). Together, these trips account for an average of 50.6 percent of the total daily trips in our data. For comparison, the 2019 Jabodetabek commuter survey (BPS, 2020) reported 56.8 percent (55.4 percent) of commuters leaving (returning to) their home between 6 – 8 am (6 – 12 pm).

Figure 8 shows our findings. For ease of exposition, we henceforth focus only on results using treatment and control locations defined as circles with a 50 m radius.[27] The estimated impact of the opening of the MRT on the volume of *Gojek* rides (panel a) and, even more so, on the average distance of *Gojek* trips (panel b) is statistically indistinguishable between rush-hour and non-rush-hour trips. Both show the same increase in ride-hailing activity within 50m of the newly opened MRT stations, accompanied by a similar drop in the average distance of *Gojek* trips starting or ending there. The only notable difference is that we see no differential change in the number of rush-hour trips near the newly opened MRT stations during the 12-day public trial of the MRT system that start on 12 March 2019. This is however only as it should be since the MRT was only operational from 8 am – 4 pm during this trial period, so not during our morning (5 – 8 am) and evening (4 – 8 pm) rush-hour periods.

Figure 8. The opening of the MRT: rush hours vs. non-rush-hours



(a) Volume of trips **(b) Average distance of trips**

Note: For part (a) of the figure, the control group includes both the planned Phase 2A station locations and the intermediate Phase 1 station locations. For part (b) of the figure, the control group is restricted to the planned Phase 2A station locations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): 8,835 (figure 7.a), 5,751 (figure 7.b). We exclude weekends and public holidays from the sample in these "(non-)rush hour regressions".

Ride-hailing services and public transport are complements for both work commuting and non-commuting related trips, providing important first- and last-mile connectivity for both types of trips. In fact, Figures 5 and 6 already provided some evidence that this is the case: our estimates also do not significantly differ

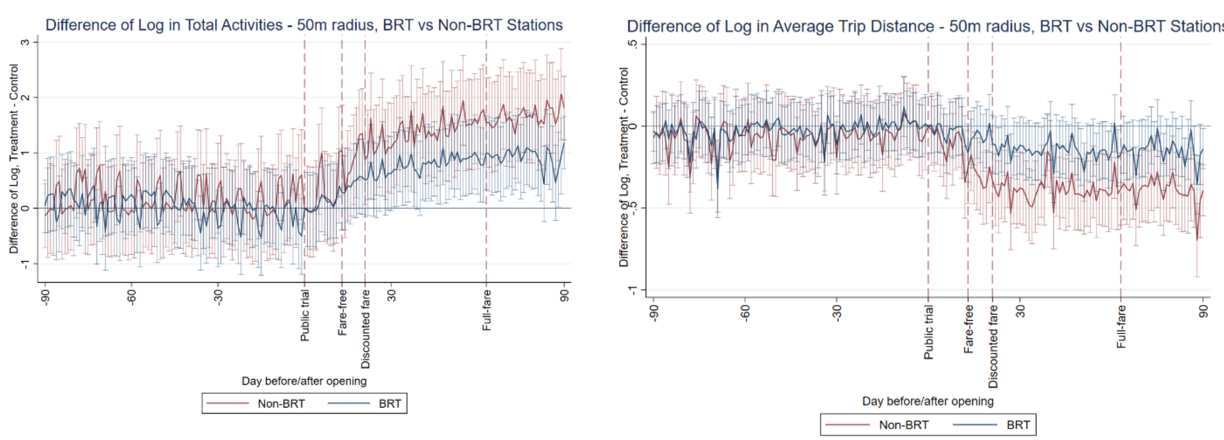
[27] Results using a 100 m radius are qualitatively identical and available on request.

between weekdays, and weekends and public holidays when less work-related commuting takes place. The figures in Annex D complement this by showing that we also find similar results when restricting the sample to weekends and public holidays only.

5.3. Does the preexistence of mass public transport matter?

As noted earlier, the MRT is not the only mass public transport system that serves Jakarta. Prior to the MRT's opening, Jakarta was already being served by one of the world's largest BRT systems, the *TransJakarta*, which opened in January 2004 (see also Gaduh, Gračner and Rothenberg, 2022 and Kreindler *et al*, 2023). There is, in fact, good reason to suspect our results to differ between MRT station locations that were already being served by the BRT, and those that were not. For the latter, the opening of an MRT station increases the location's mass public transportation options at the *extensive margin*, whereas for locations already served by the BRT it only does so at the *intensive margin* (adding some new destinations, or faster service). For those latter locations, this means that (many) travelers were already using ride-hailing for first- and last-mile connectivity to then continue their travel on the BRT. Those that, upon the opening of the MRT, switch to using the MRT instead, would neither contribute to increased ride-hailing trips nor to a change in the average distance of such trips – they simply keep making the same *Gojek* trips to the location as before.

Figure 9. The opening of the MRT: pre-existing mass rapid public transport options



(a) Volume of trips **(b) Average distance of trips**

Note: For part (a) of the figure, the control group includes both the planned Phase 2A station locations and the intermediate Phase 1 station locations. For part (b) of the figure, the control group is restricted to the planned Phase 2A station locations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): 13,071 (Figure 9.a), 8,433 (Figure 9.b).

Figure 9 presents results when considering these two different types of station locations separately.[28] While there is some overlap in the confidence intervals, they indeed suggest bigger impacts of the opening of the MRT on both the volume of ride-hailing trips and on average ride-hailing trip distance for station locations that are not also served by the BRT. This is consistent with our reasoning above that new ride-hailing trip creation for the purposes of first- and last-mile connectivity is likely to be more extensive for locations that were not already being served by the BRT. These results also raise a cautionary note for (future) studies examining the impact of public transit options on ride-hailing activity using a similar empirical design as ours: considering the presence of pre-existing rapid mass public transit options is important. One runs the risk of underestimating the degree of complementarity between the newly opened public transit option and ride-hailing activity when most of the newly opened stations in the sample were already well-served by other forms of mass-rapid transit.

5.4. Robustness – the validity of our choice of control locations

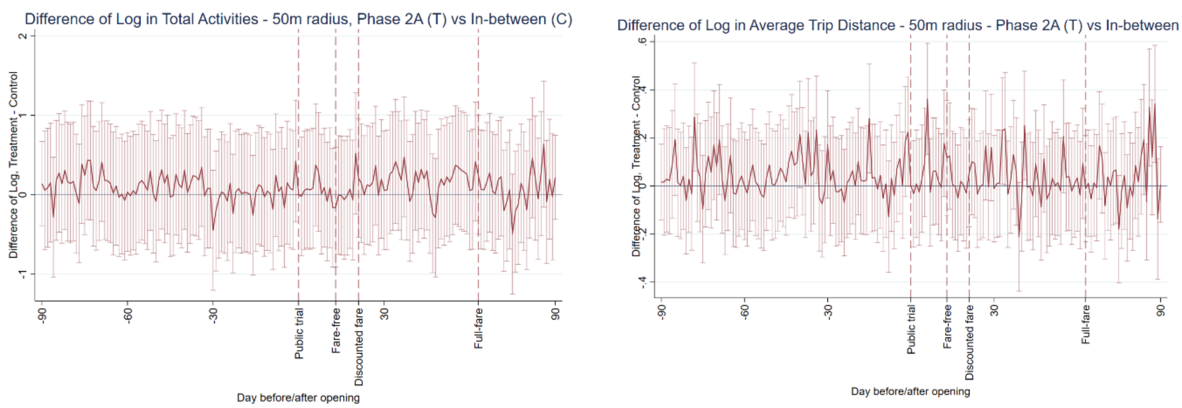
The validity of our choice of control locations is a crucial assumption underlying our event-study design. As noted in Section 3, one could raise concerns regarding both sets of control locations used in our baseline estimations. For the planned Phase 2a station locations there is an active intent to treat. Meanwhile, the intermediate locations along the opened Phase 1 line could, due to their closer proximity to the newly opened stations, experience spillovers from the opening of the MRT, running the risk of contamination bias. In fact, it was for this reason that, in all baseline results that consider average trip distance as the outcome variable, we restricted the control locations to planned Phase 2a locations only (see also footnote 12). In this section we show results that instill further confidence in our choice of control locations.

First, we conduct the following thought experiment: we re-run our baseline analysis, only now using as the treatment group the yet to open Phase 2A station locations, and the intermediate locations on the already opened Phase 1 line as control locations.[29] Figure 10 shows that the opening of the MRT system had no noticeable significantly different impact on either the total volume of ride-hailing trips or average trip distance for the yet to open Phase 2A station locations compared to the intermediate locations along the already opened Phase 1.[30] The fact that these two different sets of control locations, each chosen for completely different and unrelated reasons, do not experience significantly different trends in ride-hailing

[28] Nine out of 13 MRT stations have intermodal integration to BRT stops: ASEAN, Bendungan Hilir, Blok M, Bundaran HI, Dukuh Atas, Istora, Lebak Bulus, Senayan and Setiabudi (https://jakartamrt.co.id/id/stasiun/).
[29] Note that it is immaterial for our results which of the two sets of control locations we take as "treated".
[30] Again, these results also hold if we define locations using 100 m radii circles rather than 50 m radii circles. Results available on request.

before and after the opening of the MRT instills further confidence in our findings.[31] Only if these two sets of locations experienced the exact same spillover effects from the opening of the MRT, or were subject to the exact same underlying unobserved trends in ride-hailing activity correlated with the opening of the MRT, would we run the risk of over- or underestimating our coefficients of interest. Given the dissimilarity between our two sets of control locations, this is very unlikely.

Figure 10. The opening of the MRT: effects on our control locations?



(a) Volume of ride hailing trips **(b) Average trip distance**

Note: The treatment group corresponds to the planned Phase 2A station locations and the control group to the intermediate locations along the Phase 1 line. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): 7,549.

Second, we present results using a different set of control locations altogether. Their choice is based on a "ring-based" empirical design, as, notably, adopted by Gonzalez-Navarro *et al.* (2021). This strategy relies on comparing the impact of MRT station openings on ride-hailing activity within a given distance band from the newly opened stations relative to that in a next further out distance band from those same stations. This is equivalent to defining control locations as the donut-shaped areas that surround the circular treatment area centered on a station location. We implement this strategy by defining treatment locations as those within a 50 m radius of the Phase 1A station locations, and control locations as the 50 – 100 m donut-shaped areas (excluding the treatment "hole" in the middle) that surround them.

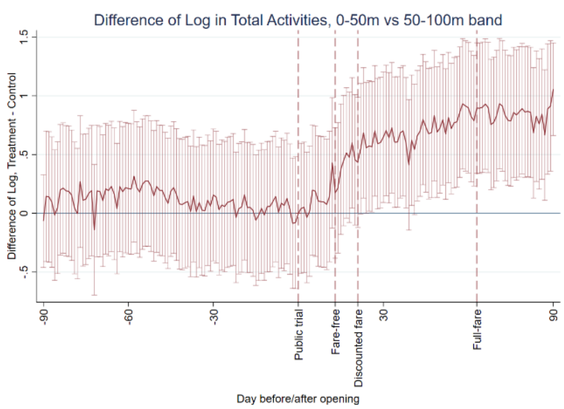
Figure 11 shows that, also when using this completely different set of control locations, we find significant impacts of the opening of the MRT of roughly similar magnitude to our baseline results on both the volume

[31] Also, given these results, it should be no surprise that all our baseline findings are robust to using either both sets of control locations, or either of the two sets of control locations individually. All results are available upon request.

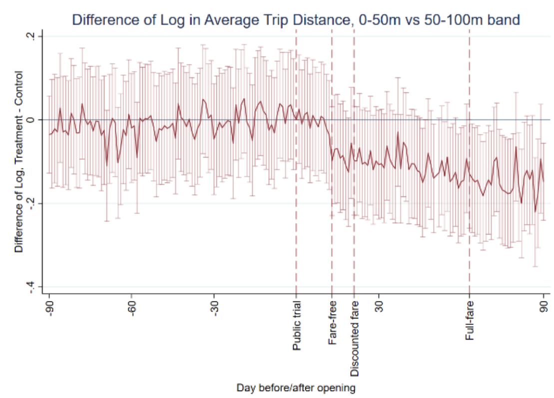
of ride-hailing trips and the average distance of ride-hailing trips (see parts (a) and (b) of the figure respectively). The patterns in our estimates over time are also very much like those in our baseline findings: only after the opening of the MRT do we find that the volume of trips starts to increase, and average trip distance starts to fall, within 50 m of the opened stations relative to 50-100 m from those same stations. Moreover, and again similar to our baseline findings, these effects are more pronounced for station locations without prior access to Jakarta's BRT system (see parts (c) and (d) of figure 11).

Figure 11. Alternative control locations: a "ring-based" empirical design

All MRT station locations

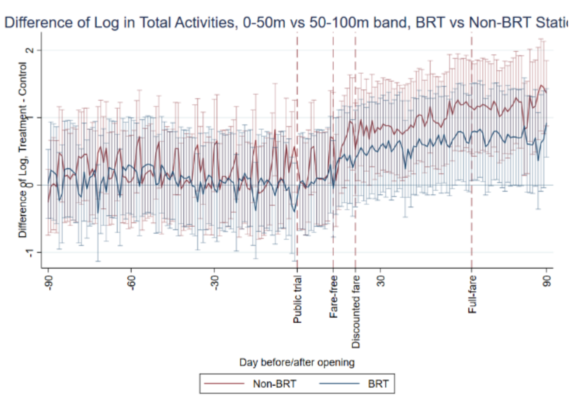


(a) Volume of ride-hailing trips

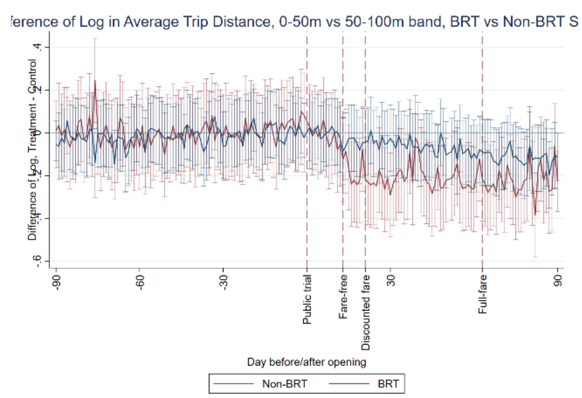


(b) Average trip distance

BRT vs. non-BRT stations



(c) Volume of ride-hailing trips



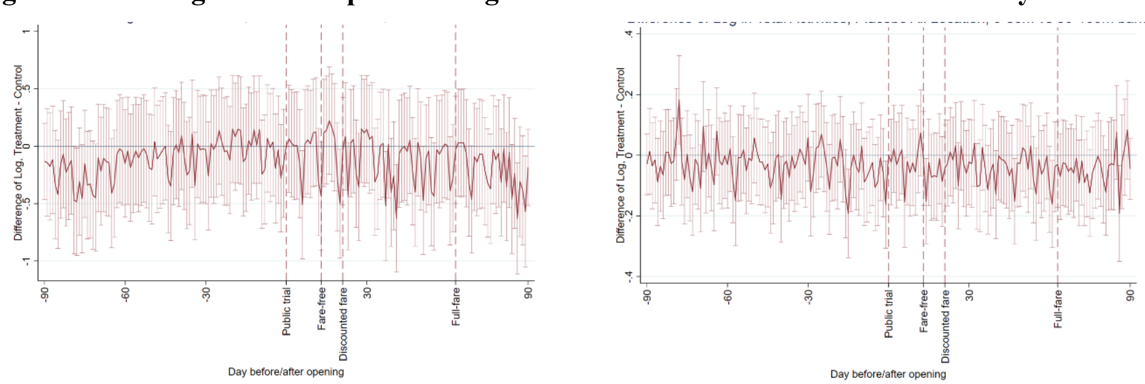
(d) Average trip distance

Notes: Treatment locations are circles of 50 m radius centered on the Phase 1 MRT station locations; control locations are the areas between 50 – 100 m from those same station locations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): 11,073.

Two months after the opening of the MRT, the volume of ride-hailing trips has increased by about 144 percent (0.89 log points), and average trip distance has fallen by 14 percent (0.15 log points), or 0.58 km, within 50 m of the newly opened stations relative to 50 – 100 m from those same stations. These estimates are somewhat smaller than our baseline findings (do note that they are not significantly different however– see the confidence intervals), which could be explained by some of the trips to those 50 – 100 m bands from the newly opened stations also being new, shorter, trips to the newly opened stations. In Annex B, we show however that, be it for the total volume of ride-hailing trips only,[32] we find no significant different effect of the opening of the MRT in places located within 100 – 200 m relative to those within 50 – 100 m the newly opened station locations. This localized effect of the opening of the MRT also alleviates concerns about contamination bias arising from the use of the "in-between" control locations in our baseline results: these control locations are at least 300 m away from a treated MRT station location (see also Section 3).

Last, but certainly not least, we combine the idea of our earlier "*placebo-results*" with the use of a "*ring-based" empirical design.* More specifically, we implement the "ring-based" method considering both our sets of control locations *only* (i.e., taking these control locations as "treated"). Figure 12 shows our findings.

Figure 12. A "ring-based" empirical design that considers our control locations only



(a) Volume of ride-hailing trips **(b) Average trip distance**

Notes: Treatment locations are circles of 50 m radius centered on all, both planned and in-between, control locations in our baseline estimates. Control locations are the areas between 50 – 100 m from the centroids of these same locations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): 15,211.

In stark contrast to the results of implementing using a "ring-based" method considering the actually opened Phase 1 station locations (see Figure 11), we find no significant effects when doing so using our control locations only, neither when it comes to the volume of ride-hailing trips nor to the average trip distance.

[32] As mentioned before, we unfortunately lack data on average trip distance for *Gojek* trips beyond 100 m from our treatment and control locations.

There is no evidence whatsoever that ride-hailing activity changed differentially in locations nearer to our control locations, providing (even more) confidence in the choice of control locations underlying our baseline estimates.

6. Conclusion

In this paper, we have empirically investigated whether ride-hailing services are a substitute or complement for mass rapid transit (MRT) in the specific case of Jakarta, one of the largest and most heavily traffic congested cities in the world. To do so, we exploited the phased and staggered opening of Jakarta's MRT system, employing an event study design to estimate the impacts of the system's Phase 1 opening on ride-hailing activity within the immediate neighborhoods of newly opened MRT stations. We find that the system's opening led to large increases in the volume of ride-hailing trips in the immediate neighborhoods of newly opened MRT stations, while at the same time reducing the average distance of ride-hailing journeys to and from these station locations. These results hold for journeys made on regular weekdays, weekends, during rush hours and during non-rush hours alike. And, they are more prominent in the vicinity of newly opened MRT stations that were not already served by Jakarta's BRT system. For these locations, the opening of the MRT increased their rapid public transit options at the extensive margin, whereas it only did so at the intensive margin for MRT station locations that were already served by the BRT.

Taken together, our results strongly suggest that ride-hailing and public transport are complements, with the new ride-hailing trips associated with the MRT system's opening providing important first- and last-mile connectivity, both for trips made for commuting and non-commuting purposes. These effects are very localized. They are primarily driven by the changes in *Gojek*-activity within 50 m of the newly opened stations. The motorbike-based ride-hailing in Jakarta, much more flexible in terms of being able to pick up and drop off customers as close as possible to their desired pick-up or drop-off location compared to the mostly car-based ride-hailing activity analyzed in earlier studies (notably Gonzalez-Navarro *et al.*, 2021), is an important explanation of this more localized effect. It is very likely to carry over to other developing country city contexts, where ride-hailing services are also primarily motorbike-based.

Our results carry several important potential policy implications. The strong complementarity between the MRT system and ride-hailing services suggests that, far from being a threat, ride-hailing services help boost demand for mass rapid public transport in Jakarta with positive implications for its long-run financial viability, as well as for the overall mobility of both workers and households within the Jakarta metro area. Especially for those that cannot afford their own vehicle, live in places without reliable public transport alternatives, and/or for whom walking to the newly opened station is not an option (either because of safety or distance considerations).

It is also worth noting, however, that our study has several limitations. Most importantly, perhaps, while our analysis focuses on the impacts of the opening of the MRT system on demand for ride-hailing services in the immediate neighborhoods of newly opened MRT stations, it is silent on impacts elsewhere in the city. In other words, our findings should strictly speaking be taken as strong evidence for *local complementarity*. The opening of the MRT may, for example, have decreased ride-hailing activity to/from locations near the newly opened MRT stations to locations further away, as people now take an MRT ride, (possibly using a *Gojek* ride for the first/last mile only) to get to that location, instead of, as before, using ride-hailing for the entire journey.

In this respect it would be particularly interesting for future research to be able to trace back how/where people who are now using ride-hailing services for their first and/or last-mile connectivity to the MRT were using ride-hailing services, possibly in combination with other forms of public transport, before the MRT system opened. Another fruitful direction of future research would be to estimate the impacts of the MRT system on local levels of pollution, greenhouse gas emissions, traffic congestion, and the use of other forms of public transport, as well as to replicate our analysis for other cities in Indonesia, and elsewhere in the developing world where the rise of ride-hailing services predates the construction of rapid mass public transit options, fewer people own their own transport, and where ride-sharing is predominantly motorbike-based.

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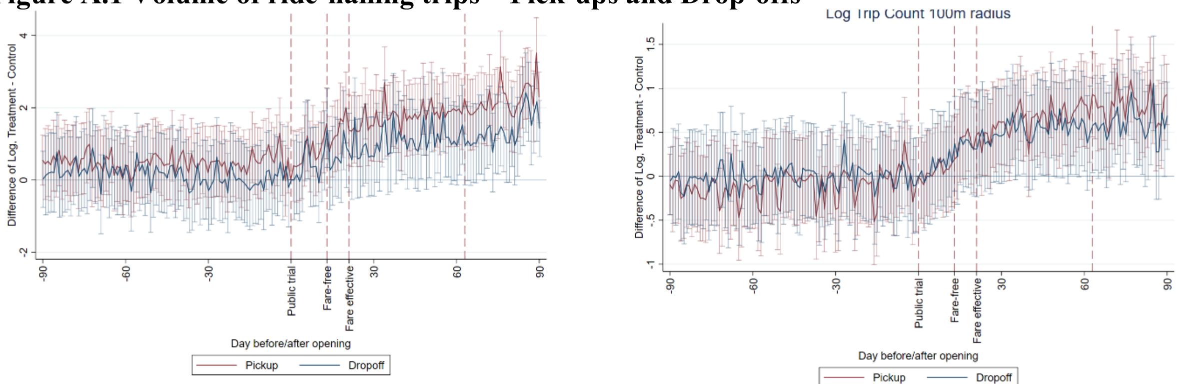
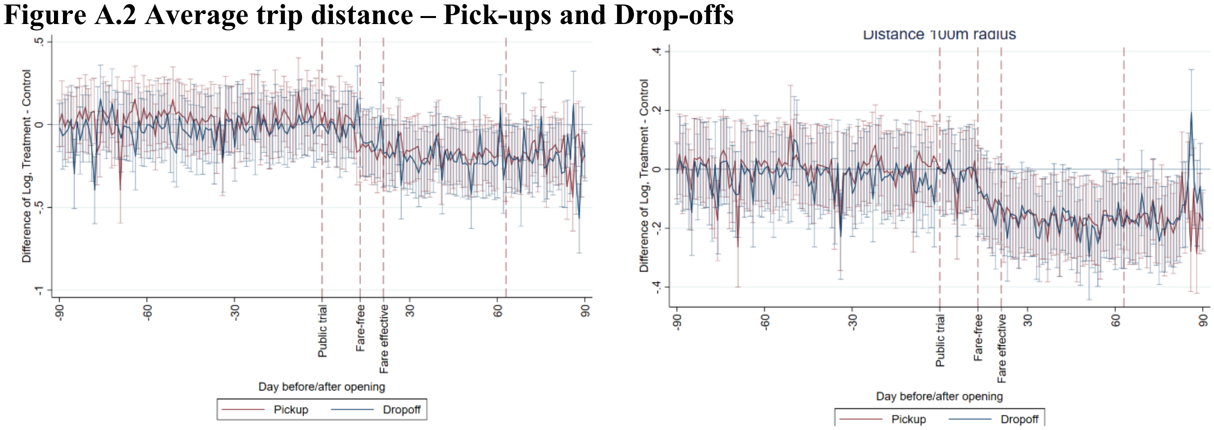
<u>Annex A</u> – The opening of the MRT: a separate look at pick-up and drop-off ride hailing trips

Figure A.1 Volume of ride-hailing trips – Pick-ups and Drop-offs



(a) 50 m **(b) 100 m**

Figure A.2 Average trip distance – Pick-ups and Drop-offs

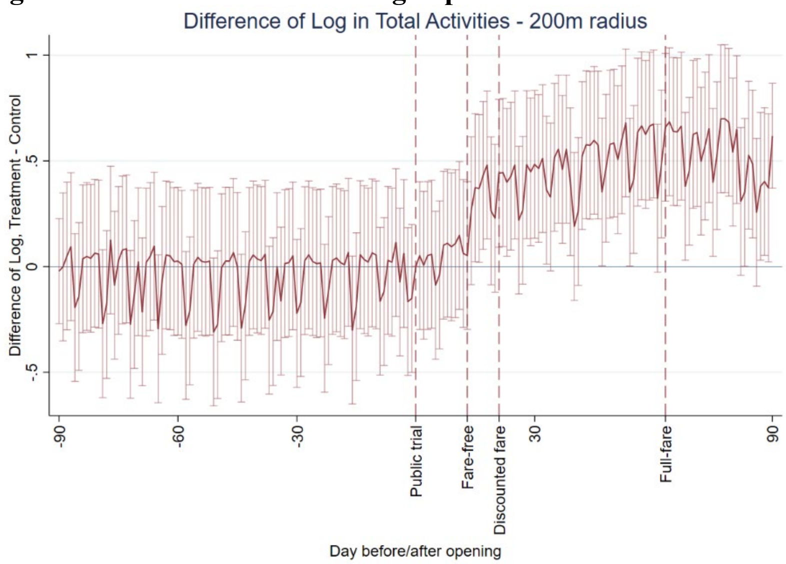


(a) 50 m **(b) 100 m**

Note: In Figure A.1, the control group includes both the planned Phase 2A station locations and the intermediate Phase 1 station locations. In Figure A.2, the control group is restricted to the planned Phase 2A station locations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): (Figure A.1) 13,071, (figure A.2) 8,433.

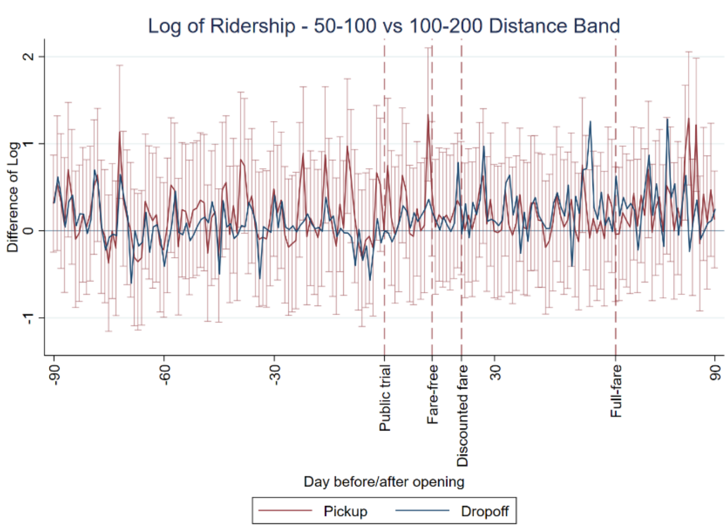
Annex B – Defining treatment and control locations using 200 m radius circles

Figure B1. Volume of ride-hailing trips



Note: Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): 13,071. We lack data on the average trip distance for journeys beyond 100m from the treatment and control locations, which prevents us from showing results on that measure when using a 200 m radius to define locations. Also, we cannot distinguish between rush and non-rush hour trips for trips that end/start beyond 100 m from our locations.

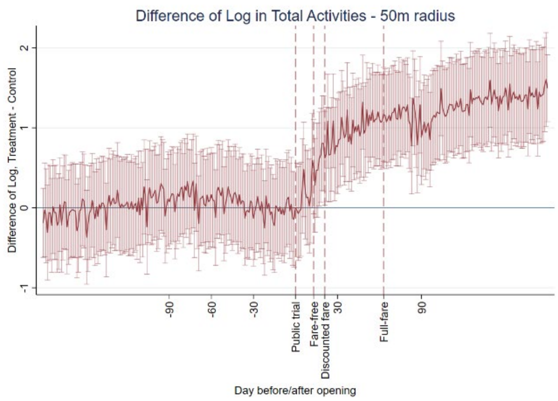
Figure B2. Total ride-hailing trips in 50 – 100m vs 100 – 200 m rings from MRT stations



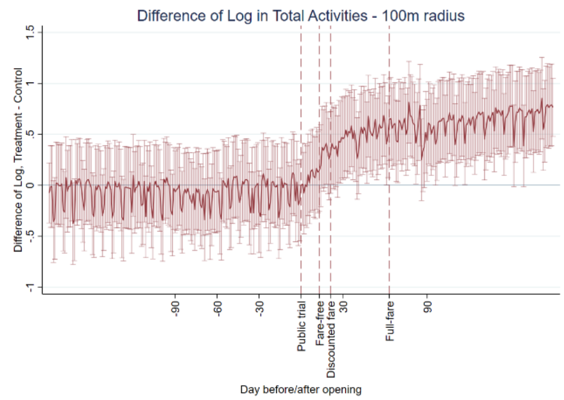
Notes: Treatment locations are the areas between 50 – 100 m from the Phase 1 MRT station locations; control locations are the areas between 50 – 100 m from these same stations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): 15,211.

<u>Annex C</u> – Results for period of full data availability (i.e., 1 September 2018 - 1 November 2019)

Figure C.1 Volume of ride-hailing trips

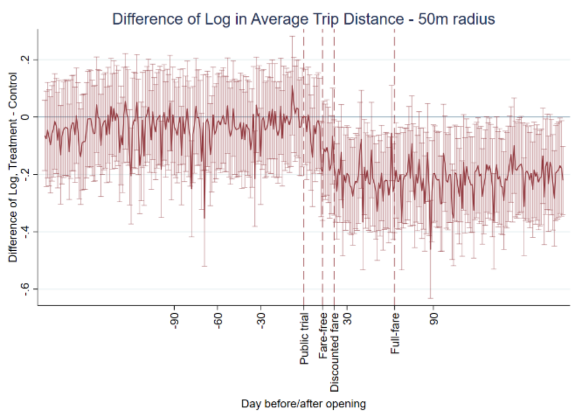


(a) 50 m

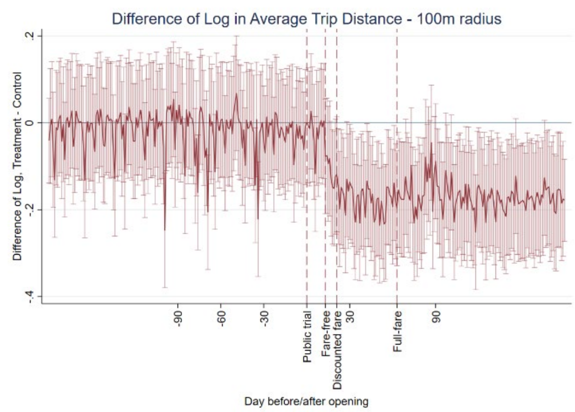


(b) 100 m

Figure C.2 Average trip distance



(a) 50 m

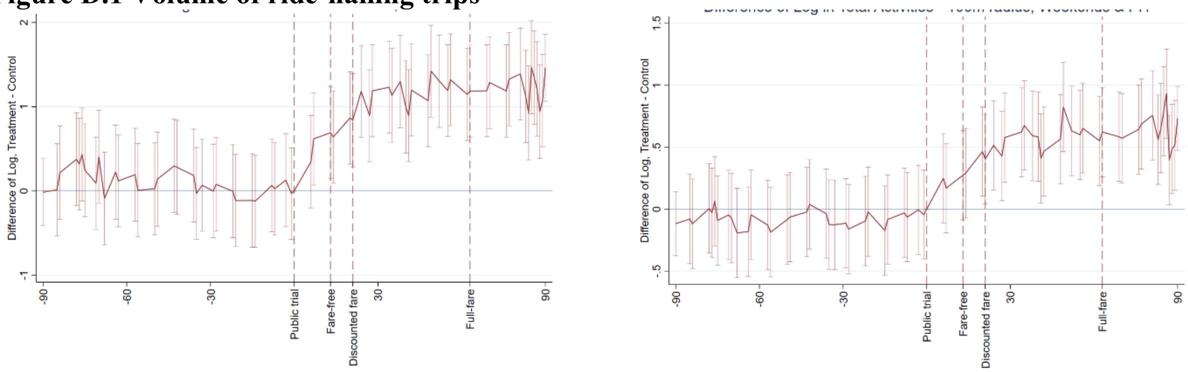


(b) 100 m

Note: In Figure C.1, the control group includes both the planned Phase 2A station locations and the intermediate Phase 1 station locations. In Figure C.2, the control group is restricted to the planned Phase 2A station locations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): (Figure C.1) 13,071, (figure C.2) 8,433.

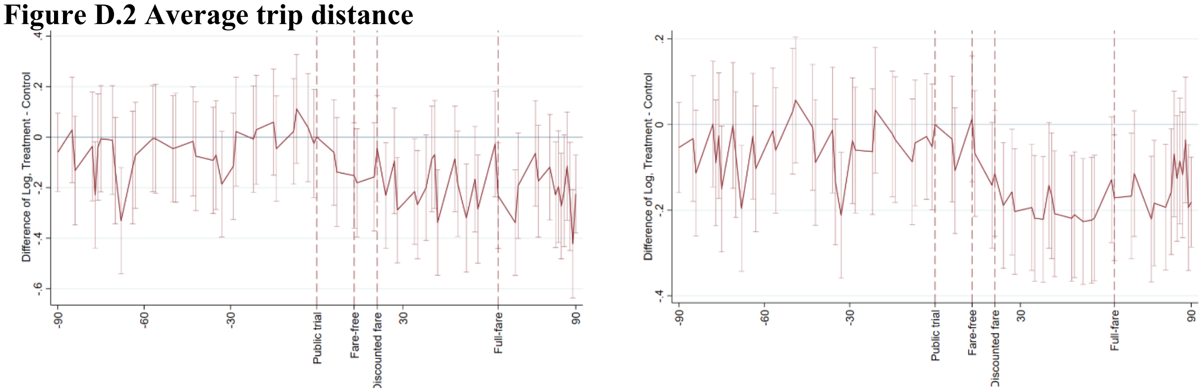
<u>Annex D</u> – Results considering weekends and public holidays only

Figure D.1 Volume of ride-hailing trips



(a) 50 m **(b) 100 m**

Figure D.2 Average trip distance



(c) 50 m **(d) 100 m**

Note: In Figure C.1, the control group includes both the planned Phase 2A station locations and the intermediate Phase 1 station locations. In Figure C.2, the control group is restricted to the planned Phase 2A station locations. Standard errors are clustered by location. 95 percent confidence intervals are shown alongside the estimated coefficients. Sample size (number of time-location observations): (figure D.1) 2,732, (figure D.2) 2,673.