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The effects of e-ridehailing on motorcycle ownership in an emerging-country megacity

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ABSTRACT

The impact of app-based e-hailing or ridesourcing services on various transport metrics is an area of active research, and research so far have focused on the car-based (or four-wheeled vehicle based) services only. In many cities in the developing and emerging countries, motorcycle-based passenger e-hailing services have become very popular in the last few years, but the implications of these have not been studied before. This study investigates the effects of motorcycle-hailing apps in Dhaka – a megacity in Bangladesh – on the size of its motorcycle fleet. We employ segmented multiple regression on timeseries data to show that there was a statistically significant increase in motorcycle ownership in Dhaka as a result of the motorcycle-hailing services. The findings were also supported by a visual intervention analysis. By the end of 2018, there were 7.45% more motorcycles in Dhaka than there would have been if these app-based e-hailing services were not available. We conclude with potential implications of these increases in motorcycle numbers and future research directions.

1. Introduction

E-hailing or ridesourcing[1] services have been a major innovation in the transport sector in the past decade and have rapidly disrupted how we travel – especially in urban areas. The providers of these services, often known as Transport Network Companies (TNCs), use an online, information technology enabled, and smart phone based platform to connect available car or taxi drivers and potential passengers in real time resulting in an efficient, convenient, quick and transparent procurement of the passenger ride service (Shaheen et al. 2015). Made popular in a very short time by the global and regional TNCs such as Uber, Lyft, Bolt, Ola, Didi-Chuxing, Grab or Careem, the services are now available in nearly every major city in the world, except where they do not comply with city regulations.

Understanding the effects of e-hailing services on various traffic or travel outcome is an active area of research, and, so far the evidence on various outcome have been mixed. While there are suggestions that e-hailing services could shift trips from private cars to transits through better first and last mile connections and thus reduce congestion (Li et al. 2017), others argue that these services may have increased traffic on the road and increased congestion, especially through empty-running and modal shift to these services (Henao and Marshall 2019, Erhardt et al. 2019). Henao et al. (2018) and Wadud (2020) show that the demand for parking at airports has decreased significantly since the introduction of the TNC services. Kirk et al. (2020) found slight reduction in serious road accident injuries, but not traffic fatalities since Uber entry in Great Britain.

Ownership of vehicles is another important metric used for measuring the impacts. Vehicle numbers can act as a proxy for vehicle

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[1] The terms e-hailing, ridehailing, ridesourcing, ridesharing are all used to mean the same thing in some parts of the world, and different things in other parts, creating some confusion. We use SAE International's (2018) definition here.

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miles travelled and congestion, but can also be an independent metric, especially since it is often argued that the e-hailing services will reduce ownership of vehicles. Although questionnaire-based work reports a modest 'intention' by the users of these services to give up their cars or delay car purchases (Rayle et al. 2016), few studies investigate the effects of e-hailing services on private vehicle ownership using actual vehicle registration data. In this regard, Ward et al. (2019) found that the ownership of private vehicles has reduced since the introduction of these services in the US, while Schaller (2019) suggest the opposite in the largest cities in the US. Our own ongoing work shows that the number of private hire vehicles (PHVs) in the UK may have increased since the entry of Uber in this market, but the effect on the number of private vehicles is still unknown.[2]

So far, research on the impacts of TNC services has been limited to services whereby a four-wheel based vehicle is used to transport the passenger and to countries from the developed world. In the last few years, two-wheeled motorcycle-based e-hailing services have become popular in many developing and emerging economies – especially in Sub-Saharan Africa and South-East Asia. These services are not only available in places where traditional motorcycle taxis were already in use as a paratransit mode, but also where motorcycles were never used before to provide commercial mobility services.[3] However, little is known about the transport related impacts of these motorcycle e-hailing services. This research aims to fill this gap by estimating the effects of motorcycle ridesourcing on the number of motorcycles in a megacity in an emerging economy: Dhaka, the capital of Bangladesh. The number of motorcycles is a useful metric not only for understanding potential travel and congestion impacts, but is also important from a safety perspective, since motorcyclists are substantially more vulnerable compared to other motorized transport users (Department for Transport, 2015).

2. Motorcycle taxis and smart-phone apps

Motorcycle taxis are a popular form of low-cost paratransit in many South-East Asian and Sub-Saharan African countries. Examples include 'win motor-sai's in Bangkok, Thailand, 'ojek's in Jakarta, Indonesia, 'okada's in Lagos, Nigeria, 'boda-boda's in Kampala, Uganda and Dar-Es-Salam, Tanzania, or 'moto's in Phnom Penh, Vietnam and Kigali, Rwanda. In Sub-Saharan Africa, motorcycles and motorcycle taxis could form up to 75% of the traffic in low volume rural roads (Transaid, 2017). For trips involving only one passenger, motorcycle taxis are convenient and can be cheaper than using regular taxis or other forms of paratransits for short distances or owning private vehicles (Ehebrecht et al., 2018). In megacities such as Bangkok, Jakarta and Lagos, where traffic congestion is a perennial problem, motorcycle taxis are especially popular due to their ability to weave through the stagnant traffic and in small alleys, making them significantly quicker than other road-based vehicles (Kamuhanda and Schmidt, 2009). Olvera et al. (2016) report that as many as 104 cities in Sub-Saharan Africa (out of a sample of 203 cities with a population larger than 100,000) had motorcycle taxis in operation.

Motorcycle taxis have traditionally flourished in an organic way - by offering a flexible, accessible and door to door service in the absence of organized, reliable transport services (Phun et al. 2019). Like other informal transport, they fill an important void in transport service provisions in most areas where they operate (Cervero and Golub 2007). In Bangkok, an estimated 200,000 motorcycle taxis served around 4 to 6 million trips every day in 2013 (Sopranzetti 2014), although recent estimates suggest the number of motorcycle taxis are as high as 300,000 (Ratanawaraha and Chalermpong 2015). Similar numbers are quoted for Ugandan capital Kampala (Ssenkaaba 2013), although only half are registered with the authorities. There are an estimated 8 Million Okada drivers in Nigeria (Akwagyiram, 2019) and around a million in Kenya (Mingmei 2019), while Tanzania has more than 800,000 motorcycle taxis (Bishop and Amos 2015). Despite the sheer volume of vehicles and operators involved in the business, motorcycle taxis are by and large an informal mode of transport, and – barring a very few exceptions – are often beyond the purview of any regulations on vehicle or driver licensing, operational jurisdiction, insurances, driver training, or fare structure (Cervero 2000). Even if some regulations exist, monitoring and enforcement is often lax.

As the numbers above show, motorcycle taxis are clearly a large source of employment – primarily in the informal sector – in many of the megacities in the developing and emerging countries (Cervero 2000, Olvera et al. 2016, Ehebrecht et al. 2018). The benefits and costs of motorcycle taxis as a paratransit mode have been discussed in literature – generally in the context of informal transport (Cervero and Golub 2007). However, motorcycles and – by extension – motorcycle taxis or e-hailed motorcycles are prone to more accidents compared to other road vehicles, and motorcycle riders are also among the most vulnerable to injury and fatality in case of accidents (Bishop and Amos 2015, Pucher et al. 2005). For example, motorcycle riders accounted for less than 1% of traffic in the UK in 2013, but 19% of the fatalities (Department for Transport, 2015). In Thailand, Cambodia and Laos, 70% of the road accidents involve motorcycles or three-wheelers (Kitamura et al. 2018). Tuffour and Appiagyei (2014) find that 72% of the motorcycle taxi passengers they interviewed have been involved in an accident in those taxis, indicating severe safety concerns.

Inspired by the popularity of smart-phone facilitated, car-based on-demand ridesourcing services offered by the TNCs in the developed and emerging economies, motorcycle taxis have also embraced the technology in several countries. Safebodas in Kampala, Uganda in 2014 and Go-Jek in Jakarta Indonesia and Safemotos (now CanGo) in Kigali, Rwanda in 2015 were the pioneering start-up companies to provide app-based motorcycle taxi services (Okunola 2018, Porter 2016). Among the traditional car-based TNCs, Grab was early to include motorcycles in its portfolio in late 2014 in Ho Chi Minh City in Vietnam (Pike 2018), while Ola and Uber both

[2] In the UK, ridesourcing vehicles are registered as private hire vehicles, which have long existed as an advance-booking-only service.

[3] We note that the term paratransit can sometimes be used in the US for transport services for people with disabilities, but here we use it in its original definition as per Kirby et al. (1974): "… those forms of intra-urban passenger transportation which are available to the public, are distinct from conventional transit (scheduled bus and rail) …", often provided by the informal sector (Cervero 2000).

Table 1
App-based motorcycle e-hailing in different countries.

Country	Current operators	First operator	First appearance
Bangladesh	Pathao, UberMoto, Shohoz, Obhai, Lily	SAM	2016
Egypt	Halan	Halan	2018
India	OlaBike, Bikxie, Baxi, Rapido, UberMoto, BYKUP,	Baxi	2015
Indonesia	Go-jek, GrabBike	Go-jek	2015
Kenya	Safeboda, BoltBoda	Safeboda	2018
Malaysia	GrabBike, DegoRide	Degoride	2016
Nigeria	Gokada, Max, SafeBoda, Oride	Max	2017
Pakistan	Bykea, UberMoto	Bykea	2016
Philippines	Angkas, GrabBike	GrabBike	2015
Rwanda	CanGo	SafeMoto	2015
Uganda	SafeBoda, Uberboda, BoltBoda	SafeBoda	2014
Vietnam	GrabBike, Go-Viet, Be	GrabBike	2014

followed suit in 2016 in several cities in India. Because of the early perceived successes and support from venture capital, motorcycle hailing apps are now quite popular in many emerging countries in the world and a countrywide non-exhaustive list is given in Table 1. These motorcycle based e-hailing services are different from the emerging micromobility services such as bicycle-share (bikeshare) or e-scooter share (Shaheen and Cohen 2019) and more similar to ridesourcing services, since the motorcycle is driven by a driver who carries a passenger for earning a fare. In some of these countries, notably in Indonesia (Go-Jek) and Bangladesh (Pathao), the provision of motorcycle e-hailing services was sometimes preceded by motorcycle-based courier services for small parcels.

The first app-based motorcycle hailing service in Bangladesh started its operation in the capital Dhaka in May 2016, by Share-A-Motorcycle (SAM). However, Pathao (meaning 'send') which had evolved from providing motorcycle-based parcel delivery services to providing motorcycle rides, possibly made the service more popular since its official launch in late 2016. Uber's car-based ride-sourcing services were launched in Dhaka in 2016, while the motorcycle service UberMoto was started in November 2017. Besides these, Shohoz and OBhai are other popular app-based motorcycle hailing services currently operating in Dhaka. In addition, Pathao expanded operation to Chittagong and Sylhet in October and December of 2017 respectively, while UberMoto started operating in Chittagong in April 2018. Within a year of its launch, Bangladesh became the largest UberMoto market for Uber (Chakravarty 2018), indicating rapid popularity of the motorcycle e-hailing services. It is estimated that there were around 200,000 e-hailing rides per day on motorcycles in Dhaka in early 2019, while the number for car-based ridesourcing was around 50,000 per day (Tarek and Amit 2019), pointing at the popularity of the motorcycle based ridesourcing services.

The business models and service provisions vary significantly between the providers, with the TNCs offering all or some of these services: motorcycle e-hailing, car-based ridesourcing, motorcycle-based parcel delivery and bicycle based food delivery. Unlike the car-based e-hailing services in Bangladesh (and in some emerging countries, too), where the driver rarely owns the car, the drivers providing the motorcycle e-hailing services tend to own their motorcycles (Shams et al., 2018). Discussions with industry leaders suggest that a large proportion of drivers drive only on a part-time basis, following the original business model for ridesourcing.

Despite the popularity of the motorcycle e-hailing services, the implications of these services on safety, travel behaviour, miles travelled or motorcycle population have not been studied in much depth. The only directly relevant work we are aware of is by Muni et al. (2018), who suggested an improvement in driver riding behaviour among the e-hailed motorcycle drivers compared to traditional motorcycle taxi drivers in Kampala, Uganda. As such there is a significant research gap in this area – whether in Dhaka, or in other cities in the emerging countries.

3. Motorcycles and vehicles in Dhaka and Bangladesh

Dhaka, the capital of Bangladesh, is a megacity of 20 Million people. Like most other megacities in the developing and emerging countries, Dhaka ranks among the most congested cities in the world. The average speed of traffic has dropped from 21 kmph to 7 kmph in the past 10 years (Fan and Rama 2017). However, compared to other South-East Asian megacities, motorcycle ownership in Dhaka (and in Bangladesh) is quite low. For example, Delhi, a similar sized city in India has around 6.6 Million registered motorcycles, while Bengaluru, a much smaller one, has around 5 Million (Philip, 2018). Karachi, a similar sized city in Pakistan has around 2.7 Million registered motorcycle (Ayub 2017). In comparison, the number of motorcycles in Dhaka has only crossed half a million by the end of 2017. Fig. 1 presents the total number of motorcycles and motorcycle ownership in several very large and megacities in South-East Asia.

Despite the relatively low ownership of motorcycles in comparison to its neighbours, two-wheelers still account for the largest category of motorized vehicles in Dhaka and in Bangladesh, as seen in Figs. 2 and 3. The two-wheeler market in Bangladesh is dominated by imported motorcycles and scooters. This is because there were no local manufacturers or assemblers in the country until 2000. In 2001 an assembly plant started its operation, while in 2007 a local company (Runner) started manufacturing motorcycles in Bangladesh in a small scale. Given the relatively high import duties and taxes and registration fees for motorcycles, the costs of owning motorcycles in Bangladesh have been comparatively high. Mizutani (2016) suggests that similar motorcycles in Bangladesh cost around 2.3 times that in India. He also shows that the price of the best-selling 100 cc motorcycle is equivalent to

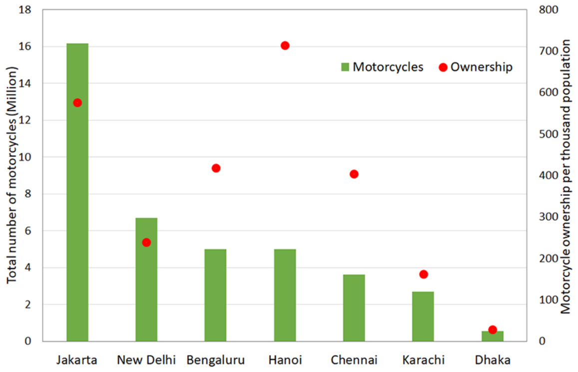

Fig. 1. Motorcycle volume and ownership in different cities.

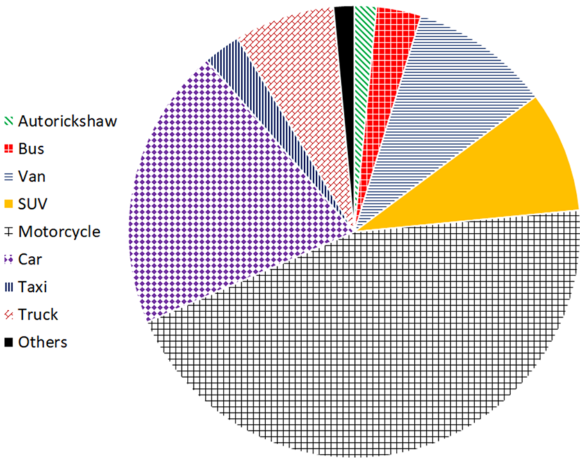

Fig. 2. Share of different classes of motor vehicles in Dhaka in 2018 (based on BRTA, 2019a).

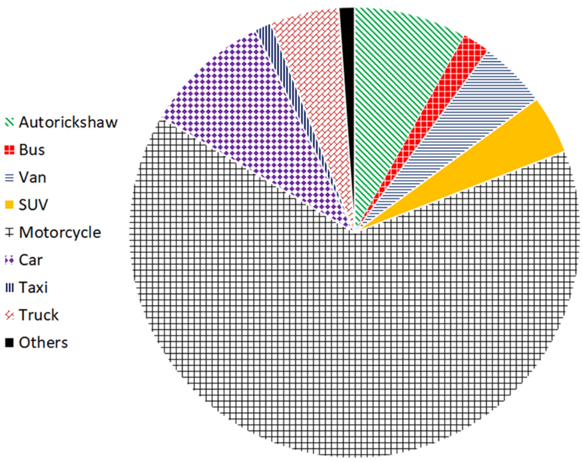

Fig. 3. Share of different classes of motor vehicles in Bangladesh in 2018 (based on BRTA, 2019b).

23 months of average wages in Dhaka, compared to 3–7 months of wages in Kuala Lumpur and Hanoi respectively. These relatively higher prices made motorcycles less affordable in Bangladesh which is likely an important cause behind low motorcycle ownership in Bangladesh compared to other countries at similar stages of development.

In recent years, motorcycle numbers have grown rapidly though. For example, motorcycle registrations in Dhaka more than doubled in the past eight years (UNB 2018). The growth in motorcycle registration in the whole country has also been high. Bangladesh has been one of the fastest growing economies in the world for the past decade, resulting in a greater purchasing power of its

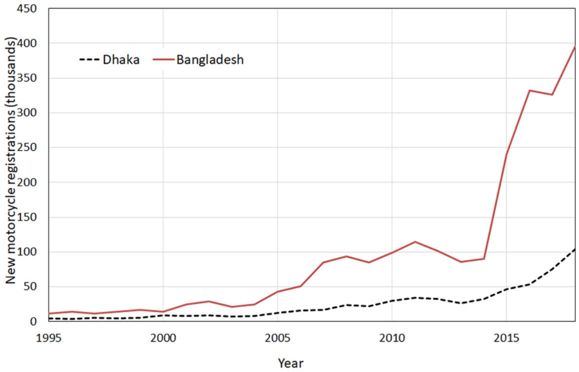

Fig. 4. New motorcycle registrations in Dhaka and the rest of Bangladesh, data source: BRTA (2019a, 2019b, previous archived years by author).

population. At the same time, an increase in the population, a gradual improvement in the conditions of rural roads and the development of a vibrant local motorcycle industry (nearly 80% of the motorcycles are now manufactured or assembled in the country, Chakma, 2019) also had played a role in increasing the motorcycle numbers in the country.

The affordability of motorcycles has improved even further very recently. In order to encourage the development of the local motorcycle assembly and manufacturing industry, the duty on imported motorcycles and parts and VAT structure for local manufacturing were changed in 2015. The resulting competition between local and imported motorcycles also led to various promotional activities from the assemblers, manufacturers and importers, which led to a reduction in motorcycle prices in the country, sometimes by up to a third (Ahmed 2019). At the same time the registration fees for motorcycles were reduced from BDT 20,000 to BDT 5,000 (USD 240 to USD 60) in order to encourage demand. On the demand side, motorcycle-based e-couriers started operating in early 2015. All of these initiatives had a role in the rapid increase in new motorcycle registrations in the country since 2015 (Fig. 4), although the increase appears visually less prominent in Dhaka.

App-based motorcycle ridehailing services are often described by transport stakeholders as a major reason behind the rapid growth in motorcycle population (Shams et al., 2018), which in turn is seen as a major precursor to accidents in the capital Dhaka (Adhikary 2018, Masum 2018). In most other cities and countries described earlier, commercial motorcycle taxis had already existed in large numbers and the e-hailing apps acted as an efficient and organised way of seeking or delivering the rides. However, motorcycle taxis have never been popular in Dhaka (or in Bangladesh). The introduction and rapid popularity of the motorcycle e-hailing apps appear to have changed this situation in Dhaka, although no analysis exists on the effects of motorcycle e-hailing services on the motorcycle population in Dhaka.

4. Data

The availability of data is always a challenge, especially in developing economies. Even when data is available, its reliability can be a cause of concern. Bangladesh Road Transport Authority (BRTA) publishes the number of new vehicle registrations[4] by vehicle types for Dhaka and the rest of the country. While a longer time series of total annual motor vehicle registrations by vehicle type are also published in the Statistical Yearbooks of Bangladesh by Bangladesh Bureau of Statistics, careful inspection reveals that the total numbers in these data tables are based on adding all previous ‘new’ registrations of BRTA and does not exclude the older vehicles which may no longer be in use. As such the total registrations in a year will likely over-estimate the number of vehicles or motorcycles and annual new registrations are more reliable compared to the total. Therefore, we developed a survival-based fleet model starting from new vehicle registrations to arrive at our own estimates of the number of motorcycles.[5]

New vehicle registrations for Dhaka and Bangladesh are available by different vehicle groups. These vehicle groups can vary between years: e.g. SUVs and microbuses have been split into two groups, vans have been split into three types, and new groups such as human haulers introduced. Unsurprisingly for motorcycles, the grouping is consistent throughout, providing us with usable timeseries data. Although new registrations data can be obtained from 1975, communication with BRTA reveals that the data on motor vehicle registrations before 1995 is less reliable. As such we use data from 1995 for our econometric model estimation (described in the next section). However, in order to get the vehicle stock (number of motorcycle in use) as mentioned above, we use earlier data on new registrations as well. Note that the influence of early data become increasingly negligible on the motorcycle stock data for our sample time periods. Fig. 4 presents the new motorcycle registrations in Dhaka and the rest of Bangladesh since 1995, while Fig. 5 presents the motorcycle fleet in use in Dhaka and Bangladesh, using the survival corrected (as mentioned earlier) and uncorrected data (assuming current total from BRTA – without any scrappage of older vehicles – is correct).

[4] Note that ‘new’ registrations do not necessarily mean new vehicles. Most of the private cars in Bangladesh are imported and were previously owned in the exporting country.

[5] This has been developed assuming a motorcycle lasts for 15 years, and that every motorcycle is scrapped by year 20. Two other scrappage functions were also used, but the econometric modelling conclusions do not vary depending on the different assumptions about scrappage.

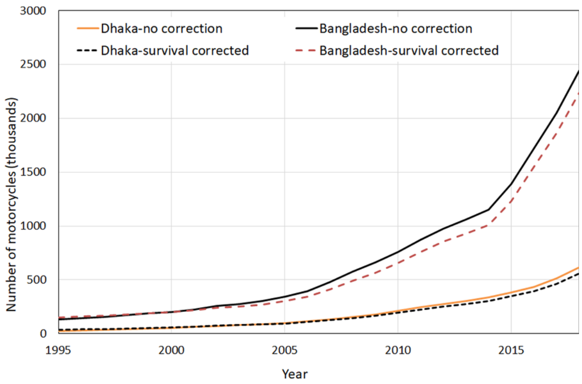

Fig. 5. Motorcycle stock in Dhaka and the rest of Bangladesh, data source: author's calculations based on BRTA (2019a, 2019b), and Statistical Yearbooks of Bangladesh by Bangladesh Bureau of Statistics (various years).

Population of Dhaka and Bangladesh is collected from the World Development Indicators of the World Bank (2019). Real GDP per capita and real GNI per capita data is collected from the same sources. These two series, however, are not available separately for Dhaka. As such we use the same data for Dhaka and the rest of the country. Given the econometric model estimation depends on yearly variations in the data, rather than the absolute value, this is less problematic if the growth rate is similar in Dhaka and the rest of the country. This is possibly a strong assumption, however, previous academic work has used similar assumptions in the absence of reliable GDP or GNI data for Dhaka city (Wadud 2014). Fig. 6 presents the population and GDP data.

5. Methods

There are several approaches to modelling the effects of an intervention or disruption using time-series data. The first is the well-known intervention analysis, proposed by Box and Tiao (1975). In this approach, an econometric model (generally a univariate ARIMA) is estimated using data until the intervention period, the estimated parameters are then used to forecast the variable of interest beyond the intervention period and these predictions are compared (graphically or statistically) with the actual data to understand the impact. Sometimes, a transfer function can also be included for the post-intervention period to directly understand the nature of the effects. The method is especially useful if there is a long timeseries or the temporal data has finer frequency than annual. Examples of application of this method are Noland et al. (2008), Park et al. (2016), Wadud (2014, 2020). However, given we have only two years of post-intervention data, a statistical comparison of predicted and observed data using this method will not be very meaningful.

The second method is known as the segmented multiple regression (Lagarde 2012) or interrupted time series approach (Bernal et al. 2017), where the effects of the disruption are simultaneously modelled along with other regression parameters. In this approach, a dummy variable is introduced for the post-intervention period, the statistical significance of which will point to the existence of an impact of the intervention. The nature of the impact is assumed to be known and can be tested through statistical significance. If the disruption results in a one-off shift in the variable of interest, then a simple dummy variable is used. Else, it can also be interacted with time if the effect is expected to be gradual and linear. Other forms of interactions are also possible in order to model other forms of impact. We follow this segmented regression approach as our primary method of analysis, although we also employ the first method to graphically check the robustness of our findings.

Our intervention occurs in mid-2016, when SAM first started its motorcycle e-hailing service in Dhaka, followed by the launch of the more popular Pathao at the end of 2016. However, given it took some time for the service to become popular and have an impact

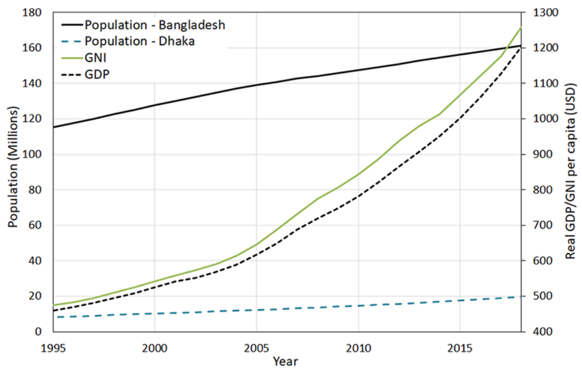

Fig. 6. Evolution of population and GDP per capita, data source: World Bank (2019).

on motorcycle numbers, we do not expect any statistically discernible effect before 2017. Such a lag is frequently observed in practice and employed in understanding the effects of TNC services, e.g. Henao et al. (2018) found a 1 to 2 year lag between the introduction of these services and a reduction in parking revenue at the airports, while Wadud (2020) found a half-year lag best fits the data while determining the impacts on parking volume at the airports. We anticipate that the effect of motorcycle e-hailing apps will not be a one-off shift in motorcycle numbers, rather a gradual increase over time reflecting the increase in popularity of these services and associated increases in the demand for motorcycles for e-hailing purposes.

Two key determinants of motorcycle numbers in emerging countries are income and population, or population density (Nishitateno and Burke 2014). Income determines the ability of the people to afford a motorcycle, while population determines the potential pool of people who can own motorcycles. Income is, of course, the key determinant of private vehicle ownership (vehicle per capita) as well, as seen from numerous studies (e.g. Dargay et al. 2007, Wang et al. 2011, Chamon et al. 2008), alongside other determinants such as vehicles prices, fuel prices, employment and public transport provision. Given the relatively short time period of our data and the generally strong correlation between income and population (as they are both time-trending variables), we choose motorcycles per capita (strictly speaking, motorcycles per thousand population) as the dependent variable, leaving income per capita as the principal explanatory factor in our econometric model.

Prices are another important determinant of demand for any good, however, motorcycle price index is not available for the duration of our time series. A continuous time variable is added to reflect the potential gradual changes in the price index. This also captures other gradual changes during the period. Also, we use a dummy variable (interacted with time) to show the major policy change in 2015, as discussed earlier, which had affected the prices and affordability of motorcycles in the country. The reduced form demand for motorcycles per capita is thus a function of income, linear time trend, and dummies for policy changes in 2015 and for motorcycle e-hailing services in 2017:

$$MC_t = \alpha + \beta T + \delta Y_t + \gamma (P15 \times T)_t + \theta (EH \times T)_t \tag{1}$$

where, MC = motorcycles per thousand people
T = time in year, representing a time trend
Y = real income per capita
$P15$ = dummy variable for policy changes in 2015
EH = dummy variable for introduction of motorcycle e-hailing services

The Greek letters are the parameters to be estimated. However, both the key variables in Eq. (1) – motorcycle ownership per thousand people and income per capita are trending in time and will likely be non-stationary, potentially making the parameter estimates spurious (unless there is cointegration). Estimating the first differenced version of Eq. (1), as presented in Eq. (2), is a better approach.

$$\Delta MC_t = \beta + \delta \Delta Y_t + \gamma P15_t + \theta EH_t \tag{2}$$

The dependent variable therefore is changes in motorcycle ownership. The statistical significance of the parameter θ, associated with the introduction of motorcycle-hailing in Dhaka, will show if motorcycle ownership has changed since the entry of these services. The sign of this parameter will reveal whether ownership had increased or decreased. The differenced dependent variable, changes in motorcycle ownership, also closely resemble the new registration data, which is more reliable compared to the total registration data, as we had discussed earlier.

In order to test that our finding regarding the impacts of app-based motorcycle hailing services is not spurious, we use the rest of Bangladesh as a counterfactual example. We test whether there is a statistically significant impact on motorcycle numbers for the same e-hailing intervention dummy for the rest of Bangladesh. Since there were no motorcycle e-hailing services in the rest of the country during that period we do not expect motorcycle ownership to deviate from the regular trend, i.e. the parameter estimate for the *EH* variable should be statistically insignificant.[6] Confirmation of such a result for the counterfactual example would give confidence that we have not captured something unknown through the dummy variable for Dhaka and would strengthen the argument regarding a causal impact.

6. Results

Table 2 presents the econometric estimation results for both Dhaka and the rest of Bangladesh samples for the survival corrected motorcycle fleet and uncorrected fleet data. Both the regional models for both sets of data are estimated twice: with and without a constant (i.e. β). The standard errors reported are robust ones. The residuals of these models are tested for no autocorrelation using the Breusch-Godfrey LM test. Several variants using logarithmic transformation have also been estimated but did not work due to autocorrelation in the residuals (results not presented here). All eight of the estimated models show excellent goodness of fit, with adjusted R^2 lying between 0.92 and 0.98. All of the models presented here use real GDP per capita proxying for income, as the residuals of the models with real GNI per capita failed to pass some of the residual autocorrelation tests.

For Dhaka, the models using the uncorrected data, D3 and D4, perform better in terms of goodness of fit statistics such as AIC, BIC

[6] Although two further cities had motorcycle e-hailing before the end of 2018, compared to the whole of Bangladesh, their fleet size would be small to show any significant changes, as we shall see in the results later.

Table 2
Parameter estimates for segmented regression models for changes in motorcycle ownership.

Region	Dhaka				Rest of Bangladesh			
Data	Survival corrected		Uncorrected		Survival corrected		Uncorrected	
Model no.	D1	D2	D3	D4	B1	B2	B3	B4
GDP per capita (*Y*)	0.0287	0.0338	0.0339	0.0342	0.0092	0.0142	0.0108	0.0149
	(11.83)***	(6.94)***	(14.43)***	(7.33)***	(10.53)***	(8.37)***	(12.38)***	(8.25)***
Policy (*P15*)	0.2631	0.1391	0.1993	0.1902	1.0789	0.9563	1.0420	0.9443
	(1.94)*	(0.73)	(1.50)	(1.05)	(5.42)***	(4.98)***	(5.40)***	(4.95)***
E-hail (*EH*)	1.1920	1.1141	1.1652	1.1595	0.0511	−0.0258	0.0411	−0.0202
	(3.48)***	(3.30)***	(3.55)***	(3.41)***	(0.25)	(-0.14)	(0.21)	(-0.11)
Constant	–	−0.1589	–	−0.0116	–	−0.1569	–	−0.1251
		(-1.60)		(-0.12)		(-4.20)***		(-3.20)***
R^2	0.967	0.928	0.975	0.936	0.973	0.969	0.977	0.968
Adj. R^2	0.961	0.917	0.972	0.926	0.969	0.964	0.974	0.963
AIC	8.567	9.061	5.910	7.902	−27.364	–32.761	−28.900	−31.654
BIC	12.106	13.773	9.445	12.614	–23.830	−28.048	−25.365	−26.942
Breusch-Godfrey test for residual auto-correlation	2.17 (p = 0.141)	1.82 (p = 0.177)	1.25 (p = 0.264)	1.26 (p = 0.261)	1.644 (p = 0.200)	0.871 (p = 0.351)	1.647 (p = 0.199)	1.422 (p = 0.233)
Portmanteau test for white-noise of residuals	14.209 (p = 0.164)	20.592 (p = 0.024)	19.141 (p = 0.039)	19.431 (p = 0.035)	5.730 (p = 0.837)	14.451 (p = 0.153)	6.473 (p = 0.774)	14.558 (p = 0.149)
Bartletts test for white-noise of residuals	0.923 (p = 0.362)	0.935 (p = 0.347)	0.829 (p = 0.498)	0.835 (p = 0.489)	0.935 (0.347)	0.816 (p = 0.518)	0.975 (p = 0.297)	0.927 (p = 0.357)
LR test	1.51 (p = 0.220)		0.01 (p = 0.926)		7.40 (p = 0.007)		4.75 (p = 0.029)	
Estimation period	1995–2018							

***Statistically significant at 99%.
**Statistically significant at 95%.
*Statistically significant at 90%.

or adjusted R^2 compared to the models using the survival corrected data (D1 and D2). However, both D3 and D4 performed poorly in the Portmanteu white-noise test for the residuals. Between the two models using survival corrected data, D1 and D2, the one without a constant in the specification, Model D1, performs better using adjusted R^2, AIC or BIC; D2 also performs poorly for the Portmanteu test. Likelihood ratio test also clearly shows that model D2 is not an improvement on D1, despite D2 having one extra explanatory factor. As such D1 – the model using survival corrected data and no constant in the specification – is the preferred model for discussing the results. The key conclusions, however, remain the same across all of these model specifications and data variants, showing robustness of the findings.

As expected, income per capita has a statistically significant effect on the increase in motorcycle ownership in Dhaka. Motorcycle ownership is known to increase with increases in income until a certain income threshold, beyond which they may start falling (when people switch to owning a car, Nishitateno and Burke 2014). Dhaka has clearly not reached that threshold yet, and motorcycle registrations continue to increase due to increased affordability.[7]

Changes in government regulations in 2015 resulted in an increase in motorcycle ownership in the city. As discussed earlier, these policies led to substantial reductions in average prices of motorcycles and the costs associated with registration, as such motorcycles became more affordable and an increase is ownership is expected. The motorcycle-based courier services also started around this time, so the 2015 dummy *P15* has captured the effects of these services as well. This finding, however, is not consistent across the other model specifications for Dhaka and therefore is less robust.

The dummy variable capturing the introduction of motorcycle e-hailing services (*EH*) – our key variable of interest in Dhaka – is statistically significant and positive, indicating that the increase in motorcycle ownership has accelerated post these services. This finding is robust against other variants of data and model specifications.

For the counterfactual models for the rest of Bangladesh, those using uncorrected data, B3 and B4, perform consistently poorly through AIC and BIC compared to the models using survival corrected data – although they are still valid, i.e. they do not fail the specification tests. Within the models using the corrected data, the one with a constant in the specification – Model B2 – performs better through AIC, BIC or likelihood ratio test; hence it is the preferred model. Once again, motorcycle ownership increases with an increase in income. This effect of income is smaller in the rest of Bangladesh compared to that for Dhaka city. 2015 changes in policies had a statistically significant impact on motorcycle ownership in the rest of the country, and this impact is substantially larger than that in Dhaka (0.956 vs. 0.263).

[7] We ran a separate regression with the square of income per capita as an additional regressor, the parameter estimate was not statistically significant, and model fit was poorer too.

Table 3
Parameter estimates for intervention models for changes in motorcycle ownership in Dhaka.

Region	Dhaka			Bangladesh	
Data	Survival corrected				
Model no.	D1-IA1	D1-IA2	D1-IA3	B2-IA1	B2-IA2
Income per capita (*Y*)	0.0284 (11.93)***	0.0270 (8.50)***	0.0281 (10.83)***	0.0140 (8.37)***	0.0147 (6.43)***
Policy (*P15*)	0.2802 (2.11)**	0.4121 (2.60)***	0.300 (2.37)***	0.9614 (5.08)***	0.9556 (4.43)***
Constant	–	–	–	−0.1527 (-4.14)***	−0.1667 (-3.21)***
Autoregression parameter	–	0.5418 (3.36)***	–	–	0.2643 (0.73)
Moving average parameter	–	–	0.440 (4.21)***	–	–
AIC	1.668	−1.683	−0.354	−29.820	−27.034
BIC	3.850	2.681	4.010	−26.547	−21.579
Portmanteau test for white-noise of residuals	18.323 (p = 0.032)	9.284 (p = 0.412)	9.915 (p = 0.357)	13.340 (p = 0.148)	10.522 (p = 0.310)
Bartletts test for white-noise of residuals	1.527 (p = 0.013)	0.468 (p = 0.981)	0.662 (p = 0.773)	0.999 (p = 0.271)	0.654 (p = 0.786)
Estimation period	1995–2016				

***Statistically significant at 99%.
**Statistically significant at 95%.
*Statistically significant at 90%.

The parameter representing the introduction of motorcycle hailing apps in Dhaka was not statistically significant in model B2 (and all other variants) for the rest of Bangladesh. This shows that the statistical significance of the *EH* variables in models D1 to D4 were not spurious and that they were indeed picking up the 'causal' effects of motorcycle hailing services in Dhaka.

As a robustness check, we also follow the intervention analysis approach. The regression parameter estimates for three models for Dhaka, all using no constants on the survival corrected dataset following earlier results (Model D1), are presented in Table 3. These models are estimated on the data until 2016. D1-IA1 is similar to D1 above (with 2 fewer observations), while D1-IA2 and D1-IA3 are ARIMA models, which are especially suited to forecasting (Box and Jenkins 1970). D1-IA2 has first order autoregression, while D1-IA3 has first order moving average error. D1-IA2 is the best model because it has the lowest AIC and BIC of all, and because its residuals are white noise, which is important for forecasting. D1-IA3 is also applicable, but model fit by AIC or BIC is marginally inferior to D1-IA2. Forecasts of changes in motorcycle ownership are presented along with changes in actual ownership in Fig. 7. The changes in actual motorcycle ownership in Dhaka are clearly substantially larger than the model forecasts during 2017–2018. The actual changes and predicted changes in ownership from D1-IA2 are converted to ownership and predicted ownership in Fig. 8, again clearly showing the divergence.

For intervention analysis for the counterfactual rest of Bangladesh case, the model with the constant (B2) is used following earlier results. The preferred model is the static regression (B2-IA1), without any autoregression (B2-IA2) or moving average error term (this model had a unit root, so results not displayed). For the sake of brevity, we convert the predicted changes in ownership from B2-IA1 to predicted ownership and present the results in Fig. 8. The forecast and actual ownership are almost indistinguishable, showing that in our counterfactual case, there were no changes in the existing trend of motorcycle ownership. Therefore, the graphical representation using a different type of modelling approach also supports the finding that the introduction of motorcycle hailing apps has increased the number of motorcycles in Dhaka. Using the parameter estimates from the econometric model, we calculate that the

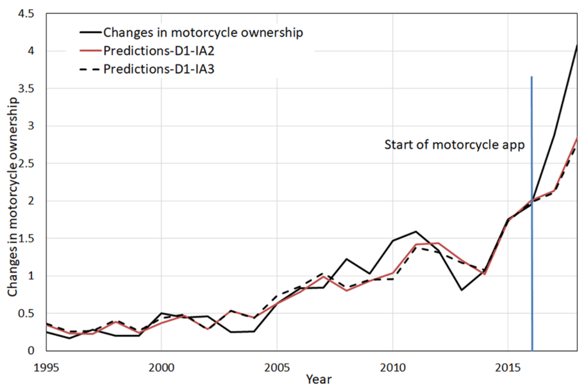

Fig. 7. Changes in motorcycle ownership in Dhaka and predictions from two intervention models.

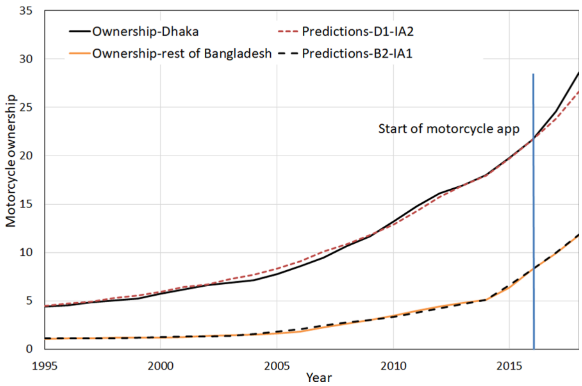

Fig. 8. Motorcycle ownership in Dhaka and Bangladesh, and predictions from the corresponding preferred intervention model.

actual number of motorcycles in Dhaka at the end of 2018 was 7.45% (around 39,000) more than what it would have been without the motorcycle e-hailing services.

The slowly growing popularity of motorcycle based delivery services and its impacts warrant some discussion. While the first information technology enabled food delivery services started as early as 2013, food delivery is done almost exclusively by bicycles. Motorcycle-based e-courier services also started in early 2015. As such our variable *P15* is possibly capturing the effects of these services too, leaving the *EH* dummy for 2017–2018 to capture the effects of motorcycle e-hailing for passengers only. Discussions with a leading TNC, which has a large presence in both motorcycle e-hailing and motorcycle-based delivery services, reveal that their delivery fleet is a very small share of the passenger e-hailing fleet, giving confidence that even if *EH* had captured partial effects of the delivery services, that would not bias our results significantly.

7. Conclusions and future directions

The key finding of this research is that the introduction of the motorcycle e-hailing services has caused a statistically significant increase in motorcycle ownership and motorcycle numbers in Dhaka, by around 7.45%. As such our results appear to agree with Schaller (2019) who found an increase in car ownership in large cities in the US due to the TNC services. Still, we believe the results are not directly comparable due to the vastly different services (car-based vs. motorcycle based) and geographies (US vs. Bangladesh). As a modelling method, the segmented multiple regression or intervention analysis, along with the counterfactual analysis – as used here – could well be applied in understanding the effects of other types of e-hailing or ridesourcing services in other cities and countries too.

How long this trend in motorcycle growth in Dhaka will last is unclear though. On one hand, motorcycle hailing services are normalizing the use of motorcycles as a quick way to travel around the congested city. As such there is a possibility that these motorcycle passengers will be encouraged by their experience and will themselves purchase motorcycles in future. On the other hand, motorcycle hailing services could discourage private ownership of motorcycles as has been argued for TNC services and car ownership in the developed world. The expected opening of Dhaka's first metro mass transit line in the next few years could also play a role in stemming the private ownership of motorcycles (and vehicles). However, compared to other megacities in South-East Asia, Dhaka is behind in the provision of motorcycle e-hailing services, indicating substantial potential for growth of the sector.

One interesting innovation in motorcycle hailing apps in Dhaka is the recent introduction of women-only services, where the drivers and passengers are both women, e.g. Lily or OBon. Given the socially conservative nature of the country, women rarely own or use motorcycles in Dhaka or in Bangladesh, meaning the current growth in motorcycle ownership and the use of motorcycle e-hailing services are almost entirely driven by male users. As such, if these female-only services become successful, it has the potential to bring about profound changes in motorcycle-based mobility in that gender segment.

The effects of motorcycle e-hailing services on travel demand or traffic congestion are more difficult to decipher. The net effect of these services on travel demand or traffic depends on whether the passengers have switched from public transport modes such as buses, minibuses or human-haulers, paratransits like rickshaws or motorized three-wheelers, or private transport like cars. There is now some literature on the modal shift to car-based TNC services in the US (e.g. Clewlow and Mishra 2017; Henao and Marshall 2019), yet such evidence is almost non-existent for motorcycle e-hailing services: only Phun et al. (2019) suggest that motorcycle taxis are used as feeder services to the mass transport system in Bangkok while Irawan et al. (2020) investigate the factors affecting the attractiveness of bus services over motorcycle e-hailing in Yogyakarta. Modelling the effects on modal shift is a vital future avenue of research – not only in Dhaka and Bangladesh, but in other cities and countries where motorcycle e-hailing services operate.

The short and long run impacts of transport disruptions on modal share of motorcycle e-hailing is also a useful research area. Especially, the impacts of Coronavirus can be a useful case study in this context. On one hand, the services are a significant risk given the passengers share the same helmet for their journeys. On the other hand, motorcycle e-hailing services, and motorcycles in general, could still be preferred by passengers wanting to escape the crowded buses. The net effect on modal shift is a matter of empirical investigation.

Potential modal shift to motorcycle e-hailing services is also important in order to understand the greenhouse gas emissions or air pollution impacts. CO_2 emissions from motorcycles are significantly lower compared to regular cars or sports utility vehicles (SUVs) given the higher fuel efficiency of motorcycles. However, emissions standards for criteria air pollutants are generally less stringent for motorcycles, leading to larger emissions than cars or SUVs. As such, any increase in motorcycle numbers due to these e-hailing services will almost certainly aggravate local air quality, which is already poor in most megacities in the emerging world, including Dhaka.

The safety impacts of motorcycle hailing services are also unclear. In some of the cities with pre-existing motorcycle taxis, TNCs have sought to introduce some order and provided safety training to the drivers or helmets for their drivers. TNCs such as SafeBoda and SafeMoto appear to advertise safety as a differentiator in some African cities and there is some evidence of improvements in riding behaviour (Muni et al. 2018). However, the situation in Dhaka is different. The rapid growth of motorcycle hailing services and the competition between the operating TNCs resulted in a shortage of motorcycle drivers in Dhaka, which allowed inexperienced drivers – sometimes with only learner's licences – to be put to service (Masum 2018). Driving hours are also not regulated and motorcycle taxi drivers are known to drive for long hours, often 10–12 hour shifts in other countries (Olvera et al. 2016, de Almeida et al. 2016, Berrones-Sanz 2018), indicating the same will likely be the case in Dhaka too. The use of the untrained drivers, long working hours and the increase in motorcycle numbers – all of which can be traced to the introduction of motorcycle e-hailing services – can substantially aggravate road safety. As such safety implications of these services and potential mitigation strategies require further attention from the policymakers and regulators.

How far can our results be generalized is an interesting question. Since the motorcycle ownership in Dhaka was low and there were no motorcycle taxi services either, the number of new motorcycles for commercial e-hailing use was relatively high as a share of the total, the statistical significance of which could be measured. On the other hand, in many Sub-Saharan African and South-East Asian cities – where motorcycle taxis were already popular – the hailing apps possibly did not create significantly more demand for motorcycles for commercial use, rather existing motorcycle taxi operators were likely re-organized under different digital platforms. Similarly, where private ownership of motorcycles is already high, any additional motorcycles for commercial use will likely be too small a share of the total fleet. Therefore, the impacts of the e-hailing apps on motorcycle ownership and associated impacts will likely be substantial and statistically discernible in places where motorcycles and motorcycle taxis are not a popular mode for transport yet. Nonetheless, the effects of e-hailing and TNC services in the cities with a large motorcycle population would still be useful from transport planning and policymaking perspective.

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