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Research paper

Measuring migration related
movements from daily mobility data

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TECHNOLOGY
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Measuring migration related movements from daily mobility data

Abstract

We merge a high frequency daily mobility dataset from Facebook with the decade old migration data from the 2011 Census of India for all the districts of India for the period March 2020 to September 2021. The purpose is to ascertain patterns of migrant mobility during the COVID pandemic in India. We find that the two datasets are significantly positively correlated implying that mobility – even during the baseline before the pandemic – is higher along district vectors more connected by migration. Thus migration partially drives mobility.

Unconditionally, mobility in India fell during the national lockdown in April to June 2020 and the second wave of COVID in February to May 2021. However, the elasticity of daily mobility to the stock of migrants peaked during these times. Thus daily mobility between districts during the times of crises is driven by migration. Firstly, by migrants returning to their home districts and then as the crises eases by them returning to their destination districts.

Finally, we study the bi-directional mobility between districts. Our findings show that during ‘normal’ times mobility along a vector (a pair of districts in this paper) is the same in both the directions. That is, net mobility is close to zero. However, during crises we get one directional movements of migrants – when they return to their home districts. Thus the net mobility increases – in the direction of the ‘exporting’ district in the pair. That is in the direction of the district which sends more migrants to the other.

Our paper is the first one to use a high frequency dataset to study mobility between districts in India driven by migration. Our findings also have significant use in policy making regarding long distance movements during crises by making the nature of these movements clear to policy makers.

Keywords: Migration, COVID19, mobility, India, high-frequency data

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Pandemic- a break from the past

People move every day and studies of mobility can provide insight into underlying economic and social behaviour of people. Patterns of movement change between normal and crisis times. Crises can induce movement that is ‘not normal’ and the study of these movements can provide information on how to manage the crises.

Patterns of movement can broadly be classified as internal (within country) and international (across countries). Internal migration include

- classification-I based on State boundaries:
 - i) intra-state (within state) and
 - ii) inter-state (between states);
- Classification-II based on source (birth place) and destination (place of enumeration) districts:
 - iii) rural-rural,
 - iv) rural-urban,
 - v) urban-rural and
 - vi) urban-urban.

Directions of movement are from source district to destination district and vice-versa.

Movement by people can be further distinguished as daily movement (or mobility) and migration. One is commuting or daily mobility - when a person moves from her place of residence to workplace or other places and returns back to her residence within the same day. Whereas, when a person travel from her source to destination district, stays for a short period¹ of time and returns back from the destination to source district, it is considered as circular migration^{2,3}.

There are different types of migrants⁴. Type-I is educated and mostly engaged in formal sector. The likelihood of these migrants moving with family to his/her destination district is high, and hence the return flow of these migrants from destination to source district is expected to be planned and hence regular. Type-II is uneducated and mostly engaged in informal sector⁵. The likelihood of these migrants moving to his/her destination district while leaving behind his/her family at source district is high, and hence the return flow of these migrants from destination to source district, and vice-versa is expected to be dependent on

¹ Short period of time could be weekly or monthly or quarterly or half yearly or yearly or others depending on the purpose of travel.

² Census definition of a migrant is “When a person is enumerated in census at a different place than his/her place of birth, she/he is considered a migrant”.

³ Chapter 12- India on the Move and Churning: New Evidence. Economic Survey Report, 2017, Department of Economic Affairs, Ministry of Finance.

⁴ Covid-19 migrant crisis: Time to reconfigure labour laws in India. The Tribune, India. Shubhashis Gangopadhyay. 20 May 2020.

⁵ India Labour and Employment Report 2016. The Institute for Human Development, Oxford University Press. Ajit Ghose. 2016.

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economic circumstances. Adverse economic shocks in the destination district – say, loss of livelihood because of the pandemic – will force them to return unpredictably.

In India, on event of the recent pandemic Covid-19, mobility restrictions in forms of lockdowns and containment zones have been imposed as a preventive measure to curb the spread of the virus since 24 March, 2020. In the initial days of lockdown, the country witnessed a large movement of migrants^{6,78} from destination to source districts.

Socio-economic effects⁹ of lockdown will vary for different types of migrants. There is incomplete existing information on near real-time migrant movements in India. Census 2011¹⁰ is the only recent official database that captures movement of people between districts within States¹¹¹². However, circular migration is not captured in Census¹³. A crisis like Covid-19 demands for day-to-day decision making where the effectiveness of a ten year old data like Census¹⁴ to inform today's decision making is uncertain.

In this paper, we try to use high frequency data along with the historic census data to capture distress movements during crisis times.

Data and construction of variables:

In this section we describe the data used in this analysis and the construction of the variables.

We primarily rely the following two datasets,

1. Migration Census, 2011¹⁵ data is population “stock” that gives information on the number of people who moved from source district to destination district within the States¹⁶. It is a snapshot of the state of migration as of 2011.

⁶ "More than 21,000 camps set up for over 6,60,000 migrants: State governments". The Economic Times. 1 April 2020.

⁷ "As migrant workers struggle for lockdown aid, India seeks to count them". Reuters. Srivastava, Roli; Nagaraj, Anuradha. 29 April 2020.

⁸ Migration and reverse migration in the age of COVID-19. Economic & Political Weekly volume 55, issue number: 19. Ajay Dandekar, et al. 2020.

⁹ Chapter-III: Covid-19 and its spatial dimensions in India. State Finances : A Study of Budgets. Reserve Bank of India. 2020.

¹⁰ Census, 2011, Office of the Registrar General & Census Commissioner, Ministry of Home Affairs.

¹¹ Schedule D-11 gives the inter-district migration within States. Census, 2011.

¹² "Coronavirus lockdown | Over 60,000 people have registered on Delhi govt portal to go back home". The Hindu. 15 May 2020.

¹³ Chapter 12- India on the Move and Churning: New Evidence. Economic Survey Report, 2017, Department of Economic Affairs, Ministry of Finance.

¹⁴In India, Census is conducted once in ten years, and it is usually in the beginning of a new decade. The demographic details and migration movements of people from their place of birth (source) to a place of enumeration (destination) are captured at district level in the Census.

¹⁵ Schedule D-11 gives the inter-district migration within States. Census, 2011.

¹⁶ According to Census 2011, the total number of districts as of December 2010 was 640, the total number of between district directional pairs across States account to 4,08,960 (difference of 4,09,600 total directional district pairs and 640 within district pairs across States respectively), and the **total number of between district**

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2. Population Movement data from Facebook¹⁷, 2020-2021 is the “flow” data that gives daily movement of Facebook app users between and within districts for all States.

In order to integrate the migration stock with Facebook daily flows between directional district pairs, district administrative boundaries as of 2011 is used as common identifiers between both datasets. Since Migration Census is available only for movement between districts within States, we analyse the migration and daily movements between districts within States for fifteen¹⁸ States respectively. Facebook Population Movement data is used from 20 Mar,2020 till 10 Sep,2021.

The unit of analysis in migration and daily movement is a vector – a pair of districts with the direction as an additional piece of information. Say for example, the number of people born in district A residing in district B. This may be different from the number of people born in B living in A. Similarly there is direction involved in movement too. The movements from A to B are different from those from B to A.

Using the example of a vector “Chennai-Kancheepuram” which are two districts within the State of TamilNadu, we demonstrate the variables used for analysis. Let Chennai be the source¹⁹ district and Kancheepuram the destination²⁰ district.

- *Migration stock* at Chennai is the number of people born in Kancheepuram living in Chennai as of 2011²¹.
- *Gross Migration stock* is the sum of migrant inflows²² from Kancheepuram to Chennai and migrant outflows²³ from Chennai to Kancheepuram.
- *Net Migration stock* is the difference between migrant stock from Kancheepuram to Chennai and migrant stock from Chennai to Kancheepuram. The “net” value indicates if a district is an importing district or exporting district. Positive “net” value implies importing district and

directional pairs within States account to 98,709 (difference of 99,349 total between district pairs and 640 within district pairs within States respectively).

¹⁷ Movement data of Facebook app users who have opted to share their mobile devices’ location history with Facebook is used to construct the database. The change in modal location of the users between three 8 hour time periods 12am - 8am, 8am - 4pm, and 4pm - 12am respectively are recorded. The de-identified data is aggregated at district level. A small random noise is added to the data to secure identity and data privacy of the users. The information is updated on a daily basis in Facebook’s Data for Good platform. For India, the data is available from 20 March, 2020. For this article, we have used data from 24 Mar, 2020 to 10 Sep, 2021.

¹⁸ Fifteen States include Andhra Pradesh, Bihar, Chhattisgarh, Goa, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Telangana, and West Bengal.

¹⁹ Source district refers to the place of birth.

²⁰ Destination district refers to the place of enumeration where people have moved to from their place of birth.

²¹ Census 2011 data was collected during the year 2010-2011.

²² People born in Kancheepuram moving to Chennai. They are considered as **inflows to Chennai** from Kancheepuram.

²³ People born in Chennai moving to Kancheepuram. They are considered as **outflows from Chennai** to Kancheepuram.

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negative “net” value implies exporting district. In this example, as per Census 2011, Chennai is the exporting district with a negative net-migrant stock of 4,59,453.

- *Daily Facebook flow* from Chennai is the number of people moving from Chennai to Kancheepuram on that particular day²⁴. Movement of people from Chennai to Kancheepuram is *Facebook Outflow*, and movement of people from Kancheepuram to Chennai is *Facebook Inflow*.
- *Baseline Facebook flow* from Chennai is the average Facebook users moving from Chennai to Kancheepuram during 45 days prior to 21th March, 2020. The baseline value remains the same for every directional district pairs by days of week (Monday to Sunday).

- *Proportion Facebook flows* from Chennai is the proportion of daily *Facebook Outflows* to *baseline Facebook Outflows* from Chennai to Kancheepuram respectively. It is given by the following definition,

$$\text{Proportion Facebook flows} = \frac{\text{Daily Facebook flow}}{\text{Baseline Facebook flow}} = \frac{Q_t}{Q_o}$$

- *Gross Daily Facebook flow* is the sum of Facebook users moving from Kancheepuram to Chennai and Facebook users moving from Chennai to Kancheepuram on a particular day.
- *Gross Baseline Facebook flow* is the sum of Baseline Facebook flows from Kancheepuram to Chennai and Baseline Facebook flows from Chennai to Kancheepuram.

- *Proportion Gross Facebook flow* is given by the following definition,

$$\text{Proportion Gross Facebook flows} = \frac{\text{Gross Daily Facebook flow}}{\text{Gross Baseline Facebook flow}} = \frac{P_t}{P_o}$$

By dividing gross daily flows with baseline flows, we are normalizing the Facebook flows along different vectors i.e. we are operating as if baseline flows are equal.

- *Physical distance* is the straight line distance between Chennai and Kancheepuram in Kilometers.

²⁴ Facebook Population Movement data between two locations are recorded for three 8 hour time periods: 12am - 8am, 8am - 4pm, and 4pm - 12am respectively for each day. In this analysis, we sum the movement across the three time periods for each day.

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Regression models used in the analysis and empirical estimation

To find the differential impact of migrant inflows and migrant outflows on daily movement, the following Simple Linear Regression models are used for the analysis purposes.

$$Y_{ij} = \beta_0 + \beta_1 \ln M_{ij} + \beta_2 S_{ij} + \beta_3 S_{ij}^2 + \sum_{k=1}^{T-1} \gamma_k D_k + \sum_{k=1}^{T-1} \alpha_k D_k \cdot \ln M_{ij} + e_{ij} \quad (I)$$

When controlled for district population at Source and Destination districts,

$$Y_{ij} = \beta_0 + \beta_1 \ln M_{ij} + \beta_2 S_{ij} + \beta_3 S_{ij}^2 + \sum_{k=1}^{T-1} \gamma_k D_k + \sum_{k=1}^{T-1} \alpha_k D_k \cdot \ln M_{ij} + \beta_4 \ln P_i + \beta_5 \ln P_j + e_{ij} \quad (II)$$

where

- Y_{ij} , - Proportion Gross Facebook flow between district i and district j.
- $\ln M_{ij}$ - Gross Facebook flow between district i and district j.
- S_{ij} , - Physical distance between district i and district j in Kilometers.
- S_{ij}^2 , - Square of physical distance between district i and district j in Kilometers.
- D_k , - Monthly time dummies. $D_k=1$ for month=k, $D_k=0$ otherwise.
 - 18 months data is used i.e. from Apr, 2020 to Sep, 2021
 - Apr, 2020 is considered as the base month
- ϑ_k , - Coefficient of Gross Facebook flow between district i and district j interacted with monthly time dummies.
 - 18 months data is used i.e. from Apr, 2020 to Sep, 2021
 - Apr, 2020 is considered as the base month
- $\ln P_i$ and $\ln P_j$ - Log of Demographic population as per Census 2011 at source district i and destination district j respectively.
- e_{ij} , - Error term

Average Movement over time:

= Sum of constant + (Sum of coefficient of Log of Gross Migration which is constant across time-periods and coefficient of Proportion Gross Facebook flow for a particular month) + (Product of coefficient of Log of Gross Migration interacted with time dummy for the month and Average Gross Migration for the entire time period i.e. 18 months)

Average Mobility during May,2020 (*when controlled for district population*)

$$= \{ \beta_0 + [(\beta_1) + (\gamma_{k=may,2020})] + [(\alpha_{k=may,2020}) * (7.5)] \}$$

$$= \{ 0.457 + [(0.041) + (-0.265)] + [(0.040) * (7.5)] \} = 0.533$$

Migration related movement over time :

= Sum of Coefficient of Log of Gross Migration which is constant across time-periods and Coefficient of Log of Gross Migration interacted with time dummy for a particular month

Migration related movement during May,2020 (*when controlled for district population*)

$$= [(\beta_1) + (\alpha_{k=may,2020})] = [(0.041) + (0.040)] = 0.081$$

Estimates for all other months are presented in Table-I.

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Regression Equation- III and IV:

To find the differential impact of migrant inflows and migrant outflows on daily movement,

$$Y_{ij} = \beta_0 + \beta_1 \ln P_{ji} + \beta_2 \ln Q_{ij} + \beta_3 S_{ij} + \beta_4 S_{ij}^2 + \sum_{k=1}^{T-1} \gamma_k D_k + \sum_{k=1}^{T-1} \alpha_k D_k \cdot \ln P_{ji} + \sum_{k=1}^{T-1} \theta_k D_k \cdot \ln Q_{ij} + e_{ij} \quad \text{(III)}$$

When controlled for district population at Source and Destination districts,

$$Y_{ij} = \beta_0 + \beta_1 \ln P_{ji} + \beta_2 \ln Q_{ij} + \beta_3 S_{ij} + \beta_4 S_{ij}^2 + \sum_{k=1}^{T-1} \gamma_k D_k + \sum_{k=1}^{T-1} \alpha_k D_k \cdot \ln P_{ji} + \sum_{k=1}^{T-1} \theta_k D_k \cdot \ln Q_{ij} + \beta_5 \ln P_i + \beta_6 \ln P_j + e_{ij} \quad \text{(IV)}$$

where

- Y_{ij} , - Proportion Daily Facebook Outflows from source district i to destination district j.
- $\ln P_{ji}$ - Log of Migrant Inflows from destination district j to source district i.
- $\ln Q_{ij}$ - Log of Migrant Outflows from source district i to destination district j.
- S_{ij} , - Physical distance between district i and district j in Kilometers.
- S_{ij}^2 , - Square of physical distance between district i and district j in Kilometers.
- D_k , - Monthly time dummies. $D_k=1$ for month=k, $D_k=0$ otherwise.
 - 18 months data is used i.e. from Apr, 2020 to Sep, 2021
 - Apr, 2020 is considered as the base month
- α_k , - Coefficient of Log of Migrant Inflows from district j to district i interacted with monthly time dummies from May, 2020 to Sep, 2021.
 - 18 months data is used i.e. from Apr, 2020 to Sep, 2021
 - Apr, 2020 is considered as the base month
- θ_k , - Coefficient of Log of Migrant Outflows from district i to district j interacted with monthly time dummies from May, 2020 to Sep, 2021.
 - 18 months data is used i.e. from Apr, 2020 to Sep, 2021
 - Apr, 2020 is considered as the base month
- $\ln P_i$ and $\ln P_j$ - Log of Demographic population as per Census 2011 at source district i and destination district j respectively.
- e_{ij} , - Error term

Migrant inflow related movement:

= Sum of Coefficient of Migrant inflows which is constant across time-periods and Coefficient of migrant inflows interacted with time dummy for a particular month.

Migrant inflow related movement in the month of May, 2020 (when controlled for district population)

$$= \beta_2 + \alpha_{k=may,2020} = 0.0117 + 0.005 = 0.0167$$

Migrant outflow related movement:

= Sum of Coefficient of Migrant outflows which is constant across time-periods and Coefficient of migrant outflows interacted with time dummy for a particular month.

Migrant outflow related movement in the month of May, 2020 (when controlled for district population)

$$= \beta_2 + \theta_{k=may,2020} = 0.016 + 0.020 = 0.068$$

Estimates for all other months are presented in Table-I.

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Results and discussion

Migration, An alternative resting position

Do migrants return back from destination districts to their source districts?

People migrate to other places in search of livelihood, marriage in the case of women, and other reasons. Also it is reasonable to assume that irrespective of the destination districts that people migrate to, a sizable portion of total migrants may usually return back to their source district in the event of cultural festivals, and crisis times such as lockdowns imposed during Covid-19 pandemic in India.

Impact of migration on mobility

Based on the above assumptions we expect movement along district-pairs with connected with more migrants to be high. For example, between pairs AB and AC where AB has more gross migrants than AC – the daily movement as measured by Facebook daily flows will be higher along AB than AC. This is observed in Fig-I where the daily movement along a vector is positively related to the migration along that vector. This is confirmed with the 42 percent positive and significant correlation estimated between Census migration data and Facebook's baseline movement between districts within States respectively.

Impact of migration on mobility over time

We ran two simple regressions to understand differential impact of Covid-19 on daily movements with and without restrictions like lockdowns, and thereby to find a causal link between migration and daily movement. The dependent variable is the Proportion Gross Facebook flow while the independent variables are Gross Migrants and Physical Distance.

Since, migrant stock is constant over time, monthly time dummies and their interactions with the migrant stock were included to observe the effect of migration on Facebook movement data over the time period May, 2020 till Sep, 2021. The model is repeated with and without controlling for population at source and destination districts. Similar results were observed in both the regressions. The results from Regression-I are presented in Figure II.

Figure-II shows the average movement and migration related movement over months respectively. We observe two crisis situations as follows,

Situation-I where there is no significant incidence of Covid-19 but a national lockdown is imposed. In the figure, it is from May, 2020 – Jul, 2020. Complete lockdown measures have been incrementally lifted since Aug, 2020.

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Situation-II where there is high incidence of Covid-19 but national or state lockdowns are not imposed till very late and governments have mostly relied on local containment. In the figure, it is from Feb, 2021 – Jun, 2021. Second wave of Covid-19 across States reached its peak in May, 2021 and vaccination drives gained momentum.

Average mobility over time

The average mobility over time is shown in Figure-II. The base effect of migration is partialled out from daily movement using the regression equation (1). We observe average mobility to be falling between Jun, 2020 and Jul, 2020. It is when unlock measures began to be introduced, and people had the choice and means to travel. As the Covid-19 situation in the country began to settle down, we observe average mobility to be rising until Feb, 2021 or the onset on second Covid-19 wave in the country. Since then, we observe an incremental fall in average mobility until May, 2021. Thus, we observe average mobility falls during crisis times and peaks up during non-crisis period. This is more evident in the second wave when people had the choice to travel with no restrictions on mobility being imposed.

Migration related mobility over time

On the contrary, in both the situations (I and II), we observe differential impact of migration on mobility. Migration related movement peaks up during crisis situation. That is, at a crisis time when nobody else is moving as seen in the downward sloping average mobility curve, we believe that migrants are moving between districts within States. This is shown with the upward sloping migration related movement curve. In each situation, when the crisis reaches its peak and starts to settle down i.e. Jun, 2020 for situation-I and Jun, 2021 for situation-II, we observe a downward sloping migration related movement curve.

Overall, the mobility response to lockdown (situation-I) is numerically same as response to Covid-19 (situation-II). So, it is not only the national lockdowns but also the Covid-19 pandemic itself that caused difficulty in individual movement patterns between districts within a State in India.

What does the direction of migration related movement tell us?

Trends and patterns of circular migration will be different for different types of migrants: Type-I and Type-II. At normal times, there is usually two way movement between source and destination districts, yet within a given period of time, frequency of two way movements by Type-II is expected to be more than the Type-I migrants. During the first wave of national lockdown in India, due to feasibility and restrictions on travel, only one way movement is expected to be observed between source and destination districts. It is mostly Type-II migrants having exhausted their savings, with no near work opportunities²⁵ and inadequate accommodation

²⁵ Rapid Assessment of the Impact of the COVID-19 Crisis on Employment. International Labour Organisation. June, 2020.

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facilities²⁶ at destination districts serve as push factors to return back²⁷ to their source districts in order to be with family and to be recipients of social security benefits^{28,29,30}.

Accordingly, at any net migrant exporting districts we expect inflow of migration related movements to be lesser and outflow of migration related movements to be higher during a crisis period. This hypothesis is shown in Fig-III where migration related movement is further broken down into migrant inflows into source districts and migrant outflows from destination districts. We observe that during crisis situations I, migrant outflows to be suddenly rising and migrant inflows to be falling, whereas when the crisis situation reaches its peak, we observe migrant outflows to be falling and migrant inflows to be rising. Also, during both crisis situations (I and II) we observe movements from destination districts to be higher than movements from source districts.

²⁶ How many casual workers in the cities have sought to go home? The India Forum. Nomaan Majid. 29 May 2020.

²⁷ The plight of migrants during COVID-19 and the impact of circular migration in India: a systematic review. Humanities and Social Sciences Communications volume 8, article number: 231. Joshy Jesline, et al. 2021.

²⁸ Pradhan Mantri Garib Kalyan Yojana (PMGKY) announced on 26 March, 2020 by Ministry of Finance, GoI. It is a comprehensive relief package of Rs 1.70 lakh crore for the poor to help them fight the battle against Corona Virus.

²⁹ State of Working India 2021: One year of Covid-19. Centre for Sustainable Employment, Azim Premji University. 2021.

³⁰ The Continuing Relevance of MGNREGA. The India Forum. Sudha Narayanan. 21 March 2020.

Conclusion:

Usefulness of machine generated movement data in times of crisis

How to identify migration related movement from real time movement data?

Real time location data can be generated^{31,32} from sensors on devices like smartphone or smart watches, telecom signals, and social media feeds. Using one such datasets i.e. Facebook's Population Movement data we have attempted to identify migration related movement from daily movements since March, 2020 till Sep, 2021 in India.

- There is higher movement along district-pairs with more migrants.
- Daily movements between two districts within a State peaks up during a crisis situation. This is observed by return flow of people from destination districts to source districts. Once the crisis reaches its peak, we observe a re-return³³ flow of people from source to destination districts.
- Any convergence of migrant inflows and migrant outflows between source and destination districts could be attributed to movement during normal times. On the other hand, any widening and contracting parts of the gap between migrant inflows and migrant outflows could be attributed to migration related movement from destination to sources districts (at crisis times) and regular migration from source to destination districts (after the crisis reaches its peak) respectively.

Facebook's Population Movement map data is a timely initiative by Facebook's Data for Good Programme, yet it may not as representative as cellular networks data in India. While Facebook's Population Movement data is generated for a specific user-case, the cellular network data³⁴ is not. The challenge lies with a timely use of the later in its existing form during crisis situations along with historic Census and national surveys. This will help in improving the accuracy in understanding people's movement to enhance day to day decision making processes within governance systems.

³¹ The data generated on the device flows to a server where the data gets processed in real-times, and later shared with consumers like web service providers, web interfaces, and native or hybrid apps who optimize their services using real-timeliness of the data. (Trivedi,N, 2018)

³² Some of the challenges in generating location data are real timeliness, accuracy and battery drain apart from diverse devices, hardware components, OS versions, network conditions, and privacy concerns. (Deorah,K. 2018)

³³ Destination district to Source district is return flow. Destination to Source and back to Destination district is considered as re-return flow.

³⁴ Exploring the use of mobile phone data for national migration statistics. Palgrave Communications volume 5, article number: 34. Shengjie Lai, et al. 2019.

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As migrant workers struggle for lockdown aid, India seeks to count them. Reuters. Srivastava, Roli; Nagaraj, Anuradha. 29 April 2020.

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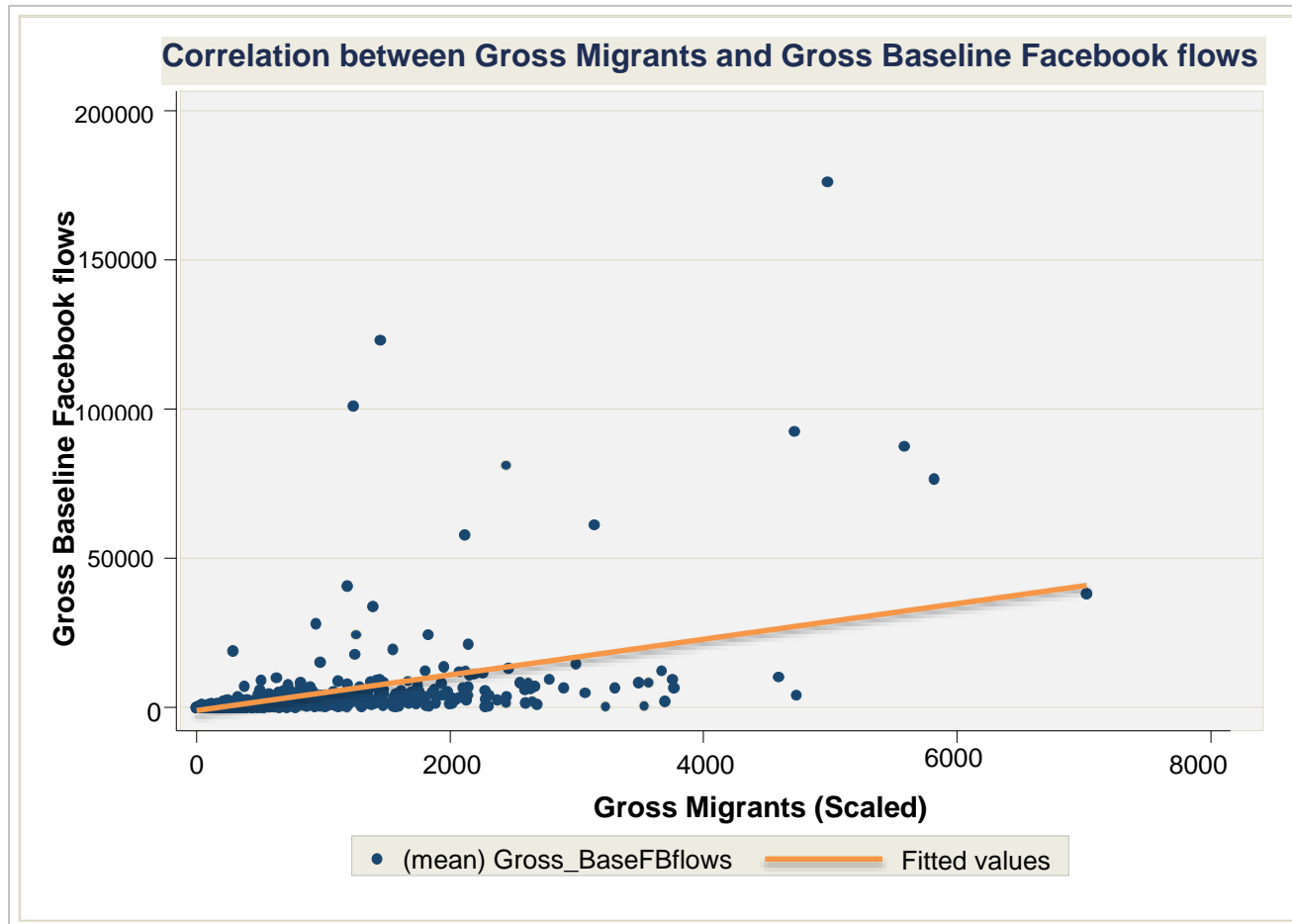
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The plight of migrants during COVID-19 and the impact of circular migration in India: a systematic review. Humanities and Social Sciences Communications volume 8, article number: 231. Joshy Jesline, et al. 2021.

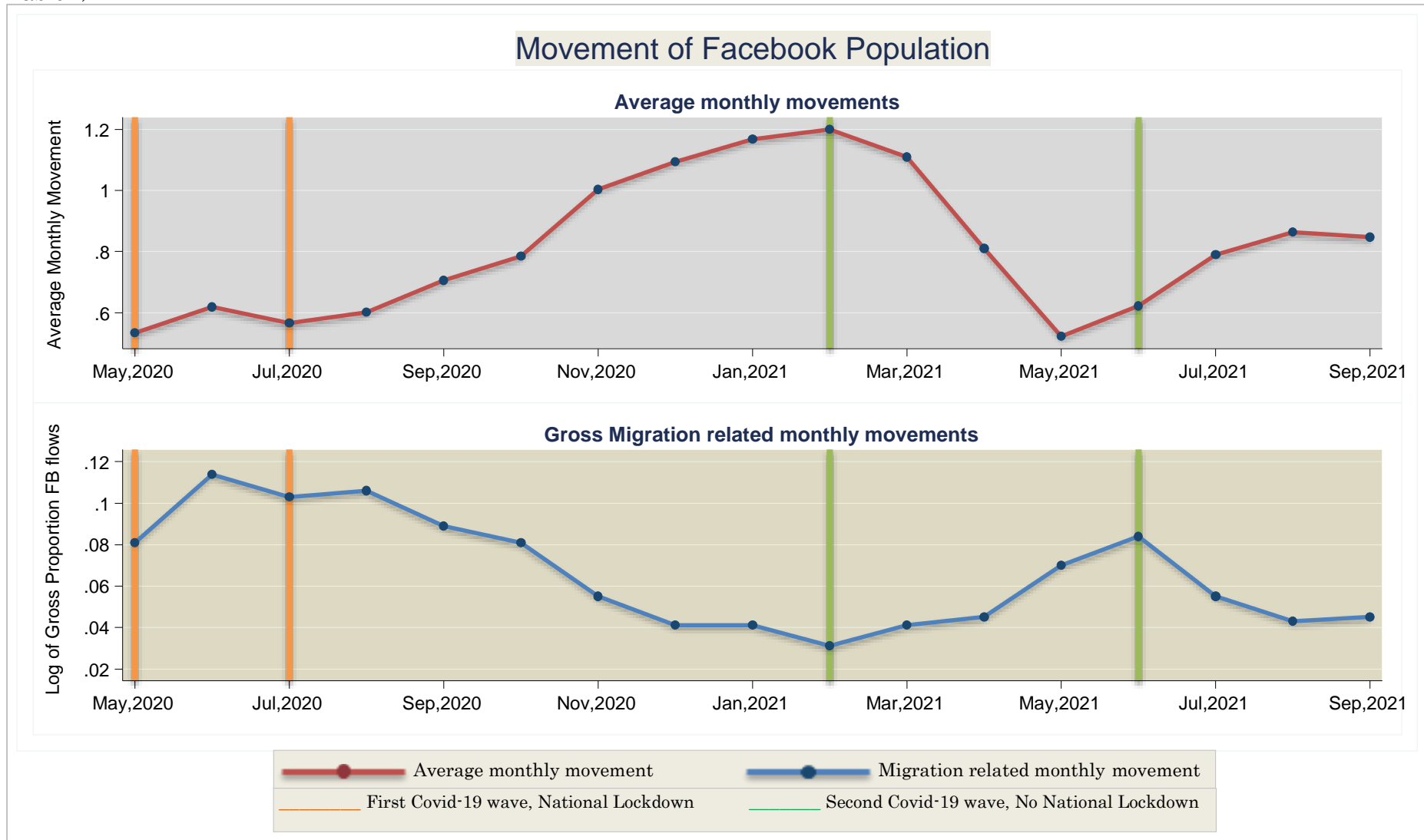
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Fig-I: Correlation between Gross Migrants and Gross Baseline Facebook flows



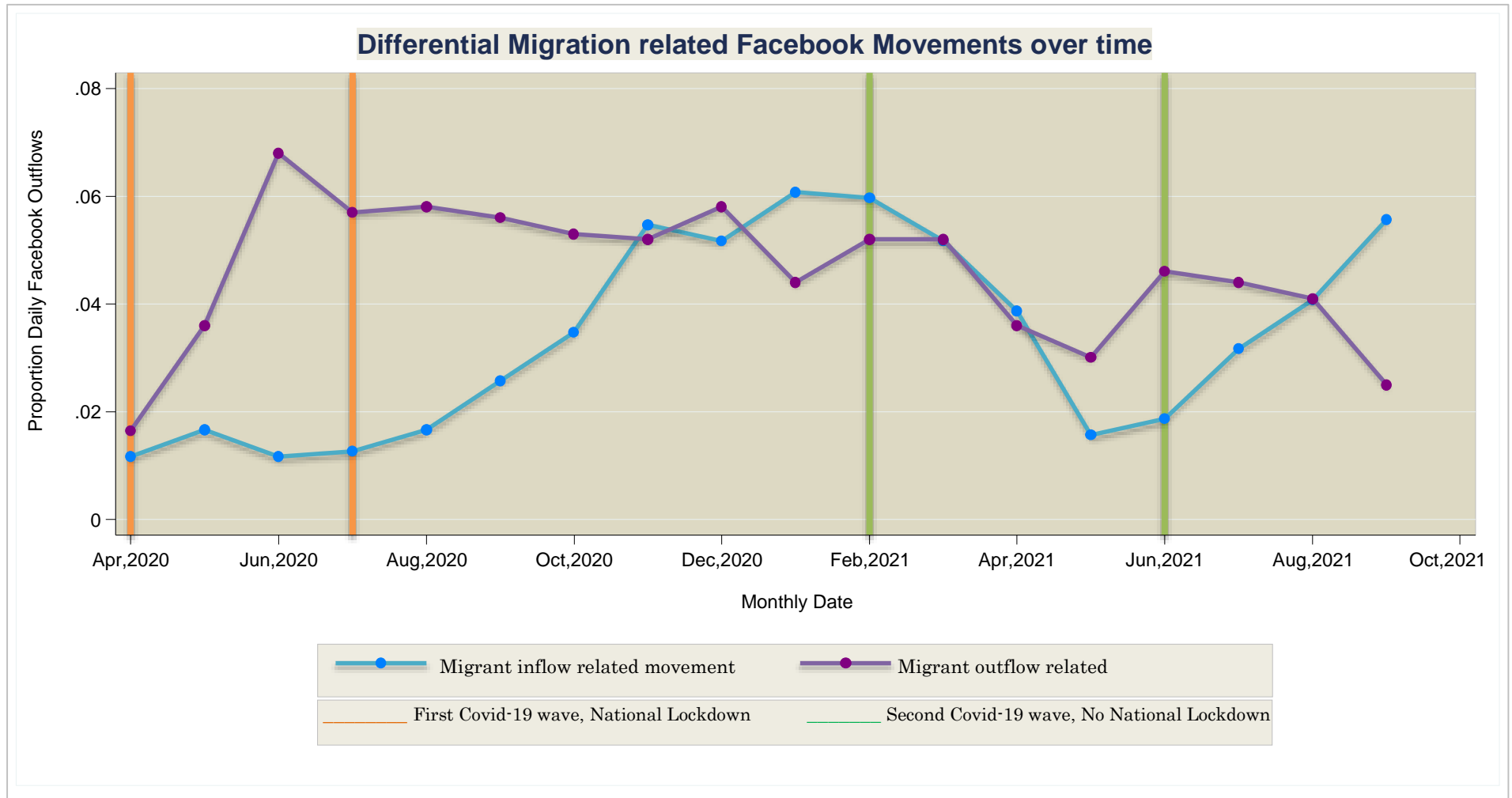
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Fig-II: Facebook Population _ Average movement and Migration related movement over the months respectively (Ref: Calculated estimates from Table-I)



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Fig-III: Migration related mobility over time _ Migrant inflows, Migrant outflows (Ref: Calculated estimates from Table-I)



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Table-I: Estimated values using point estimates from regression models - I, II, III and IV respectively for analysis purposes. (Ref: Annexure I, II)

Monthly date	Reg-I		Reg-II		Reg-III		Reg-IV	
	With no control on district population		With control on district population		With no control on district population		With control on district population	
	Average movement	Gross Migration related movement	Average movement	Gross Migration related movement	Migrant Inflows	Migrant Outflows	Migrant Inflows	Migrant Outflows
Apr,2020					0.01	0.01	0.01	0.02
May,2020	0.18	0.53	0.07	0.08	0.01	0.03	0.02	0.04
Jun,2020	0.27	0.62	0.11	0.11	0.01	0.07	0.01	0.07
Jul,2020	0.21	0.57	0.10	0.10	0.01	0.05	0.01	0.06
Aug,2020	0.25	0.60	0.10	0.11	0.01	0.06	0.02	0.06
Sep,2020	0.35	0.71	0.08	0.09	0.02	0.05	0.03	0.06
Oct,2020	0.43	0.78	0.07	0.08	0.03	0.05	0.03	0.05
Nov,2020	0.65	1.00	0.05	0.06	0.05	0.05	0.05	0.05
Dec,2020	0.74	1.09	0.03	0.04	0.05	0.06	0.05	0.06
Jan,2021	0.75	1.17	0.03	0.04	0.06	0.04	0.06	0.04
Feb,2021	0.80	1.20	0.02	0.03	0.06	0.05	0.06	0.05
Mar,2021	0.70	1.11	0.03	0.04	0.05	0.05	0.05	0.05
Apr,2021	0.46	0.81	0.04	0.05	0.03	0.03	0.04	0.04
May,2021	0.17	0.52	0.06	0.07	0.01	0.03	0.02	0.03
Jun,2021	0.27	0.62	0.08	0.08	0.01	0.04	0.02	0.05
Jul,2021	0.44	0.79	0.05	0.06	0.03	0.04	0.03	0.04
Aug,2021	0.52	0.86	0.04	0.04	0.04	0.04	0.04	0.04
Sep,2021	0.50	0.85	0.04	0.05	0.05	0.02	0.06	0.03

Measuring migration related movements from daily mobility data

Annexure-I: Results from regression models I and II

Regression Equations used- I and II		
Analysis: India (15 States)		
	Regression-I	Regression-II
	Gross_prop_FBflows (with no control on district population)	Gross_prop_FBflows (with control on district population)
Log Gross Migration	0.0345*** (-26.34)	0.0410*** (-30.36)
Distance	-0.00244*** (-122.22)	-0.00224*** (-90.68)
Distance square	0.00000302*** (-79.17)	0.00000279*** (-65.43)
md2_may2020	-0.265*** (-9.32)	-0.265*** (-9.33)
md3_jun2020	-0.427*** (-11.81)	-0.427*** (-11.82)
md4_jul2020	-0.397*** (-11.68)	-0.397*** (-11.69)
md5_aug2020	-0.384*** (-11.77)	-0.384*** (-11.78)
md6_sep2020	-0.153*** (-4.69)	-0.153*** (-4.69)
md7_oct2020	-0.0145 (-0.40)	-0.0145 (-0.40)
md8_nov2020	0.401*** (-9.63)	0.401*** (-9.63)
md9_dec2020	0.596*** (-13.83)	0.596*** (-13.83)
md10_jan2021	0.669*** (-16.14)	0.669*** (-16.14)
md11_feb2021	0.777*** (-17.54)	0.777*** (-17.54)
md12_mar2021	0.612*** (-15.16)	0.612*** (-15.16)

Measuring migration related movements from daily mobility data

md13_apr2021	0.283*** (-10.8)	0.283*** (-10.8)
md14_may2021	-0.194*** (-8.29)	-0.194*** (-8.30)
md15_jun2021	-0.198*** (-6.07)	-0.198*** (-6.07)
md16_jul2021	0.186*** (-5.66)	0.186*** (-5.66)
md17_aug2021	0.351*** (-10.15)	0.351*** (-10.15)
md18_sep2021	0.319*** (-5.28)	0.319*** (-5.28)
md2_may2* Log Gross Migration	0.0403*** (-13.6)	0.0403*** (-13.62)
md3_jun2* Log Gross Migration	0.0732*** (-19.33)	0.0732*** (-19.35)
md4_jul2* Log Gross Migration	0.0627*** (-17.59)	0.0627*** (-17.6)
md5_aug2* Log Gross Migration	0.0656*** (-19.17)	0.0656*** (-19.18)
md6_sep2* Log Gross Migration	0.0485*** (-14.3)	0.0485*** (-14.31)
md7_oct2* Log Gross Migration	0.0407*** (-10.82)	0.0406*** (-10.82)
md8_nov2* Log Gross Migration	0.0140** (-3.27)	0.0140** (-3.27)
md9_dec2* Log Gross Migration	-0.000635 (-0.14)	-0.000634 (-0.14)
md10_jan* Log Gross Migration	-0.00987* (-2.31)	-0.00988* (-2.32)
md11_feb* Log Gross Migration	-0.0163*** (-3.56)	-0.0163*** (-3.56)
md12_mar* Log Gross Migration	-0.00749 (-1.80)	-0.00749 (-1.79)

Measuring migration related movements from daily mobility data

md13_apr*	0.00422 (-1.6)	0.00422 (-1.6)
md14_may*	0.0293*** (-12)	0.0293*** (-12.02)
md15_jun*	0.0430*** (-12.6)	0.0430*** (-12.6)
md16_jul*	0.0147*** (-4.31)	0.0147*** (-4.31)
md17_aug*	0.00275 (-0.77)	0.00276 (-0.77)
md18_sep*	0.00477 (-0.76)	0.00476 (-0.76)
Log of Population at Source district		-0.0200*** (-20.00)
Log of Population at Destination district		-0.00949*** (-7.52)
Constant	0.111*** (-8.35)	0.457*** (-18.95)
Number of Directional district-pairs	834094	834094
t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001		

Measuring migration related movements from daily mobility data

Annexure-II: Results from regression models III and IV

Regression-III and IV		
Analysis: India (15 States)		
	Reg-III	Reg-IV
	Proportion FB Outflows (with no control on district population)	Proportion FB Outflows (with control on district population)
Log Migration Inflows	0.00747*** (-10.47)	0.0117*** (-16.37)
Log Migration Outflows	0.0132*** (-19.82)	0.0164*** (-24.71)
Distance	-0.00185*** (-253.16)	-0.00171*** (-227.90)
Distance square	0.00000244*** (-241.12)	0.00000231*** (-225.7)
md2_may2020	-0.119*** (-19.89)	-0.119*** (-19.91)
md3_jun2020	-0.242*** (-32.54)	-0.242*** (-32.57)
md4_jul2020	-0.194*** (-27.76)	-0.194*** (-27.79)
md5_aug2020	-0.219*** (-31.90)	-0.219*** (-31.93)
md6_sep2020	-0.255*** (-36.40)	-0.255*** (-36.43)
md7_oct2020	-0.294*** (-41.18)	-0.294*** (-41.21)
md8_nov2020	-0.386*** (-46.50)	-0.386*** (-46.52)
md9_dec2020	-0.398*** (-49.61)	-0.398*** (-49.63)
md10_jan2021	-0.385*** (-51.70)	-0.385*** (-51.71)
md11_feb2021	-0.411*** (-50.31)	-0.411*** (-50.32)

Measuring migration related movements from daily mobility data

md12_mar2021	-0.366*** (-48.36)	-0.366*** (-48.38)
md13_apr2021	-0.232*** (-42.94)	-0.232*** (-42.98)
md14_may2021	-0.0864*** (-16.65)	-0.0864*** (-16.67)
md15_jun2021	-0.178*** (-26.64)	-0.178*** (-26.66)
md16_jul2021	-0.234*** (-36.39)	-0.234*** (-36.41)
md17_aug2021	-0.264*** (-39.52)	-0.264*** (-39.55)
md18_sep2021	-0.280*** (-24.33)	-0.280*** (-24.33)
md2_may2* Log Migration Inflows	0.00521*** (-3.47)	0.00521*** (-3.47)
md3_jun2* Log Migration Inflows	0.000951 (-0.89)	0.000951 (-0.89)
md4_jul2* Log Migration Inflows	0.00147 (-1.39)	0.00147 (-1.39)
md5_aug2* Log Migration Inflows	0.00525*** (-5.11)	0.00525*** (-5.12)
md6_sep2* Log Migration Inflows	0.0144*** (-13.42)	0.0144*** (-13.45)
md7_oct2* Log Migration Inflows	0.0239*** (-21.24)	0.0239*** (-21.27)
md8_nov2* Log Migration Inflows	0.0433*** (-26.58)	0.0433*** (-26.58)
md9_dec2* Log Migration Inflows	0.0407*** (-30.5)	0.0407*** (-30.47)
md10_jan* Log Migration Inflows	0.0498*** (-33.7)	0.0498*** (-33.69)
md11_feb* Log Migration Inflows	0.0488*** (-35.07)	0.0488*** (-35.06)

Measuring migration related movements from daily mobility data

md12_mar*	0.0401***	0.0401***
Log Migration Inflows	(-31.84)	(-31.86)
md13_apr*	0.0272***	0.0272***
Log Migration Inflows	(-23.4)	(-23.43)
md14_may*	0.00404***	0.00404***
Log Migration Inflows	(-4.38)	(-4.39)
md15_jun*	0.00746***	0.00746***
Log Migration Inflows	(-7.45)	(-7.46)
md16_jul*	0.0209***	0.0209***
Log Migration Inflows	(-19.93)	(-19.96)
md17_aug*	0.0291***	0.0291***
Log Migration Inflows	(-25.93)	(-25.95)
md18_sep*	0.0449***	0.0449***
Log Migration Inflows	(-21.32)	(-21.3)
md2_may2*	0.0202***	0.0202***
Log Migration Outflows	(-15.16)	(-15.18)
md3_jun2*	0.0528***	0.0528***
Log Migration Outflows	(-43.9)	(-44.04)
md4_jul2*	0.0413***	0.0413***
Log Migration Outflows	(-35.33)	(-35.44)
md5_aug2*	0.0423***	0.0423***
Log Migration Outflows	(-37.86)	(-37.97)
md6_sep2*	0.0400***	0.0400***
Log Migration Outflows	(-34.93)	(-35.02)
md7_oct2*	0.0377***	0.0377***
Log Migration Outflows	(-31.18)	(-31.24)
md8_nov2*	0.0361***	0.0361***
Log Migration Outflows	(-23.14)	(-23.15)
md9_dec2*	0.0426***	0.0426***
Log Migration Outflows	(-29.44)	(-29.44)
md10_jan*	0.0288***	0.0288***
Log Migration Outflows	(-19.49)	(-19.5)
md11_feb*	0.0362***	0.0362***
Log Migration Outflows	(-24.63)	(-24.63)

Measuring migration related movements from daily mobility data

md12_mar*	0.0362***	0.0362***
Log Migration Outflows	(-26.69)	(-26.71)
md13_apr*	0.0208***	0.0208***
Log Migration Outflows	(-19.46)	(-19.5)
md14_may*	0.0142***	0.0142***
Log Migration Outflows	(-15.28)	(-15.34)
md15_jun*	0.0308***	0.0308***
Log Migration Outflows	(-27.72)	(-27.78)
md16_jul*	0.0283***	0.0283***
Log Migration Outflows	(-25.78)	(-25.83)
md17_aug*	0.0255***	0.0255***
Log Migration Outflows	(-22.13)	(-22.16)
md18_sep*	0.00956***	0.00956***
Log Migration Outflows	(-4.31)	(-4.31)
Log of Population at Source district		-0.0206***
		(-62.22)
Log of Population at Destination district		-0.0232***
		(-54.92)
_cons	0.186***	0.743***
	(-62.94)	(-101.39)
Number of Directional district-pairs	2972656	2972656
t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001		