DEMOGRAPHIC AND ECONOMIC CENTER OF GRAVITY OF NEPAL

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Abstract

In this paper, an attempt has been made on determination of the Demographic Center of Gravity (DCG) and Economic Center of Gravity (ECG) of Nepal The results are then used for the study of historical demographic dynamics and present spatial heterogeneity in distribution of population and economic activities across the country. Census data from 1971–2021 shows the net shift of DCG of Nepal by about 12.5 km toward South–West direction with location in 2021 being at 84.588°E 27.648°N, Khairhani Municipality, Chitwan. Likewise, the ECG of Nepal in FY 2020/21 was at 84.780°E 27.655°N, near the tri–junction point of Chitwan, Makawanpur and Dhading districts. Due to unavailability of enough historical data of Provincial Gross Domestic Product (PGDP), the historical shift in ECG couldn't be traced. Besides this, the Geographic Centroid (GC) of Nepal is estimated being at 83.920°E 28.277°N, Pokhara, Kaski. From these findings, it is seen that the DCG and ECG lie towards the South–East of GC of Nepal suggesting that the population and economic activities of Nepal is more concentrated on the southern Terai part of Nepal than Hills and inclined toward Eastern part of Nepal than the West.

Key words: Economic Center of Gravity, Demographic Center of Gravity, Demographic Dynamics, Spatial Distribution of Population and Economic Activities
JEL Classification Code: R12, R23

1.   Introduction

Mathematically, a centroid is a point on a polygonal uniform lamina where it can be balanced perfectly. Since map is a two-dimensional projection of the surface of the Earth, its centroid can be determined by treating it as a polygon. This geometric centroid of territory represented by the map is called Geographic Centroid (GC) of the area. In Physics, the center of gravity of an object is where we can consider all of the weight of the object is concentrated. Knowing the center of gravity of a given object gives an idea of distribution of matter inside it. Talking about Economic and Demographic Center of Gravity, the concept is similar to that in Physics, but here, population and economic activity play the role of the weight. The Demographic Center of Gravity (DCG) is the point at which an imaginary, weightless, rigid, and flat surface representing a territory would balance if weights of identical size were placed on it so

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that each weight represented the location of one person (U.S. Census Bureau, 2021). Similar to DCG, Economic Center of Gravity (ECG) represents a balance point on territorial plane if weights are placed on it such that each one is equivalent to economic activities at the corresponding place. It can be tempting to interpret the ECG and DCG as the region of high economic and population centralization, but that's not the case. Both of these points can lie in those places where there is no population and economic activity at all.

Borrowing the idea of center of gravity from physics, researchers in social sciences have used it to represent and study the spatial distribution and dynamics of population and economy. Grether and Mathys (2010) calculated the World's Economic Center of Gravity (WECG) to study the rise of Asian economies in global arena. Quah (2011) extended the study and projected that WECG will lie between India and China by 2050. The idea has been adopted for the study of regional economy inside a country (Breau, Toy, Brown, Macdonald, & Coomes, 2018). Similarly, USA publishes its Center of Population for every census (U.S. Census Bureau, 2021). In this paper, we have performed similar analysis in the domestic context of Nepal.

Nepal's demographic transition is best described as, "In demographic terms, Nepal is gradually turning from a rural mountainous country to a plains-urban country" (Sharma, 2022). According to preliminary data of Census 2021, 53.66% of population lives in Terai region and 10.26% in 3 districts of Kathmandu Valley, totaling to 63.92% of population of Nepal. That's approximately two thirds of the country's population living either in Terai or Kathmandu Valley. Similarly, as per Census of Nepal 2011, 27 districts were facing depopulation phenomenon (decreasing of population compared to previous census). In 2021, it reached to 32 districts and all of them from hills and mountains (Central Bureau of Statistics, 2022). Migration of population from the hilly and mountainous region of Nepal to Terai and Kathmandu Valley in the last several decades has been a well-recognized phenomenon in Nepal. Hill to Terai migration was observed in huge volume after late 1950s when Malaria was eradicated in Terai region and Government of Nepal initiated land resettlement programs. The migration took place in search of arable and fertile land (Shrestha, Velu, & Conway, 1993; Gartaula & Niehof, 2013). Similarly, regional developmental disparity has always been a concern in Nepal. The Kathmandu Valley alone accounts for 30% of the country's Gross Domestic Product (Asian Development Bank, 2013). Government puts this figure at 23.4% (Ministry of Finance, 2015).

2. Review of Literature

Grether & Mathys (2010) used Economic Center of Gravity approach to study the rise of Asia as an economic powerhouse of the World. They calculated World's Economic Center of Gravity (WECG) for 1975-2004 using GDP data from 392 cities

with more than 1 million inhabitants in 80 countries. WECG was found to be located beneath Iceland in mid 1970s. And over the time, it was shifting eastward indicating the rapid economic growth in Asia compared to the Western World. They concluded that WECG was not yet into Asia at that time but following the eastward shift, they projected that it would cross the Asian border sometime in the future.

Quah (2011) extended the work of Grether & Mathys by using GDP data from nearly 700 identifiable locations which incorporated both urban agglomerations and regions outside of it. This study used cylindrical projection rather than spherical one used by Grether & Mathys. Calculations showed that WECG was in mid-Atlantic in 1980, then following the continuous rise of China and the other East Asian economies, it drifted east. In 2008, it reached close to Izmir. Extrapolating the data predicted that by 2050, WECG will lie between India and China indicating the 9300 km shift in WECG in 70 years. Work of Grether & Mathys and Quah both drew same conclusion about the rise of Asia and eastward shift of WECG.

Use of ECG in study of domestic economy of a country can be seen in the work of Breau and et al. (2018). They tracked the historical movement of Canada's ECG from 1926 to 2013 and compared it with occurrence of six distinct historical moments during which major spatial realignment occurred in the Canadian economy. They found that, Canada's ECG shifted by net distance of 204 km westward in nearly 9 decades.

Shrestha and et al. (1993) discussed in detail about the migration of hill population to Terai after eradication of Malaria in Terai during late 1950s. Similarly, policy of resettlement was adopted by Government of Nepal which amplified this migration phenomenon. They stated, "As the information about land distribution and malaria eradication spread in the surrounding hill villages, Chitwan experienced a phenomenal annual population growth (6.8%) due to migration." Gartaula & Niehof (2013) also wrote about the heavy migration of population from Hill to Terai after 1950s but they also drew attention toward the out-migration from Terai to urban centers of the country and abroad after 1990s.

Migration inside Kathmandu Valley and subsequent growth of urban settlement inside the Valley is well discussed in the work of Pradhan (2004). This article talks about the historical settlements in Kathmandu valley, rapid population growth, migration inside the Valley and various environmental issues caused by this phenomenon. It has shown that the urban population of Kathmandu valley increased by almost 500% within five decades after 1950s. The article concludes with a number of policy recommendations including urban land development, creating awareness among people, development of outskirts of the valley's cities etc.

Upreti (2008) talked about the phenomenon of internal migration from rural areas of Nepal to urban centers due to armed insurgency in Nepal. During the armed conflict, displacement was seen in various section of society including rich and powerful local elites, government staff and their relatives, local leaders of political parties, poor and socially excluded groups etc. Migration was preferred to urban areas because they were perceived as safer and could provide better livelihood opportunities.

We couldn't find any previous work related to estimation of Demographic and Economic Center of Gravity of Nepal. Since center of gravity approach is useful in analysis of dynamics and spatial distribution of population and economic activities, we attempt to fill this gap.

The objectives of the study is to estimate Demographic and Economic Center of Gravity of Nepal. Further, the results will be used to show the historical dynamics and current status of spatial distribution of population and economic activities across the country.

3. Methodology

Data from various sources has been used for this study. They are as follows: Maps required for the study were downloaded from National Spatial Data Center: Geoportal website maintained by Survey Department, Ministry of Land Management, Cooperatives and Poverty Alleviation, Government of Nepal. Maps related to national, province, district and local bodies boundary were downloaded in shape-file format. Data related to population of Nepal were taken from the census reports published by Central Bureau of Statistics, National Planning Commission, Government of Nepal. GDP data granular at provincial level was collected from website of Central Bureau of Statistics, National Planning Commission, Government of Nepal. All the GDP data are in nominal form. We couldn't find GDP data more granular than this.

Firstly, Geographic Centroid (GC) of each district and the whole country of Nepal were determined by analyzing corresponding map file using GeoPandas Python library. GCs were determined in the form of latitudes and longitudes. For determination of GCs, mercator projected map of Nepal is used. Issue faced while determining World's Economic Center of Gravity regarding projection of three-dimensional earth into two-dimensional map by Grether and Mathys (2010) and Quah (2011) is not significant in our context because Nepal is a small country with narrow North-South width. So, the territory of Nepal is assumed to be a flat surface such that DCG and ECG always lie on its surface. Mercator projection is used because it preserves the shape of the geographic area to a greater extend which is crucial to determine centroids. GCs of districts has been used in the further calculation, while GC of the country was determined for comparison purpose. Population of each district was assumed to be concentrated at its GC. Once

we know the population and GC of each district, we can calculate Demographic Center of Gravity (DCG) of the country.

Suppose DLat and DLong be the latitude and longitude of DCG of given territory to be determined. Similarly, Gi Lat and Gi Long be the latitude and longitude of GC of ith division inside it. Also, Pi be the population of ith division. Then we can find DCG by weighted mean method using Equation (1) and Equation (2).

$$D_{Lat} = \frac{\sum(G^i_{Lat} \times P^i)}{\sum P^i}$$
(1)

$$D_{Long} = \frac{\sum(G^i_{Long} \times P^i)}{\sum P^i}$$
(2)

where i = 1,2,3 ... N.

Here, for determination of DCG of Nepal, district level administrative division is used. This calculation gives DCG for one particular census. When same calculation is applied for data of each census, we get a set of latitude-longitude pairs representing a set of DCG points on map. This shows the shift in DCGs over time.

For the purpose of determination of Economic Center of Gravity (ECG), GDP data granular at province level is used. Since, provinces are relatively larger in size than districts and distribution of economic activities across each province is not uniform, so assuming that the total productive activities of given province being concentrated at GC of the province will give large error. In general, population are concentrated at places with higher economic activities. Thus, assuming that total productive activities of a province being concentrated at its DCG would be a better assumption. We determined DCG of each province using district level data in the same way we did for DCG of the country. Once we have latitude and longitude of DCG of each province and corresponding GDP, we can calculate the ECG of the country.

Suppose ELat and ELong be the latitude and longitude of ECG of given territory to be determined. Similarly, Di Lat and Di Long be the latitude and longitude of DCG of ith division inside it. Also, GDPi be the Gross Domestic Product of ith division. Then we can find ECG by weighted mean method using Equation (3) and Equation (4).

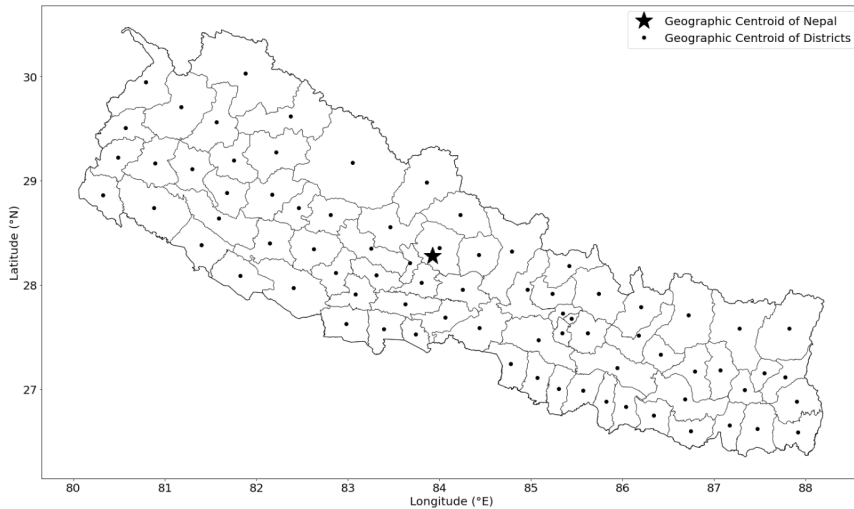$$E_{Long} = \frac{\sum(D^i_{Long} \times GDP^i)}{\sum GDP^i} \qquad\qquad (3)$$

$$E_{Lat} = \frac{\sum(D^i_{Lat} \times GDP^i)}{\sum GDP^i} \qquad\qquad (4)$$

where i = 1,2,3 … N.

4. Result

Geographic Centroid of the country and districts of Nepal were determined from map data using GeoPandas Python library. It can be plotted in map as shown in Figure 1.

Figure 1: Geographic Centroid of the Country and Districts of Nepal


The GC of Nepal is found to be at 83.920°E 28.277°N, which lies near Hemja, Pokhara in Kaski district. Kaski has already been introduced as the district lying at the centroid point of the country (District Coordination Committee Office Kaski, 2022). It should be noted that determination of exact GC of Nepal is beyond the scope of our work. This result should be enough for comparison with ECG and DCG in later part of this paper.

Eastern Rukum and Western Rukum used to be a single district by the name Rukum before 2015. In the same year, Nawalparasi district was divided into two parts which was later named as Nawalpur and Parasi. So, for compatibility with population data from census before 2015, separate GC was calculated for Rukum and Nawalparasi. Similarly, Tibrikot was one the district found in Census Data from 1971. It has been assumed that GC of Tibrikot coincide with that of current district of Kalikot. GC of all other districts is assumed to be unchanged for date range 1971 to 2021. Census before 1971 used to collect population data with different administrative division format and we encountered challenges to calculate and make those results comparable with later census. Boundary of administrative division of districts formed in 1962 is more or less stable till date. So, to make census to census result comparable, we have limited our analysis to data from 1971 census and later.

After determining GC of districts of Nepal and collecting district level population of Nepal from census reports, DCG of Nepal for different census year were calculated. It is shown in Table 1 and Figure 2. According to the preliminary data from census of Nepal 2021, DCG lies at 84.588°E 27.648°N which is in Khairhani Municipality, Chitwan District.

Table 1: Demographic Center of Gravity of Nepal 1971-2021		
Year (A.D.)	Longitude (°E)	Latitude (°N)
1971	84.690	27.716
1981	84.676	27.688
1991	84.645	27.676
2001	84.612	27.674
2011	84.581	27.673
2021	84.588	27.648
Source: Author's calculation		

Figure 2: Demographic Center of Gravity of Nepal 1971-2021
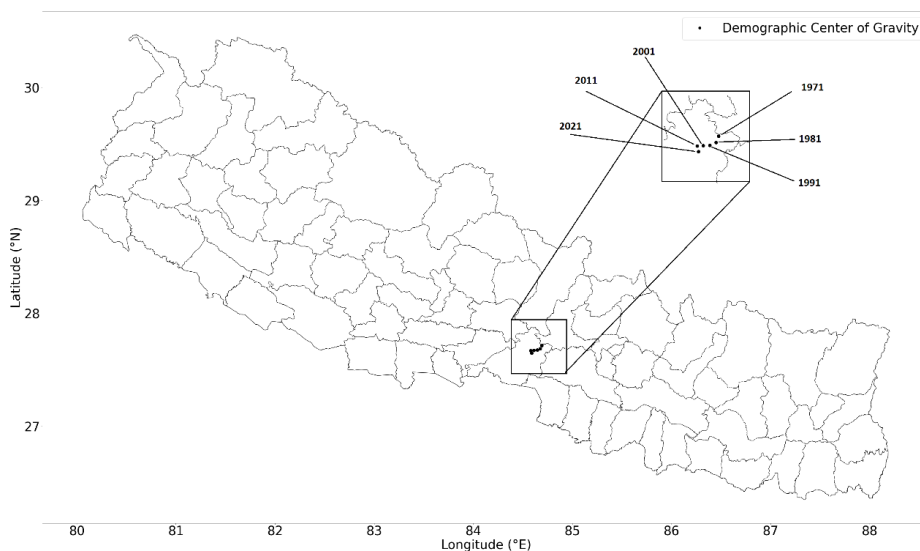
To calculate ECG from GDP data granular at province level, DCG of each province need to be calculated. We assumed that total productive activity of a province is concentrated at its DCG. Since we only have provincial GDP data from FY 2018/19 to 2020/21, we used DCG of provinces calculated from preliminary population data of 2021 census. The Demographic Center of Gravity of provinces of Nepal as of 2021 is shown in Table 2.

Table 2: Demographic Center of Gravity of Provinces of Nepal 2021		
Province	**Longitude (°E)**	**Latitude (°N)**
Koshi	87.399	26.825
Madhesh	85.715	26.920
Bagmati	85.310	27.660
Gandaki	84.012	28.162
Lumbini	82.798	27.884
Karnali	81.965	28.867
Sudurpaschim	80.813	29.092
Source: Author's calculation		

The ECG of Nepal thus calculated are as shown in Table 3 and Figure 3. Shifting of ECG is a slow process and doesn't shift noticeably in span of few years. Thus, ECG from FY 2018/19 to FY 2020/21 almost coincide with each other. As of FY 2020/21, it lies near the tri-junction point of Chitwan, Makawanpur and Dhading districts.

| Table 3: Economic Center of Gravity of Nepal FY 2018/19 - FY 2020/21		
Fiscal Year (A.D.)	**Longitude (°E)**	**Latitude (°N)**
2018/19	84.786	27.654
2019/20	84.772	27.657
2020/21	84.780	27.655
Source: Author's calculation		

5. Discussion

From all these calculations and results, we can have some crucial insights in historical dynamics and spatial distribution of population and economic activities inside the country. These observations serve as the mathematical confirmation of various phenomena in demography and economy of Nepal.

From result in Table 1 and Figure 2, we observe Demographic Center of Gravity of Nepal has shifted from 84.690°E 27.716°N in 1971 to 84.588°E 27.648°N in 2021. This is about 12.5

Figure 3: Economic Center of Gravity of Nepal FY 2018/19 - FY 2020/21
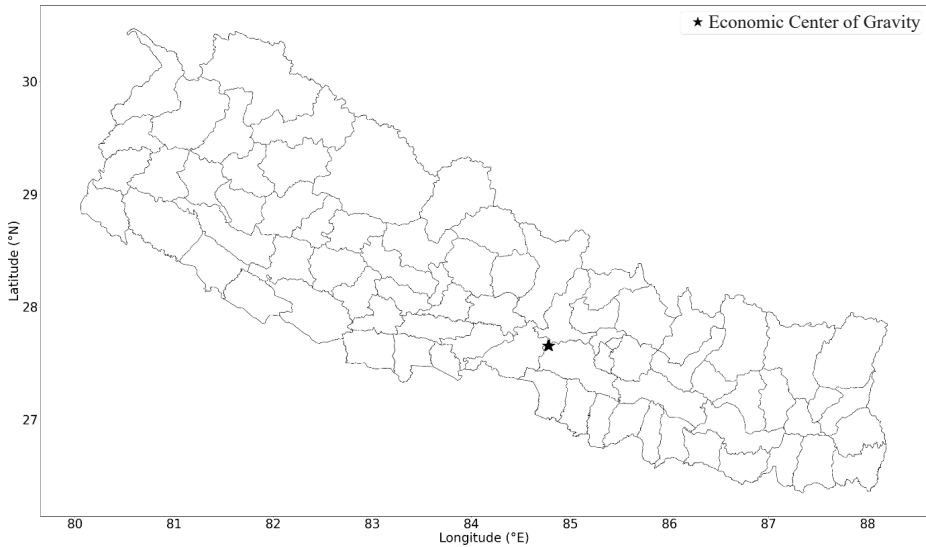
km shift toward south-west direction in 5 decades. Assuming the average north-south width of the country being 193 km (Department of Information and Broadcasting, 2021), we can calculate the shift in Demographic Center of Gravity of Nepal as about 6.5% of width of the country in between 1971 to 2021.

This result is obvious because migration of people from Northern hilly and mountainous region to southern plain of Terai region is the well-known phenomenon. Similarly, Kathmandu Valley, which is a part of hilly belt of the country has been the destination of population migration. This increase in population of Kathmandu Valley has obviously acted as a pull force on DCG of the country but despite the pull force of Kathmandu Valley, we clearly observe that there has been net shift of population of Nepal toward South-West direction.

Figure 4 shows GC, DCG (for year 2021) and ECG (for FY 2020/21) in single map. DCG and ECG of Nepal lies about 92km and 105km respectively South-East of GC. It reflects that southern part of the country has more population and economic activities than northern part. Similarly, population and economic activities of Nepal is more inclined toward eastern part (this includes Kathmandu valley) in comparison to western part of the country. ECG lies about 19km east of DCG. This suggests that eastern part of Nepal has higher GDP per capita than western part of Nepal.

Figure 4: Geographic, Demographic and Economic Center of Gravity of Nepal 2021
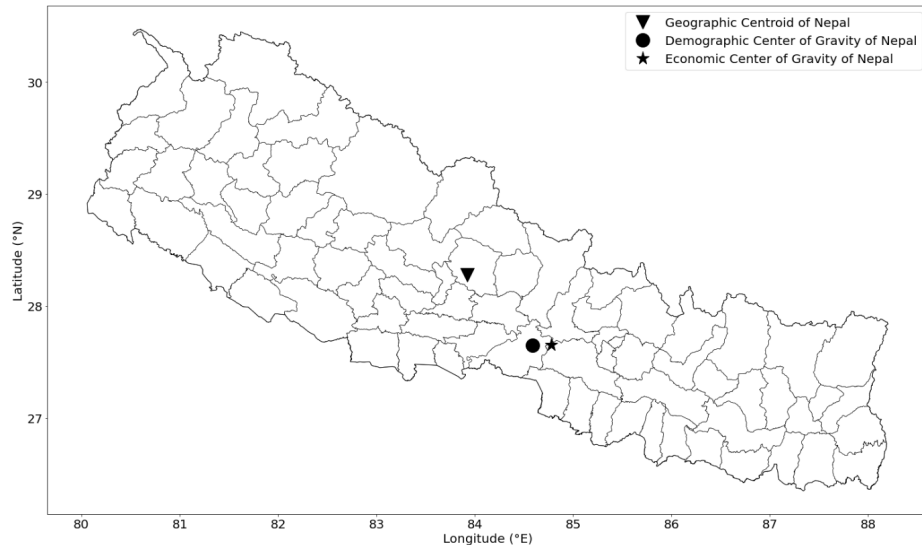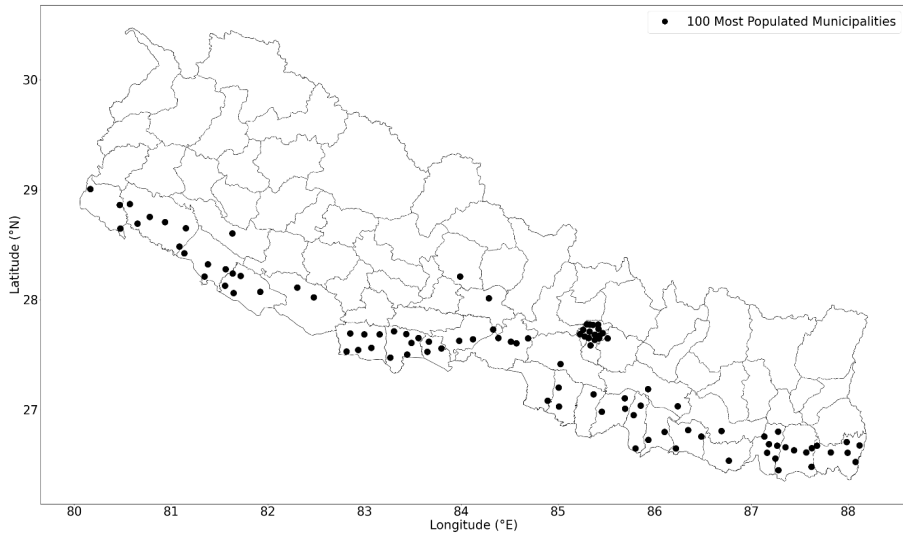

Figure 5 shows the location of 100 most populated municipalities of Nepal (Central Bureau of Statistics, 2022). Almost all of these municipalities are located either in Kathmandu Valley

Figure 5: 100 Most Populated Municipalities of Nepal

or in Terai belt. It should be noted that these municipalities vary significantly in terms of their area and thus Figure 5 doesn't perfectly represent urban agglomerations of the country but still it shows population concentration in Terai belt and Kathmandu valley.

6. Conclusion

Migration of people from hills to Terai is well known phenomenon of Nepal. Population of Nepal has heavily concentrated in Kathmandu Valley and Terai belt of Nepal. Same thing is true for economic activities in the country. Our calculations of Demographic and Economic Center of Gravity of Nepal confirm this reality. This changing scenario of Nepal is a two-sided sword for Nepal. In one hand, formation of huge cities brings a lot of economic opportunities for the country. A huge urban agglomeration creates huge product and job market in the economy. Transportation cost will be much lower. It will be easier and cost effective to build health, education and transportation infrastructures. Huge job market helps to promote specialization in labor force. But on the other hand, this sort of population centralization has serious environmental consequences. Shortage of drinking water and lack of waste management will be serious issue, which is already happening in Kathmandu Valley. Air, water and noise pollution will be difficult to manage. Difficulty in traffic management is another such problem. Hence, government should focus on managing the downside of population centralization and taking maximum benefits from the opportunity it creates in the economy.

The major limitations of our work are as follows:
  • In popular belief, migration toward Terai is considered as migration toward

South. But, East-West extend of the country doesn't perfectly align with latitudes and thus some part of Terai lies actually in north of other parts of hilly and mountainous region. Hence, migration from Hill to Terai can contribute to Northward shift of DCG. For example, migration from Sandhikharka, Arghakhachi to Dhangadhi, Kailali shifts DCG to North.

- Our study limits the study of DCG from 1971 to 2021. We couldn't properly demarcate the territory of administrative division used before 1971 Census. Since migration of population from Hills to Terai started in large volume after 1950s, we have missed to capture early 2 decades of these demographic shifts.
- We have used population data granular at district level and GDP data granular at provincial level. More accuracy could be achieved if more granular data is used.

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