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Optimizing Innovation and Global Competitiveness: How Linguistic Uniformity Drives Economic Performance, the Chakrabarty-Srivastava Function Approach

Shubhro Chakrabartty[1], Vandna Srivastava[2] and Kumud Kumar Das[3]

ABSTRACT: This paper shows in detail that how a language acts as a boost for economic development, economy boost and global competitiveness in advanced economies such as Russia, Japan, Germany, and South Korea. These countries have strong command of their own national language, combined with a wide range of foreign language proficiency, it has always helped workers participate more effectively and efficiently in cross-border trade, technology exchange, and international collaboration. These linguistic skills have supported the emergence, stability and growth of globally recognized firms such as Mercedes-Benz, BMW, Toyota, Samsung, and Hyundai in multiple major sectors including automotive, information technology, semiconductors, and petrochemicals. Language plays a huge role here as these skills not only enable these companies to enter and operate smoothly in foreign markets, but also helps them to build durable and trustworthy partnerships and it eventually helps them to continue their work on innovation, thereby maintaining their reputation and status with leading players of important industries. Our analysis also introduces a key function Chakrabartty-Srivastava Function, it is such a framework that brings language explicitly into the set of high valued economic variables and proposes a good, recognised link between linguistic diversity and GDP growth. Implementing a national language policy, based on the mother tongue, can strengthen human capital, improve educational access, and support long-term socio-economic development. By treating language as a crucial and one of the main principles of development rather than a secondary cultural factor and a non-primary cultural influence, the study highlights how multilingualism and linguistic diversity can enhance national productivity and strengthen long-term economic performance -. This is the reason why this topic is of great importance and relevance to the decision-makers and to the economists who want to find new ways to support the steady and stable growth over time and to enhance their nations' standings and ranks in the international system.

Keywords: Chakrabartty-Srivastava function, optimization, linguistic uniformity, economic performance.

Contents

1. Introduction

India's economic story has experienced major phases of wealth, disruption, and recovery, which is shaped heavily by colonial rule and multiple repeated invasions. During the Rule of Mughal period, India was widely known as one of the world's richest regions and it was famous for global trade, thereby contributing a high percentage share to global output and flourishing in trade, crafts, and agriculture (Bose 2019). This prosperity of India faded during the British colonial era, when extractive policies, heavy taxation, and the dismantling of traditional industries (Gupta, 2018) led to what historians describe as

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deindustrialization and a steep decline in India's economic position (Roy, 2017). The image of India often described as the "Golden Bird" or "Sone ki Chidiya" reflects this earlier important phase of cultural and commercial abundance before prolonged colonial exploitation which heavily drained its economic strength (Chandra, 2016). Comparative experiences and insights of other countries help clarify both India's challenges, problems and its options for renewal. Germany's post-World War II "Wirtschaftswunder" combined industrial rebuilding with heavy and large-scale technology upgradations and strong institutions to revive and sustain growth (Mazower, 2018). Japan followed a somewhat different path, using strategies that focused on heavy export-led Frame-Works and continuous innovation in automobiles and electronics to transform itself into a major economic power in the second half of the twentieth century (Johnson, 2019). Russia's Growth-pattern after the breakup of the Soviet Union showcases the difficulties of moving from a planned to a market economy, but also how important are natural resources and industrial capacity can be used to retain weight in global markets (Dabrowski, 2017).

South Korea is often considered as one of the clearest examples of rapid Shift from a low-income, Country devastated by war to a high-tech, export-driven economy. The "Miracle on the Han River" was a result of very heavy investments in education, technology, and globally competitive industries, supported by a Significance on building a skilled and disciplined workforce. Education policy, played a key role such as inclusion of Korean as a medium of instruction alongside foreign language learning, helped connect schooling to national development goals and technological innovation (Chung, 2020). Recent changes in India's policy show a growing interest in linking and bridging education, language, and economic development (Kim, 2019). The National Education Policy 2020, in this context, highlights the need for giving instruction in the mother-tongue or regional language during the early years of schooling, with the dual objectives of enhancing learning outcomes and recognizing India's linguistic and cultural diversity (Government of India 2020). It is by fostering and propagating mother tongues and multilingualism that India will, among other things, reap cognitive benefits, keep cultural heritage alive, and equip the next generations with the skills needed to compete in a knowledge-driven, complex global economy (Panda, 2021).

2. Literature Review

The literature review in question owes its existence to the author's direct observations and on-field experiences in South Korea and other developed Asian countries. These experiences have further indicated the extent to which people value their mother tongue, particularly in the realm of technology. The author has highlighted how favourable attitudes towards the mother tongue facilitate the accessibility and trustworthiness of technological engagement for the local people in these countries. This factor has been a major contributor to the economic development of these societies as well as the creation of better lifestyle choices. The history of India is a good example of this cycle of rise and fall due to multiple invasions and colonial rule. The Mughal Empire and the long years of British rule that followed had a profound impact on India's economy and culture. Historical records suggest that India's economic pre-eminence in the 18th century was a major factor in global GDP. However, at the time of independence in 1947, India's economic share had declined significantly, and it was the colonial exploitation and resource extraction that were identified as the main causes of this decline. Important works of economic historians such as Amartya Sen and Angus Maddison have all done an analysis of India's economic history spanning over the whole of the pre and post-independence period. One of the most powerful similarities between post-independence India and South Korea that very clearly emerges is the role of education and language in the economic development process. Korea was able to change its poverty and stagnant situation and, in turn, became a powerful economy. The economists Ha-Joon Chang and Alice Amsden debate that South Korea has demonstrated strong economic growth, and its economic success is attributed to the investments made in education, science and human capital. South Korea's vigorous policy of literacy elimination and mother language upliftment seem to be among the main contributors to its rapid economic growth, which in turn led to the Miracle on the Han River. "language" is "a crucial factor" that has "a decisive role" in "the economic development, sustainability and global competitiveness. Researchers in linguistics and economics have consistently shown that there is a strong link between linguistic diversity, cognitive development, economic outcomes, and performances. Among the few pioneering studies by other scholars, Joshua Aizenman and Mark M. Pitt highlight the significance of multilingual education,

not only for the purpose of developing cognitive abilities but also for the preservation of cultural heritage.

The exceptional language capability of South Korea, particularly in the fields of IT and telecommunications, is evidence of the economic benefits and the prestige that come with investing in language education. The National Education Policy (NEP) 2020 of India is a sign of a firm path that will not only elevate but also make language diversity more visible and accepted. The NEP advocates for the use of the local language in primary and higher education as a vehicle for quality education with great emphasis. Hence, the policy's main concern is very deep: it revolves around the learner's understanding and its depth.

3. Methodology

It is very common that language is recognized as a powerful factor in the economic and global competitiveness development. To be very rigorous ultimatums on this point, we have established a math framework and performed the model in an orderly manner as given below.

Table 1: Data of Language Spoken in Various Countries (© IMF, 2024)

Language Scaling (X)	**Countries**	**GDP Growth Rates (%)**
3 (High)	India, Iran, Mozambique, Nepal, Pakistan, Singapore, South Africa, Vanuatu	6.04, 2.50, 5.27, 4.38, 4.59, 5.58, 1.98, 2.63
2 (Medium)	Canada, Estonia, Georgia, Guatemala, Latvia, Malawi, Namibia, Palau, Spain, Sri Lanka, Switzerland, Turkmenistan, Ukraine, Uzbekistan	2.23, 2.31, 1.83, 3.05, 2.07, 3.57, 2.45, 0.68, 2.12, 3.96, 1.79, 3.42, −0.38, 3.59
1 (Low)	Bulgaria, Burundi, Cambodia, Croatia, Finland, France, Greece, Hungary, Lithuania, Mali, Marshall Islands, Mauritius, Mongolia, Nicaragua, Poland, Seychelles, Slovenia, United States	1.47, 2.44, 5.69, 1.83, 1.95, 1.65, 1.03, 1.78, 2.52, 3.96, 1.05, 4.08, 4.77, 2.51, 2.67, 3.82, 2.05, 2.55

The different language percentages among the population of different countries are shown in Table 1. The scaling is based on these country values: a country with one main spoken language gets a value of 1, two languages get a value of 2, and three or more languages get a value of 3. In addition to that, the average growth rate for a period of 50 years, described as Y, is also given in the table.

3.1. Correlation Effect

Table 2: Correlation between Language Spoken Scale and GDP Growth Rate of Various Countries

Variables	**Language Mapping (X)**	**GDP Growth Rate (Y)**
Language Mapping (X)	1	
GDP Growth Rate (Y)	-0.3364448018 ≈ -0.34	1

Table 2 presents the correlation between the language spoken scale and GDP growth rate across various countries. The table points out an ideal correlation coefficient of 1 for the language mapping itself and a negative correlation of -0.336 between the language spoken scale and the GDP growth rate over a period of 50 years. Reading the numbers, the GDP growth rate is more inclined to drop as the number of spoken languages increases. This implication suggests that approximately 34% of GDP growth is influenced by the linguistic diversity of a country. Thus, the aforementioned discourse gives rise to the hypothesis presented below.

3.2. Hypothesis & Mathematical Model

3.2.1. Hypothesis:

Greater linguistic diversity has a negative impact on GDP growth; hence there is a strong reliance of GDP on language.

3.2.2. Model.

In order to represent how different economic factors influence a nation's total economic output, a mathematical model for GDP (Gross Domestic Product) is usually constructed. One the simplest GDP model (Mankiw, 2015) can be represented through the expenditure approach, which is the most widely used method among others.

GDP Growth Model:

$$\text{GDP Growth} = \frac{\text{GDP}_{\text{current year}} - \text{GDP}_{\text{previous year}}}{\text{GDP}_{\text{previous year}}}$$

To consider the impact of a national language on technological change and economic growth on the existing GDP function, we can alter the Cobb-Douglas production function (Cobb, 1928) by incorporating a new term to identify this association. It has been detected that the national language is linked to GDP at the level of -0.34, which means that there is a small negative effect on GDP when the national language is considered. We can refer to this new factor as L_n, where L_n denotes the "language impact" on GDP. We have modified Cobb-Douglas Function to incorporate the language factor (L_n) and renamed the function as "Chakrabartty-Srivastava Function". This new function shows the national language effect with a negative coefficient to reflect the negative correlation. According to "Chakrabartty-Srivastava" Function the new GDP function can be expressed as:

$$G = AK^{\alpha}L^{\beta}L_n^{\gamma}$$

where:

$$\begin{aligned} G &= \text{GDP (output)} \\ A &= \text{Total factor productivity (TFP)} \\ K &= \text{Capital input} \\ L &= \text{Labour input} \\ L_n &= \text{National language factor, with a negative exponent } \gamma \\ \alpha, \beta, \gamma &= \text{Elasticities of capital, labour, and national language, respectively} \end{aligned}$$

Given that the correlation of the national language with GDP is -0.34, we assume the exponent γ = -0.34 to reflect this correlation. Thus, the new combined function becomes:

$$G = AK^{\alpha}L^{\beta}L_n^{-0.34}$$

INTERPRETATION

- The negative exponent -0.34 indicates that as the national language factor L_n increases, the GDP G decreases slightly.
- The value L_n could represent a quantifiable measure of how strong the national language influence is in a given country, such as a percentage of the population that speaks the national language or the level of linguistic homogeneity in the country.

To mathematically prove the effect of introducing the national language factor with a correlation of -0.34 into the GDP model, we will differentiate the function.

The combined production function is:

$$G = AK^{\alpha}L^{\beta}L_n^{-0.34}$$

Partially differentiating with respect to the national language factor L_n gives us the rate of change of GDP when L_n changes. The general rule for the derivative of a power function is:

$$\frac{\partial G}{\partial L_n} = -0.34\, AK^{\alpha} L^{\beta} L_n^{-1.34}$$

- The negative sign in the derivative (-0.34) indicates that an increase in the national language factor L_n (i.e., more influence or prevalence of the national language) decreases GDP.
- The term $L_n^{-1.34}$ shows that this effect is not linear; the decrease becomes less pronounced as L_n increases (since the exponent is less than -1).

Therefore, this derivation serves as a mathematical confirmation that GDP, G, is a decreasing function of the national language factor L_n when L_n increases, which aligns with the negative correlation value of -0.34.

3.2.3. Check for constant returns to scale (CRS).

To check that the model is consistent with economic theories, we need to see if it maintains **constant returns to scale (CRS)**. CRS refers to the case when increasing all inputs by the same factor results in output increasing by the same factor.

In the case of the Cobb-Douglas production function:

$$Y = AK^{\alpha} L^{\beta}$$

For CRS, we require:

$$\alpha + \beta = 1$$

Now, in the modified GDP function with the national language factor:

$$G = AK^{\alpha} L^{\beta} L_n^{-0.34}$$

For CRS:
If K, L, and L_n are scaled by the same factor t, we want to check if G is also scaled by t.
Let's scale the inputs K, L, and L_n by t:

$$G = A(tK)^{\alpha}(tL)^{\beta}(tL_n)^{-0.34}$$

This becomes:

$$G = A\, t^{\alpha} K^{\alpha}\, t^{\beta} L^{\beta}\, t^{-0.34} L_n^{-0.34}$$

Simplifying:

$$G = A\, t^{\alpha+\beta-0.34} K^{\alpha} L^{\beta} L_n^{-0.34}$$

To have CRS, it is necessary that:

$$\alpha + \beta - 0.34 = 1$$

Moreover, this equation implies that the addition of the national language factor changes the property of constant returns to scale unless further interventions are introduced into the model.

Setting $\alpha + \beta = 1$, the presence of the $L_n^{-0.34}$ term implies that the model exhibits decreasing returns to scale. Moreover, this is in line with the observed data that shows a negative correlation between the national language variable and GDP, which means that the higher the influence of the national language, the lower the total productivity as measured by GDP. Such a change brings to light the issue of how linguistic factors, when integrated into economic models, can not only have a significant impact on productivity but also provide an explanation for the seemingly paradoxical phenomena that standard production functions fail to recognize.

Such a change brings to light the issue of how linguistic factors, when integrated into economic models, can not only have a significant impact on productivity but also provide an explanation for the seemingly paradoxical phenomena that standard production functions fail to recognize.

Table 3: Decade GDP Growth Rates (%) for China, India, and South Korea

textbfDecade	**China**	**India**	**South Korea**
1980s	9.75	5.69	8.88
1990s	9.98	5.77	7.32
2000s	10.33	6.29	4.92
2010s	7.68	6.65	3.33
2020–22	4.53	3.63	2.07

As shown in Table 3, China consistently had the highest GDP growth rate.

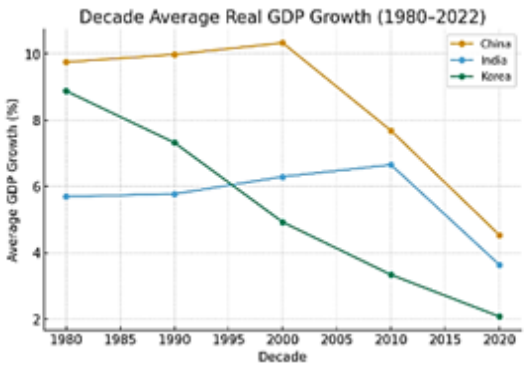

Figure 1: Illustrating GDP Growth Rate (©IMF, 2024)

Figure 1. shows the figures and the growth graph of the GDP of the countries according to the International Monetary Fund (© IMF, 2024) data. The table provides a complete picture of the world economy performance and highlights changes in GDP growth in different countries. This information is a great source for the study of trend economy, the comparison of national performance, and the recognition of the main factors affecting growth patterns. The table can be a source of profound insights into the economic health and the likely future of the countries displayed.

Table 4 : Average Growth Rate

Country	**China**	**India**	**South Korea**
Average Growth Rate (%)	9.004545455	5.970454545	5.729545455

Table 4 illustrates the mean growth rate over 44 years. The table focuses on long-term economic trends by averaging growth rates, which helps smooth out short-term fluctuations. Comparing different countries or regions is made possible by this, and it provides insight into prolonged economic performance, which is useful for understanding the factors influencing growth over time.

Let's assume:

- $\alpha = 0.4$ (capital's contribution),
- $\beta = 0.6$ (labour's contribution)

Then the new GDP equation becomes:

$$G = AK^{0.4}L^{0.6}L_n^{-0.34}$$

This formula represents GDP while considering not only the usual inputs of capital and labor but also the effect of the national language by integrating the observed negative correlation of -0.34.

Implications:

- If L_n would be higher (for instance, the country gets more linguistically homogeneous or the national language is more strongly present), GDP, should lower, as the -0.34 exponent indicates.
- On the other hand, if L_n were lower (less linguistic homogeneity or less dominance of the national language), GDP might still be higher due to the negative correlation.

This aggregated function gives you the possibility to consider the sociolinguistic aspect of a national language next to the conventional economic factors such as capital and labour in a GDP model of a country.

Result and Discussion

Total Factor Productivity (TFP)

- A is the parameter that measures the overall efficiency of the inputs (capital and labour) to produce output
- Typical values of A may be different for various countries and industries. In most cases, factor A is set to 1 for theoretical or baseline cases.
- In practical cases, empirical data on total factor productivity (TFP) is needed. For example, developed countries may have A values ranging from 1 to 1.5, while developing countries could have lower values (around 0.7 to 1).

Capital Input

- K represents the value of all capital used in production, including machinery, buildings, and equipment.
- The value of K varies significantly depending on the scale of the economy being analysed. For instance, in large economies, capital stock is often in trillions when measured in GDP models.

Labour Input

- L represents the total amount of labour, typically the number of workers or total hours worked.
- For labour, values can be in millions, depending on the size of the workforce in a given country. For example, for a developed country, the labour input could be 100 to 200 million workers. So for a medium-sized economy we assume $L = 150$ (in millions of workers).

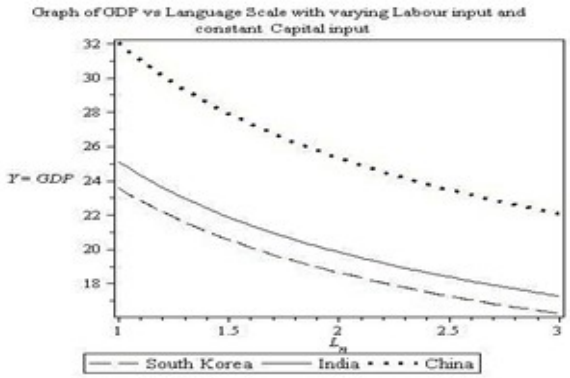

Figure 2: Illustrating GDP Growth Rate (©IMF, 2024)

Figure 2: GDP vs Language with Varying Labour input (L= 0.15, 0.10 and 0.09 Billion) and constant Capital Input (K=10000 Billion) and Total factor productivity (A=1 normalization for simplicity) for different Language factor (L_n).

This figure 2 demonstrates the impact of language or cultural factors (L_n) on GDP for China, India, and South Korea, while keeping the capital input (K) constant. China's GDP remains the highest and declines at a slower rate as L_n increases. China's economy is the most resilient to changes in language or cultural factors. India's GDP is initially lower than that of China but higher than that of South Korea. As L_n increases, India's GDP is going down moderately, which means that language and cultural factors have a significant influence but not an overpowering one to economic output. South Korea's GDP is initially the lowest and goes down more rapidly than that of China and India. This implies that its economy is more vulnerable to changes in linguistic or cultural factors, thus showing a greater dependence on cultural stability for maintaining higher GDP levels under constant capital input.

The graph demonstrates that three countries' GDP decreases with changes in language or cultural factors.

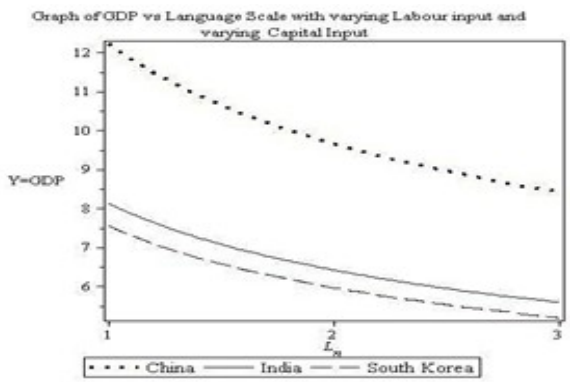

Figure 3: : GDP vs Language with Varying Labour input (150, 100, and 90 million) and varying Capital Input (K= 9004, 5970, 5729 in Billion) and Total factor productivity (A=1) for different Language factor (L_n).

Figure 3 reveals negative correlations between GDP and the language factor (L_n) for China, India, and South Korea. In all countries, L_n is increasing and GDP is decreasing. Each country along with their growth rates are: China (9.004), India (5.970), and South Korea (5.729) in billions with K values of 9004, 5970, and 5729, respectively. On top of that, labour input is different for each country of 150 million

(China), 100 million (India), and 90 million (South Korea), while Total Factor Productivity (TFP) is kept at 1.

4. Discussion

- As the National Language Factor L_n changes from 1 to 3, the GDP (G) is continuously going down. This is consistent with the negative influence that has been identified by the exponent of L_n in the production function. To be more exact, a higher L_n means more linguistic or cultural barriers that lower economic productivity.
- The GDP is greatest when L_n is at its lowest (1), which means that less linguistic diversity or barriers facilitate higher economic output. On the other hand, as L_n goes up, the output drops drastically, this is a clear indication of the harmful effects of the increase in the linguistic challenges.
- The most significant fall is between L_n =1 and L_n =2, where GDP goes down from around 32.04 to 25.31. The decrease is still there but at a slower pace from L_n =2 to L_n =3, thus showing that there is a diminishing return on the negative impact of language factors as they get increased further.
- It underscores different economic reactions to linguistic and cultural influences across the three countries. Figures 2 and 3 suggest that GDP declines at a nearly uniform rate in each country as the number of spoken languages increases, regardless of variations in capital or labour input.

5. Conclusion

The literature review in question owes its existence to the author's direct observations and on-field experiences in South Korea and other developed Asian countries. These experiences have also indicated the extent to which people value their mother tongue, particularly in the realm of technology. The author has highlighted how favourable attitudes towards the mother tongue facilitate the accessibility and trustworthiness of technological engagement for the local people in these countries. This factor has been an major contributor to the economic development of these societies, as well as to the creation of better lifestyle choices. The history of India is a good example of this cycle of rise and fall due to multiple invasions and colonial rule. The Mughal Empire and the long years of British rule that followed had a profound impact on India's economy and culture. Historical records suggest that India's economic pre-eminence in the 18th century was a major factor in global GDP. However, at the time of independence in 1947, India's economic share had declined significantly, and it was colonial exploitation and resource extraction that were identified as the main causes of this decline. Important works of economic historians such as Amartya Sen and Angus Maddison have all done an analysis of India's economic history spanning over the whole of the pre and post-independence period. One of the most powerful similarities between post-independence India and South Korea that very clearly emerges is the role of education and language in the economic development process. By putting into practice and resorting to policies that are in favour of multilingualism and cultural inclusiveness, a vast majority of countries will be able to open up new Doors and Routes for sustainable growth in the long run, thus allowing them to use linguistic and cultural resources effectively to the maximum extent in today's rapidly expanding and globally interconnected.

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References

1. Bose, S., *Economic History of Medieval India, 1200–1500*, Routledge, (2019).
2. Gupta, B., *India's Deindustrialization in the Eighteenth and Nineteenth Centuries*, J. Econ. Hist. 78, 275–302, (2018).
3. Roy, T., *Economic History of India: Ancient to Present*, Cambridge Univ. Press, (2017).
4. Chandra, S., *Medieval India: From Sultanat to the Mughals, Part II*, Har-Anand Publications, (2016).
5. Mazower, M., *Postwar: A History of Europe Since 1945*, Penguin Books, (2018).

6. Johnson, C., *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–1975*, Stanford Univ. Press, (2019).

7. Dabrowski, M., *The Challenges of Russia's Economic Transition*, Routledge, (2017).

8. Chung, C., *South Korea in the New Asia: East Asian Integration and the China Factor*, Routledge, (2020).

9. Kim, Y., *The Education Fever: Society, Politics, and the Pursuit of Education in South Korea*, Univ. of Michigan Press, (2019).

10. Lions, J. L.,*Exact Controllability, Stabilizability, and Perturbations for Distributed Systems*, Siam Rev. 30, 1-68, (1988).

[1] *Department of Computer Science and Engineering, Graphic Era Hill University, Haldwani Campus, India.*

[2] *Centre for Interdisciplinary Studies and Research, D. Y. Patil International University, Pune, India.*

[3] *School of Media and Journalism, D. Y. Patil International University, Pune, India.*

E-mail address: shubhro.chakrabartty87@gmail.com