



REPUBLIC OF TÜRKİYE

ALTINBAŞ UNIVERSITY

Institute of Graduate Studies

Business Administration Department / MBA

**IMPACT OF COVID-19 ON GLOBAL ECONOMICS  
BY FORECASTING GDP USING ENSEMBLE OF  
MACHINE LEARNING MODELS**

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Master's Thesis

Supervisor

Asst. Prof. Dr. Emir Kaan CENGİZ

İstanbul, 2024

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2024

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Waseem Sajjad MALIK

Signature



## **DEDICATION**

This thesis is dedicated to the most incredible pillars of support in my life. To my dear wife, Mahnoor Anjum Malik who has been a constant companion and support throughout this journey, walking beside me every step of the way—your love and encouragement have made all the difference. To my friend, Dr. Sana Tameer, whose support, and assistance have been invaluable, thank you for always being there when I needed guidance and encouragement. And to my siblings, who have provided not just financial but also moral support, thank you for believing in me and backing my dreams with such generosity. Each of you has played a crucial role in my journey, and this accomplishment is a tribute to your unwavering faith and support.



## ABSTRACT

# IMPACT OF COVID-19 ON GLOBAL ECONOMICS BY FORECASTING GDP USING ENSEMBLE OF MACHINE LEARNING MODELS

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Date: 06/2024

Pages: 107

Covid-19 pandemic effected the global economy ineptly. It includes widespread recession marked by decreased economic activity, liquidation of business and disturbance in supply chains. Parallel to it, unemployment, industries and travel was affected badly. Volatility in financial market was experienced as well. Besides, ample data has been generated and stored to analyze the trend of global GDP growth. The dataset contains 20 countries belonging to G7, G8 and G20 economic block from 2000 to 2019. For that purpose, the usage of machine learning (ML) is widely adopted to forecast the economic condition. In this paper, combination of adaptive boosting (AdaBoost), Bayesian neural network (BNN) and linear regression (LR) is used to forecast the global GDP from 2020 to 2039. The finding from ML models contributes to understand the multifaceted challenges occurred by pandemic, enables researches, policymakers and businesses to perform data-driven decision making.

**Keywords:** Covid-19, Adaptive Boosting (AdaBoost), Bayesian Neural Network (BNN), Linear Regression (LR), Machine Learning.

## ÖZET

# MAKİNE ÖĞRENME MODELLERİ TOPLULUĞUNU KULLANARAK GSYİH TAHMİNİNİN KÜRESEL EKONOMİ ÜZERİNDEKİ COVID-19'UN ETKİSİ

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Tarih: 06/2024

Sayfa: 107

Kovid-19 salgını küresel ekonomiyi beceriksizce etkiledi. Bu, ekonomik aktivitenin azalması, işletmelerin tasfiyesi ve tedarik zincirlerindeki bozulma ile belirginleşen yaygın durgunluğu içermektedir. Buna paralel olarak işsizlik, sanayi ve seyahat de olumsuz etkilendi. Finansal piyasalarda da dalgalanmalar yaşandı. Ayrıca, küresel GSYİH büyüme eğilimini analiz etmek için bol miktarda veri oluşturulmuş ve saklanmıştır. Veri seti, 2000'den 2019'a kadar G7, G8 ve G20 ekonomik bloğuna ait 20 ülkeyi içeriyor. Bu amaçla, ekonomik durumu tahmin etmek için makine öğreniminin (ML) kullanımı yaygın olarak benimseniyor. Bu makalede, uyarlanabilir güçlendirme (AdaBoost), Bayes sinir ağı (BNN) ve doğrusal regresyonun (LR) kombinasyonu, 2020'den 2039'a kadar küresel GSYİH'yı tahmin etmek için kullanılıyor. ML modellerinden elde edilen bulgular, salgının neden olduğu çok yönlü zorlukların anlaşılmasına katkıda bulunuyor , araştırmacıların, politika yapıcıların ve işletmelerin veriye dayalı karar almalarını sağlar.

**Anahtar Kelimeler:** Kovid-19, Uyarlanabilir Güçlendirme (AdaBoost), Bayesian Sinir Ağı (BNN), Doğrusal Regresyon (LR), Makine Öğrenimi.

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## ABBREVIATIONS

|          |   |                                  |
|----------|---|----------------------------------|
| %MAPE    | : | Percentage Mean Absolute Error   |
| Adaboost | : | Adaptive Boosting                |
| AI       | : | Artificial Intelligence          |
| DBN      | : | Deep Belief Network              |
| DQN      | : | Deep Q-Network                   |
| GDP      | : | Gross Domestic Product           |
| GRU      | : | Gated Recurrent Unit             |
| GTAP     | : | Global Trade Analysis Project    |
| ILO      | : | International Labor Organization |
| IMF      | : | International Monetary Funds     |
| LR       | : | Linear Regression                |
| MAE      | : | Mean Absolute Error              |
| ML       | : | Machine Learning                 |
| MSE      | : | Mean Square Error                |
| RMSE     | : | Root Mean Square Error           |
| TCN      | : | Temporal Convolution Network     |
| UK       | : | United Kingdom                   |

# 1. INTRODUCTION

As the COVID-19 pandemic broke, the year 2020 witnessed drastic global crisis affecting every facet of human life. Despite the fact that it has brought devastating impact on public health, the global economy has also observed severe decline during the pandemic period. Governments worldwide implemented a range of measures, from strict lockdowns to unprecedented economic recovery reforms, in order to curb the spread of the epidemic and mitigate economic downturns. This study embarks a comprehensive view of consequences of COVID-19 on a global economy, with a determined focus on employing machine learning (ML) models to forecast the future analysis of global economy in terms of gross domestic product (GDP).

## 1.1 BACKGROUND

Beyond its calamitous toll on public health, the pandemic's repercussions reverberated throughout the global economy, as shown in Figure 1.1. The abrupt contraction in economic activity, depicted by the sharp decline in GDP growth rates, is indicative of the profound economic challenges faced by nations worldwide. Among economies of developed countries, the debt to GDP ratio is shown to rise from 3.3% in 2019 to 14.4% in 2020; while ratio for the United States (US) is estimated to revolt from 6.3% to 18.7%, respectively, which is the highest ratio for any country or region across the globe. According to the International Monetary Funds (IMF), France, Germany, Italy, Japan, and the United Kingdom (UK) have each announced public sector support measures that total more than 10% of their annual GDP (IMF,2020).

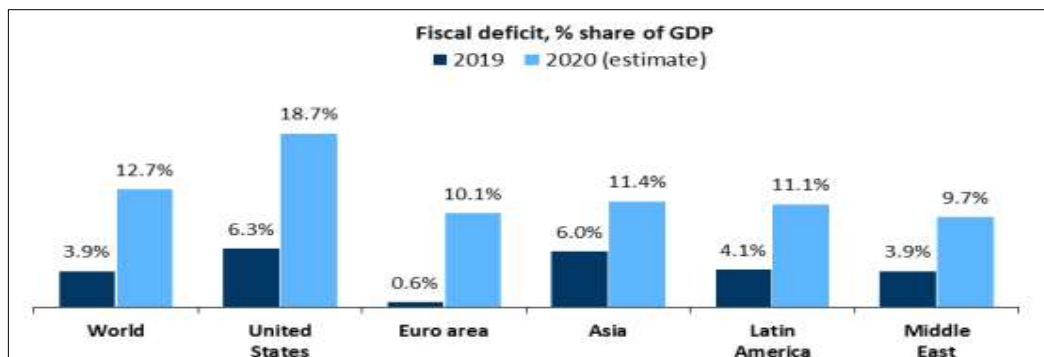


**Figure 1.1:** Global GDP Growth Rate over 2019-2020.

Source: Fiscal Monitor, International Monetary Fund (IMF), 2020.

In developing countries, the fiscal debt to GDP ratio is observed to revolt from 4.9% to 10.7%, substantially increasing their debt burden and raising prospects of debt rescheduling. The IMF warned that the debt levels in some developing countries might become too much to handle and could put pressure on their banks (IMF), 2020). This situation could lead to challenges such as defaults on debts or the need to reschedule debt payments (Debata, B., Patnaik, P. and Mishra, A., 2020).

In response to the economic turmoil, governments mobilized unprecedented fiscal responses, injecting trillions of dollars into their economies. These stimulus packages aimed to cushion the impact of business closures and job losses, preventing a more severe economic downturn. The complex connections in the world's economy went through a tough time, causing a lack of goods in different industries. This showed the way of setting up the supply chains was not very strong and was prone to weaknesses.

COVID-19 as a shock, had serious repercussions for the economy. In particular, the pandemic outbreak in early 2019, which was one of the worst global pandemics in recent years according to the records. It had a detrimental effect that was multi-faceted in nature, almost synchronized within and across countries, and had a fatal impact on the economy not only in the foreseeable weeks following the crisis but also over a long period of time span (Ludvigson et al., 2020).

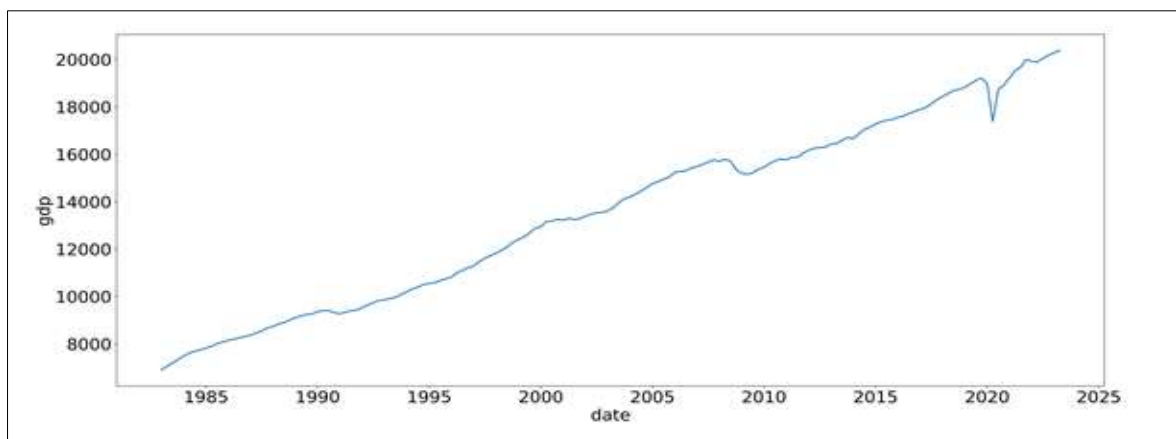


**Figure 1.2:** GDP of US Change over 40 Years.

Source: U.S. Bureau of economic analysis.

Nonetheless, it can be demonstrated from the Figure 1.2, there is a significant increase in the US economy in 2020, mainly due to the COVID-19 that had been hovering the world and its

economy since the beginning of the year, and its macroeconomic impact is greater than any disastrous event that had occurred since last 40 years.

Amidst this economic turbulence, the integration of advanced machine learning methods emerged as a beacon of insight into the intricacies of the crisis. Artificial Intelligence (AI) and ML algorithms have played a pivotal role in dissecting vast datasets related to COVID-19 and the global economy. These algorithms, by processing and recognizing patterns, have enabled a deeper understanding of the correlations between the pandemic and economic variables (Al-Maadid, A., Alhazbi, S. and Al-Thelaya, K., 2022).

As the pandemic strained global supply chains, depicted in Figure 1.3, machine learning algorithms have been instrumental in optimizing supply chain management. By identifying vulnerabilities and offering solutions, these technologies have proven invaluable in addressing shortages in various industries. Forecasting GDP is crucial for guiding economic policy, facilitating informed decision-making, managing risks, and promoting overall economic stability. It serves as a fundamental tool for stakeholders at various levels, from governments and businesses to investors and consumers. While in this research, different ML models have been chosen to forecast the global GDP on the basis of economy.

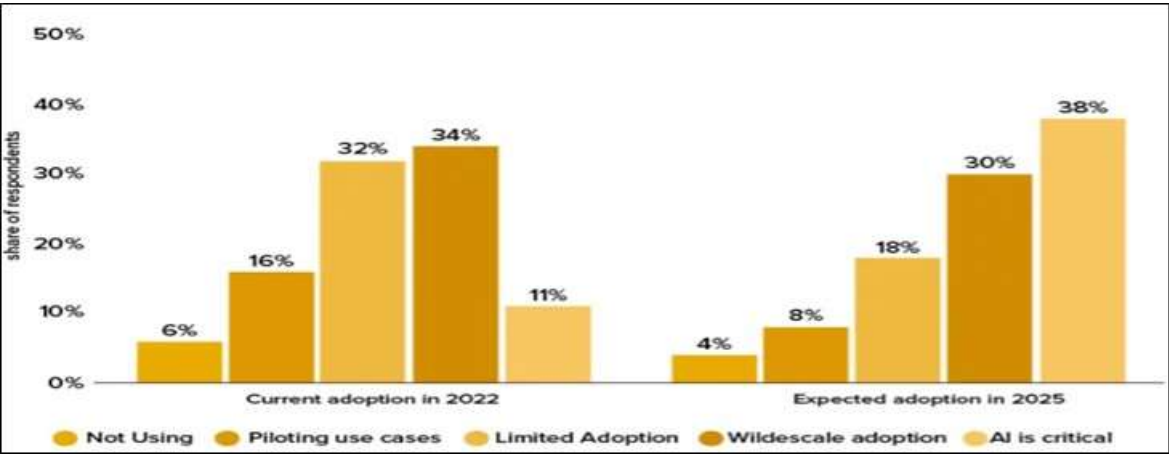


**Figure 1.3:** Machine Learning in Optimizing Global Supply Chain.

Source: Appinventiv. (2023) 'AI in Supply Chain Analytics: Revolutionizing Logistics and Operations', *Appinventiv*.

This dissertation seeks to advance the understanding of the pandemic's economic rectification and contribute valuable insights to the broader discourse on crisis management and resilience, through a comprehensive analysis of the impact pandemic on global

economics and the application of ensemble machine learning techniques to GDP forecasting. This research aims to equip policymakers, economists, and businesses with the tools and knowledge needed to navigate the turbulent waters of the post-pandemic world and build a more resilient and sustainable future, by shedding light on the intricate dynamics at play and providing evidence-based forecasts.

## **1.2 PROBLEM STATEMENT**

The pandemic has brought significant disruptions across the global economy, leading to economic recessions, supply chain breakdowns, and heightened uncertainties. Understanding the dynamic relationships between the pandemic and economic variables is critical for effective policymaking, risk management, and strategic decision-making. While traditional economic analyses provide valuable insights, the complexity and scale of the challenges demand advanced methodologies. This dissertation aims to address the few problems. Firstly, the need for a comprehensive review of the multifaceted impact of the COVID-19 on the global economy. Secondly, the role of machine learning methods in processing vast and diverse datasets related to COVID-19 and economic indicators, and lastly the potential of machine learning to offer nuanced insights, predictions, and solutions for navigating the challenges posed by the ongoing crisis. The overarching goal is to contribute to have a keen understanding of the pandemic's economic repercussions and leverage machine learning as a powerful tool for generating actionable insights in the face of unprecedented global challenges.

The COVID-19 pandemic has witnessed unprecedented challenges for the global economy, disrupting supply chains, decimating industries, and triggering widespread uncertainty. In line with these complexities, accurately forecasting Gross Domestic Product (GDP) has become increasingly critical for policymakers, economists, and businesses seeking to navigate the turbulent economic landscape. However, traditional forecasting methods often fall short in capturing the dynamic and nonlinear relationships between pandemic-related variables and economic indicators. Furthermore, there is a pressing need for advanced forecasting techniques that can effectively model the intricate interplay between COVID-19 dynamics and global economic performance. This research aims to address this gap by leveraging an ensemble of machine learning models to forecast GDP amidst the complexities

of the COVID-19 pandemic, providing valuable perspective for informed decision-making and strategic planning amid uncertain circumstances and events.

### **1.3 OBJECTIVES OF THE RESEARCH**

The objectives of this study is to use ML approaches to o conduct an analysis of the effect of the COVID-19 pandemic on the global economy. The objectives are listed below:

- a. To process and analyze diverse datasets related to COVID-19, incorporating infection rates, mortality rates, government responses, and economic indicators.
- b. To apply machine learning algorithms for data processing to identify correlations and trends in the complex reciprocity between the pandemic and economic variables.
- c. To employ predictive modeling techniques, including AdaBoost, BNN and LR to forecast economic trends.
- d. To evaluate the performance of ML models by the means of quantifying measures.

### **1.4 SIGNIFICANCE OF THE STUDY**

The significance of this research lies in its contribution to a comprehensive understanding and analysis of the intricate relationship between the COVID-19 and the global economy, employing cutting-edge machine learning methods. By addressing the research objectives, this research aims to provide valuable insights for researchers, policymakers, and businesses navigating the challenges posed by COVID-19.

This study makes a benchmark for researchers, policymakers, and businesses who are trying to figure out how to deal with the challenges caused by the ongoing crisis. The aim is to discover really important information that can help people make smart decisions and plan for the future, even when things are tough. Basically, it's all about finding useful answers that can help everyone, no matter what field they're in, make better choices during difficult events such as COVID-19.

### **1.5 ORGANIZATION OF THE THESIS**

The thesis is organized into 5 chapters. Below is the browsing list of chapters:

- a. Chapter 1 contains the introduction and the problem statement with aims and objective.

- b. Chapter 2 reviews relevant literature on the historical context of pandemics, economic impacts, and the role of machine learning in economic analysis.
- c. Chapter 3 outlines the methodology, detailing data collection, machine learning algorithms and techniques, ethical considerations, and limitations.
- d. Chapter 4 discusses the findings, comparing them with previous studies and exploring their implications, challenges, and opportunities.
- e. Chapter 5 provides comparison of input and forecasted GDP. It also discussed the effects on economic indicators, sectoral impact (tourism, healthcare, manufacturing etc.) and policy implications due to anti-COVID-19 measures.
- f. Chapter 6 provides conclusion and offers recommendations for future research.

## 2. LITERATURE REVIEW

This chapter presents the literature review of key studies and trends in the convergence of the COVID-19 pandemic, global economy, and implementation of machine learning models. It establishes a foundation for the proposed dissertation, emphasizing the need to leverage advanced methodologies to address the unique challenges held after the pandemic.

Traditional economic analyses have been very important in understanding the impact of various global and regional events on the economy. However, the multifaceted and complex nature of the COVID-19 pandemic has revealed limitations in traditional models. The study by Shiroy in 2021 highlighted the challenges in accurately predicting economic outcomes, given the dynamic and interconnected nature of the crisis (Shiroy, A.A., 2021). On other hand, the study also showed the dynamic turnover of growth rate during pandemic period as shown in Figure 2.1.

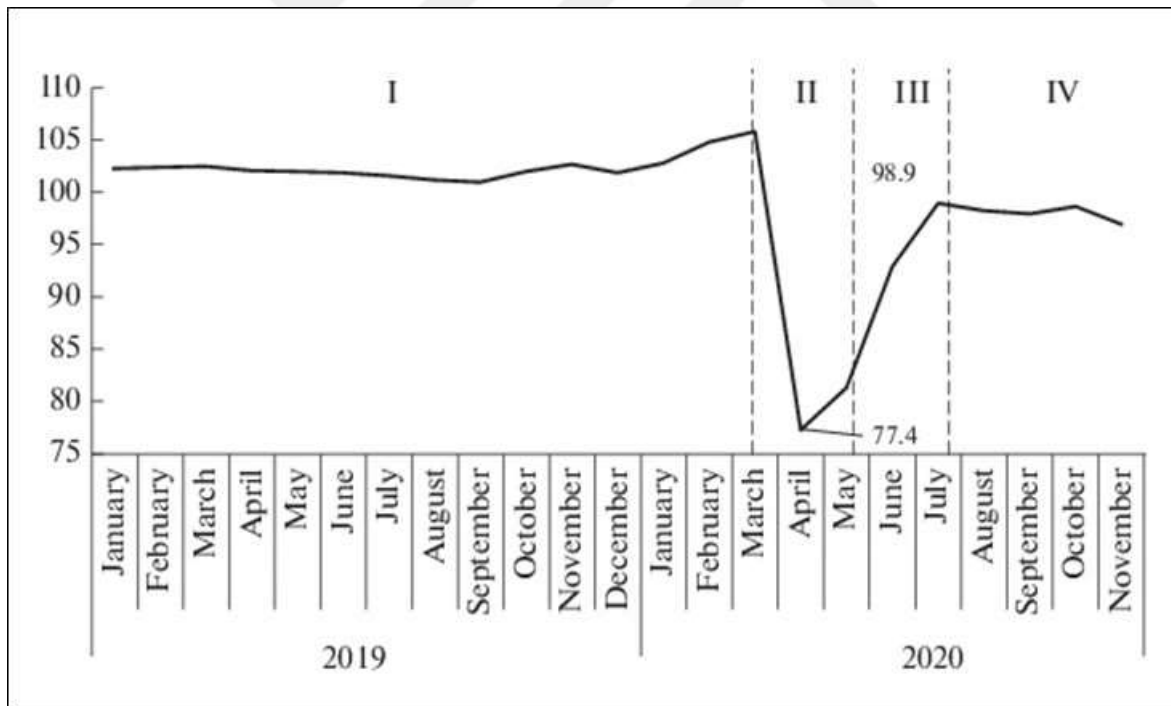


**Figure 2.1:** Viral Turnover in Growth Rate during Pandemic Period.

Furthermore, a comparative survey was conducted on the economics of COVID-19 in 2021. The authors stated that his survey which initially provides an overview of the data sets and the techniques uses to measure social distancing and COVID-19 cases and deaths. Secondly, it reviews the literature on the determinants of compliance with and the effectiveness of

social distancing. At third, it mentions the macroeconomic and financial impacts including the modelling of valid mechanisms. At fourth, it summarizes the literature on the socioeconomic consequences of the global pandemic, focusing on those aspects related to labour, health, gender, discrimination, and the environment; and lastly sums up the literature on public policy responses (Brodeur, A et al, 2021).

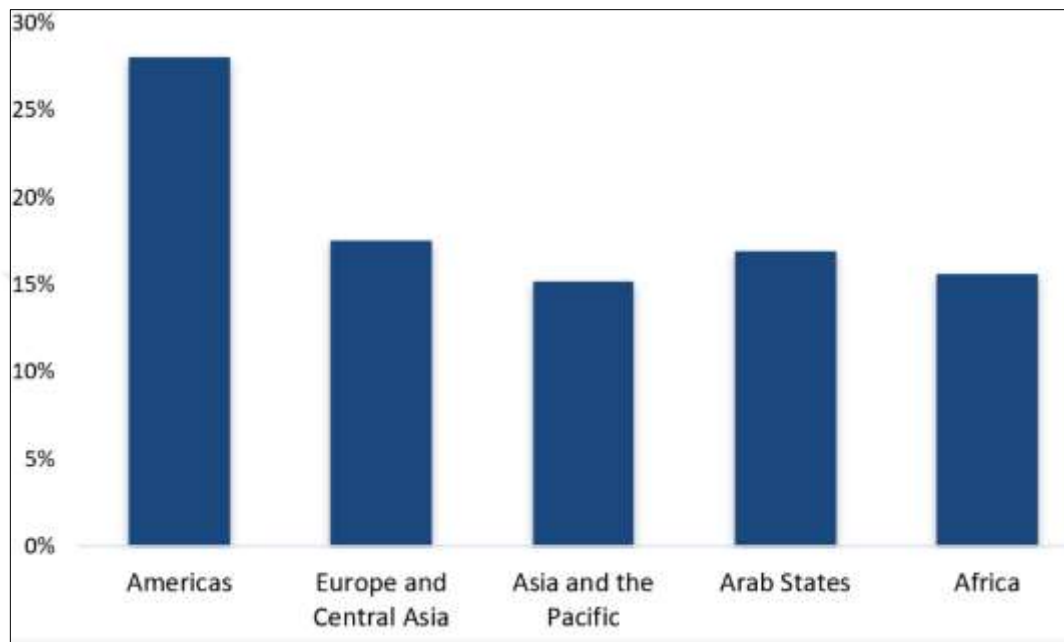


**Figure 2.2:** Decrease in Working Hours, Second Quarter 2020.

Source: Clemente-Suárez, V.J et al, 2021.

Moreover, according to Figure 5, the job losses across the globe were estimated to be 495 million in the second quarter of 2020, a substantially larger decline than the 195 million estimated in April for the same quarter, projecting the worsening situation in many parts of the world. According to the last International Labour Organization (ILO) Monitor (2020), 94% of the world's workers are currently facing a workplace closure measure in their countries or a reduction in their working hours (Clemente-Suárez, V.J et al, 2021).

## **2.1 LITERATURE REVIEW ON ECONOMIC ANALYSIS DURING THE COVID-19 PANDEMIC**

The pandemic's effect on global trade and supply chains has been a central focus of economic analyses. Study by Karmaker, C.L, et al in 2023 delve into the disruptions faced by industries heavily reliant on international supply networks. These disruptions have triggered a

reassessment of global trade dynamics and supply chain resilience (Karmaker, C.L, et al, 2023).

Higher bodies and governments worldwide implemented diverse fiscal and monetary policies to decrease the economic fallout from the pandemic. In 2022, study came out to assess the effectiveness of stimulus packages, interest rate adjustments, and other policy interventions in stabilizing economies, preventing widespread bankruptcies, and supporting employment (Dergiades, T, et al, 2022). While on the other side, the pandemic-induced economic downturn led to significant shifts in labor markets globally. It has been observed that unprecedented levels of unemployment, changes in remote work dynamics, and the implications of these shifts on income inequality and social stability.

Different economic sectors experienced varying impacts during the pandemic. In 2022, the study was conducted to analyze the economic impact of the COVID-19 crisis on Korea and other major nations using the standard Global Trade Analysis Project (GTAP) model. According to the GTAP database, the researchers created three different cases that differed in the severity of the impact of global pandemic, divided the economic shocks witnessed in each scenario into three stages, and applied them at varying degrees to six regions and 10 industry sectors. This comprehensive analysis contributes to make a keen understanding of the pandemic's economic repercussions (Choi, Y., Kim, H.J. and Lee, Y., 2022).

The economic strain caused by the pandemic has raised concerns about international debt levels in 2020, this research was conducted to develop a point of view based on socio-economic, governance and institutional factors and policy. Under the dynamic econometric assessment for the last two decades as per author's analysis, economic growth, interest rate, mortality rate, unemployment rate, government regularities and the last sovereign debt crisis have resulted as being the major determinants of its evolution. It highlights the highest potential for financial instability (Briceño, H.R. and Perote, J., 2020).

there are a number of studies which observes the adverse impact of COVID-19 on both global and national economies. According to Di Mauro, B.W., (2020), the pandemic has activated an unparalleled economic distress, leading to serious contraction in GDP, decline in unemployment rates, and disruptions in trade and supply chains on global scale. These

impacts were felt more acutely in countries with high levels of international trade and also tourism and manufactures were affected as well (Di Mauro, B.W., 2020).

Research has also shed light on the impact of the pandemic globally. For instance, study by Fernandes, N, (2020) highlights how main industries i.e. tourism, hospitality, and retail market has experienced significant

economic stress, while on the other hand, technology and healthcare were on increasing demand. These variations have deep rooted impact on almost every sector and experienced shock form the pandemic (Fernandes, N., 2020).

As discussed above from the previous study that healthcare industry has gained much attention during pandemic. It is observed by the researchers that economic outcome and healthcare industry has been proportional to each other and are critical to analyse. In 2020, Cutler, D. M focuses attention on the importance of public health and its preventive measure to control the viruses, Contrary to it, the economic recovery was bit hard to facilitate. The cost of healthcare services, vaccine, medical logistics and long-term check-ups have been centre of attention (Cutler, D.M., 2022).

The aforementioned review provides insights into the diverse areas of economic analysis during the pandemic. Each research contributes to a comprehensive understanding of the multifaceted economic challenges posed by the global health crisis.

## **2.2 LITERATURE REVIEW ON ROLE OF MACHINE LEARNING IN ECONOMIC ANALYSIS**

The adoption of machine learning approaches to the economic analysis has opened avenues for researches and analyst. Researchers have introduced the potential of ML algorithms in processing large datasets, identifying patterns, and providing real-time optimization, revolutionizing traditional economic modeling.

Machine learning models have significantly demonstrated efficacy in predictive modeling and forecasting economic indicators. In 2020, Ramirez and Soto showcase how ML algorithms, including neural networks and ensemble methods, outperform traditional models in predicting GDP growth, inflation rates, and other critical economic variables (Ramírez, K.M., Hormaza, J.M. and Soto, S.V., 2020).

The ability of machine learning to process vast amounts of real-time data is a significant asset in economic analysis. An empirical study carried out to evaluate and analyze Internet of Things (IoT) sensing networks, artificial intelligence-based decision-making algorithms, and real-time process monitoring in sustainable Industry 4.0. The study observed and estimated the interconnected data processing in smart manufacturing and business analytics (Nica, E. and Stehel, V., 2021).

While on the other side, disturbance in global supply chain during the pandemic have given place to ML for optimization of the process of supply chain. ML approaches have identified the vulnerabilities and offered solution to enhance supply chain resilience. A study was hold in 2021 by Nagurney for optimizing supply chain network with inclusion of labor by using ML. The supply chain network framework, which includes e-commerce, is relevant to many different supply chain applications including protective personal and medical equipment (Nagurney, A., 2021).

In a broader perspective, economics policies primarily concern itself with comprehending specific social phenomena, emphasizing causal hypothesis to make connections between causes and its effects. In addition, economics is keenly interested in factual forecasting, which involves considering various potential states of reality by amending cases or model parameters. Moreover, in contrast, ML predominantly focuses on predictive tasks, without explicitly addressing causal relationships between chosen variables. Thus, it is easy to keep differences between economics and computational sciences (Hansen, 2018). Importantly, classic economic inquiries, including human decision making, market institutions or the nature of company, often pose challenges beyond the capabilities of machine learning techniques to address adequately. They need convincing interpretations rather than precise calculations with restricted meaning (Backhouse, 2011). To be valid, ML models and algorithms taken off-the-shelf are by and large inappropriate for economists working with this motivation in mind as they typically produce outcomes of a distinct nature when contrasted with the economists' expectations.

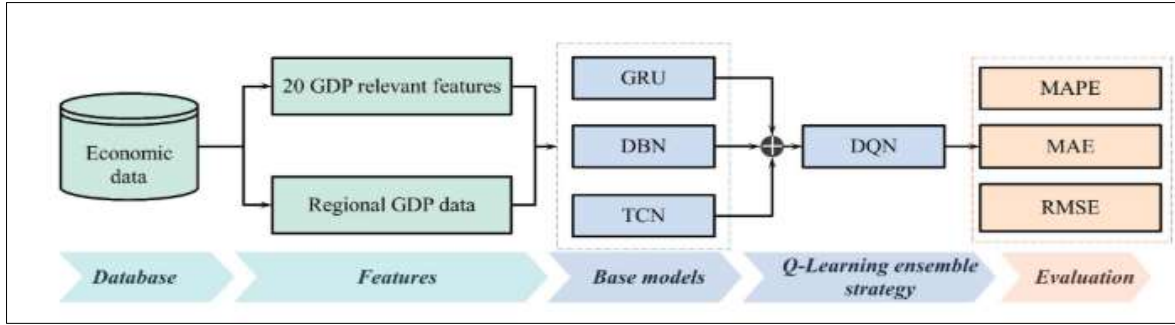


**Figure 2.3:** Layout for Multi-predictor Ensemble Decision Framework Based on Deep Learning for Regional GDP Predictions.

Source: Li, Q., et al, 2022.

Figure 2.3 illustrates the multi-predictor ensemble decision framework for regional GDP prediction. The study has a great potential to combat the issues which arises after the COVID-19 effecting the economy. This study presents a deep network ensemble model based on DQN. GRU, DBN, and TCN are used as base models to observe the preliminary prediction of regional GDP of different regions. DQN was adopted first to optimize the model ensemble process. The layout for the propose model is displayed in Figure 6. Firstly, the economic data are analysed and 20 GDP-relevant features are extracted. Then, GRU, DBN, and TCN are adopted to study the deep relationship between features and GDP and achieve preliminary prediction results. Conclusively, DQN is modified to realize the combination of the results given by the base models and provide a more accurate GDP forecasting result.

It has been observed in recent researches that ML techniques has created a positive impact in economic forecasting and help to make suitable policies during the pandemic. Research by López de Prado, M., 2022 illustrates that how ML and DL can handle complex econometric models and removes utmost errors. The author also emphasizes that ML model can also forecast GDP, rate of unemployment and other associated variables and provide aid to policymakers (López de Prado, M., 2022).

While in 2023, a review survey is conducted on machine learning approaches on economy. The main purpose of this research is to explore how machine learning can be used. The research focuses on 1) when ML was used? 2) What kind of ML models can be employed? 3) and how they are used in economic analysis? This review study also highlights the key aspects of usage of different data set with ML approaches. The complex nature of

econometric models creates volatility, for that sake ML approaches works effortlessly to econometric toolboxes (Desai, A., 2023).

## 2.3 SUMMARY

Table 1 demonstrates the literature review matrix which encompasses the recent past studies in global economy with strengths and limitations. As the domain progresses, challenges persist, including model interpretability and data privacy concerns. The authors also highlight these issues and suggest future research directions, such as refining algorithms, addressing ethical considerations, and further integrating machine learning into mainstream economic analyses. Overall, the literature review underscores the multifaceted role of machine learning in shaping the landscape of economic analysis, offering insights, predictions, and solutions across diverse domains.

**Table 2.1:** Literature Review Matrix.

| <b>Author(s) and Year</b>  | <b>Research</b>                                                                              | <b>Strength</b>                                                                                                                                  | <b>Limitations</b>                                                                   |
|----------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Shirov, A.A., 2021         | The Pandemic Crisis as a Challenge for Economic Analysis and Policy.                         | To changes in the epidemiological situations are considered.                                                                                     | Solutions are not provided.                                                          |
| Karmaker, C.L, et al, 2023 | Industry 5.0 challenges for post-pandemic supply chain sustainability in an emerging economy | To understand the challenges of implementing I5.0 when managing the impact of SC disruptions due to the COVID-19 pandemic in an emerging economy | Existing supply chain strategies are inadequate for coping with risks of disruption. |

**Table 2.1:** Literature Review Matrix “Table Continued”.

|                                                   |                                                                                                    |                                                                                                                                                                                                                     |                                                                                       |
|---------------------------------------------------|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Choi, Y., Kim, H.J. and Lee, Y., 2022             | Economic consequences of the COVID-19 pandemic: will it be a barrier to achieving sustainability?  | The results revealed an increase in investments and a decrease in GDP, income, production, and exports, with private household expenditure and export value showing the largest declines in all regions.            | As a comparative static model, it is difficult to estimate economic impacts over time |
| Briceño, H.R. and Perote, J., 2020                | Determinants of the public debt in the Eurozone and its sustainability amid the COVID-19 pandemic. | Substantial reforms in European pension and unemployment insurance systems are necessary conditions to ensure public debt sustainability amid COVID-19 pandemic.                                                    | None.                                                                                 |
| Ramírez, K.M., Hormaza, J.M. and Soto, S.V., 2020 | Artificial intelligence and its impact on the prediction of economic indicators.                   | The approach of the research questions allowed to describe the outcomes in categories where the studies by predicted economic indicator and applied artificial intelligence method have been successfully included. | Limitation of dataset.                                                                |

**Table 2.1:** Literature Review Matrix “Table Continued”.

|                               |                                                                                                                                                             |                                                                                                                                                                                                                            |                                                  |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| Nica, E. and Stehel, V., 2021 | Internet of things sensing networks, artificial intelligence-based decision-making algorithms, and real-time process monitoring in sustainable industry 4.0 | To evaluate and analyze Internet of Things sensing networks, artificial intelligence-based decision-making algorithms, and real-time process monitoring in sustainable Industry 4.0                                        | Outliers in complied data.                       |
| Nagurney, A., 2021            | Optimization of supply chain networks with inclusion of labor: Applications to COVID-19 pandemic disruptions.                                               | The modeling framework considers first elastic demands for a product and then fixed demands, coupled with distinct types of labor capacities in order to capture the availability of this valuable resource in a pandemic. | Computational errors.                            |
| Fernandes, N., 2020           | Economic Effects of Coronavirus Outbreak (COVID-19) on the World Economy                                                                                    | The study provided estimation of the potential global economic costs of COVID-19, and the effect on GDP growth of different countries.                                                                                     | Limited data set to make comprehensive analysis. |
| Cutler, D.M., 2022            | The Economic Cost of Long COVID-19: An Update.                                                                                                              | Relationship between healthcare and economy.                                                                                                                                                                               | More economic analysis must have been done.      |

**Table 2.1:** Literature Review Matrix “Table Continued”.

|                          |                                                             |                                                                                       |                                             |
|--------------------------|-------------------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------|
| López de Prado, M., 2022 | Machine Learning for Econometricians: The Readme Manual.    | The study’s aim is to facilitate the adoption of ML techniques among econometricians. | Issue in transparency of econometric model. |
| Desai, A., 2023          | Machine Learning for Economics Research: When What and How? | Detailed review study on usage of ML models in econometrics.                          | Data compilation methods.                   |

### **3. METHODOLOGY**

This section reveals the proposed methodology of the study which demonstrates the stages of forecasting the global GDP countries effected during the COVID-19 pandemic. The proposed schematics has adopted a combination of different machine learning algorithms i.e. AdaBoost, BNN and LR. On the basis of forecasting the global GDP with ML techniques to provide comprehensive economic analysis during the COVID-19 pandemic.

#### **3.1 DATA COLLECTION**

By collecting data from authentic sources, this research ensures a robust foundation for subsequent machine learning analyses. The combination of economic indicators enables a comprehensive understanding of the economic landscape during the pandemic, incorporating quantitative dimension.

##### **3.1.1 Chosen Variables**

The list of the chosen variables are listed below:

- a. GNI per Capita (Current International)
- b. Carbon Dioxide Emission (metric ton per capita)
- c. GDP (Current US \$)
- d. GDP Growth Annual
- e. Inflation, GDP deflator
- f. Foreign Direct Investment, net flow (Current US \$)

GNI per capita, GDP, and GDP growth annual are key indicators of economic performance, while carbon dioxide emissions and inflation reflect environmental and economic factors that can be impacted by the COVID-19 pandemic. Due to the unavailability of the data set, it was crucial to conduct the analysis with limited variables. For that sake, FDI was chosen as one of the variables as it creates a relationship with the economy globally.

By using these variables in the context of the COVID-19 pandemic using combination of machine learning models, this research has brought the potential to uncover valuable insights

into the complex interactions between economic and environmental factors during times of crisis. The relationship of GDP among chosen variables is one of the concrete ways to choose a ML model. The Table 2 illustrates the relationship among each other.

**Table 3.1:** The Relationship of GDP Among all Chosen Variables.

| Variables                              | Relationship with GDP                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| GDP                                    | The total sum of money produced within the boundaries of a country over a certain time period is recognized as the Gross Domestic Product or GDP. It functions as the primary indicator of economic expansion and prosperity                                                                                                                                                                                      |
| GNI per capita                         | Gross national income (GNI) per capita is a gauge of the financial condition of a country which reflects the average amount of income that people in that nation generate. GDP is positively impacted by rising rates of Investments consumptions and total economic expansion that are usually considered with the higher GNI per capita                                                                         |
| Carbon Dioxide (metric ton per capita) | The overall quantity of carbon dioxide generated or released by the people living in a nation is calculated by its carbon dioxide emission per capita. Excessive or a large amount of emissions can lead to damage or degradation of the environment changes in climate and economic interruptions ultimately impaired GDP growth even though carbon dioxide might indicate industrialization and economic growth |

**Table 3.1:** The Relationship of GDP Among all Chosen Variables “Table Continued”.

|                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Inflation, GDP deflator | The rate at which the average cost products and services increases or grows over time is referred to as inflation. A moderate amount of inflation can boost the economy by encouraging and boosting investment and consumption. On the contrary, volatile and uncertain inflation rates may undermine consumers trust, decreasing purchasing power and disrupt the financial stability and the equilibrium of the economy, all of which have adverse and detrimental effect on GDP growth.                                        |
| FDI (current US\$)      | Investments made in the domestic markets by foreign entries are commonly referred to as foreign direct investment or FDI. Inflows of FDI can accelerate GDP growth by facilitating trade and development in industrial sector, providing or contributing more capital funds for investments, and transferring skills and technology. FDI impact on GDP is reliance and sensitive due to a number of variables including the level of quality of the investment, the host Nations regularity framework and its absorbent capacity. |

### 3.2 SAMPLED COUNTRIES AND DATA-SET

The chosen countries span multiple regions across the globe, including Asia (India, Bangladesh, and Singapore), Europe (Germany, Italy, Denmark, and UK), North America (US), Oceania (Australia), and the Middle East (Saudi Arabia, UAE). This geographical diversity ensures a comprehensive representation of global economic dynamics and allows for cross-regional comparisons. Additionally, the selected countries exhibit a wide range of economic characteristics, from advanced economies (US, UK, Germany) to emerging markets (India, Bangladesh, Turkey) and oil-rich nations (Saudi Arabia, UAE). By analysing

countries with diverse economic structures and development levels, this study can capture the heterogeneity in the impact of COVID-19 on different types of economies.

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Moreover, the chosen countries represent world's two major economic blocks and its very pertinent to compare the future growth of these two blocks after the COVID-19 shock. Further, the countries in these blocks represent almost every region of the world, studying the effect of the COVID-19 shock may very well help us anticipate and understand the trends of the overall world economic growth. Further, COVID-19 outbreaked in China and China was among the first to get affected and recovered from this shock. China is also member of G20 block and the intensity of impact was not felt by small economies that much the way it was felt by the big economies of the world like US, UK, Australia, Germany, China, India, Russia etc. Therefore, if we forecast by selecting G20, G7 and G8 countries and their response / measures to COVID-19, we can have bigger representative sample of such countries, whose growth/ GDP before and after COVID-19 may have been much affected due to their independent and unique mitigation strategies and policies of every country which is apparently different from each other, but was a result of a common resolve to avert and avoid COVID-19 exposure and after-shocks on the economic growth. The data used for the purpose of study spans for 20 years starting from the year 2000 to 2019.

While the list of the chosen countries is also listed below and shown in Table 3.2.

**Table 3.2:** The Countries from Different Economic Blocks Used for this study.

| Country   | Region (G7/G8/G20) | Country | Region (G7/G8/G20) |
|-----------|--------------------|---------|--------------------|
| Australia | G20                | Brazil  | G20                |
| Canada    | G7,G8,G20          | China   | G20                |
| France    | G7,G8,G20          | India   | G20                |

**Table 3.2:** The Countries from Different Economic Blocks Used for this study “Table Continued”.

|                    |             |              |     |
|--------------------|-------------|--------------|-----|
| Germany            | G7, G8, G20 | Indonesia    | G20 |
| Italy              | G7,G8,G20   | Mexico       | G20 |
| Japan              | G7,G8,G20   | Saudi Arabia | G20 |
| United Kingdom     | G7, G8, G20 | South Africa | G20 |
| United States      | G7,G8,G20   | South Korea  | G20 |
| Russian Federation | G8,G20      | Turkey       | G20 |
| Argentina          | G20         | Brazil       | G20 |

Source: World Bank, World Development Indicator.

### 3.3 RELATIONSHIP OF GDP WITH CHOSEN VARIABLES

In this section, the chosen variables are discussed briefly with respect to the GDP (US\$). They have been discussed in a keen manner to explain a relationship with GDP (US\$).

#### 3.3.1 Impact of GNI Per Capita, PPP on GDP

By comparing the GDP data for the G7/G8 and G20 countries with GNI per capita adjusted by Purchasing Power Parity, an articulate relationship between the levels of income and economic performance is revealed (Brandusoiu, I. C.et al., 2010).

The gross national income which is adjusted by purchasing power parity (PPP), considers the differences in the cost of living between countries that represents average income of people living in a nation. These figures have huge impact on choices of investment, consumers’ disbursements trends and overall economic bustle, which all will contribute to the GDP (Ahmad, S. et al., 2003).

Moreover, as foreign investors are attracted to the countries with higher income because it is perceived that the countries with higher income have stability and profitability in their markets. This concept has a huge influence on investment decisions. This influx support of

foreign capital may increase productivity, advancement in technology and capital formation to help grow GDP (Amirahmadi, H., & Wu, W., 1994).

Conclusively, a higher GNI per capita that is adjusted by Purchasing Power Parity (PPP) shows that a nation's boosted economic prosperity and purchasing power that is supporting the investment economic growth and consumption ultimately have a positive impact on GDP.

### **3.3.2 Impact of Carbon Dioxide Emission (Metric Ton Per Capita) on GDP**

The amount of carbon dioxide emitted by each person is one of the essential environmental pointers that indicate a nation's degree of industrial development, consumption of energy and sustainability of environment. By studying fastidiously through the connection between the economic activity and environmental depreciations is of key importance to comprehend how carbon dioxide emissions can affect the GDP growth (Wang, J., Usman, M. et al., 2023).

Initially, it is observed that there is a positive relation between the GDP and carbon dioxide emissions per capita, particularly in struggling nations that are industrializing rapidly. Consumption of energy increases in tandem with GDP, and burning of fossil fuels is a very known and common way to meet this need and to contribute in carbon dioxide emissions. In developing Nations, the production of electricity, industrial operation, and transportation (all are greatly increasing carbon dioxide emission) depends mostly on heavy industry and coal fired power plants (Li, H., Li, B., & Lu, H. et al., 2017).

However, with the development of economies and awareness of environmental issues within the public rises the similar relationship between GDP and carbon dioxide mission might become more complex and nuanced. The uses of renewable energy and efficiency in energy measures and use of advanced technology may help separate GDP growth and carbon dioxide mission. For example, by investing in infrastructures of clean energy and maintainable practices may help reduce the emission while also promoting the growth of economy (Dar, A. A., Hameed, J., Huo, et al., 2022).

Furthermore, the excessive emission of carbon dioxide can have harmful and negative effects on the environment. This excessive emission may result in air pollution, climate change, dilapidation of ecosystem; all of these are hazardous and harmful for human health and stability of economy. The ever changing and unpredictable patterns of weather, diminishing

of agriculture yields, and expenses that are related to health linked to pollution can obstruct economic expansion and also encumber permanent opulence (Ramanathan, R., 2006).

The policies that are developed for the regulation requirements and are designed to reduce carbon dioxide emission, carbon pricing and emissions trading may also affect the link between the carbon dioxide emissions and GDP. Initially these policies may foist cost on industries, but in the long term these regulations may encourage enhancement of investments in technology, innovation can be fortified and increase in productivity can also be achieved. A low-carbon economy can also lift springiness to hazards linked and related with ever changing climate, might spawn novel job opportunities and upsurge and escalate public health. All of these aspects can upkeep this ecological growth of economy (Gani, A., 2012).

To summarize this up, it is noticed that the relation between the GDP and carbon dioxide emission per capita is multifarious and vibrant. The emission of carbon dioxide may eventually reach a point where environmental concerns may require decoupling of CO<sub>2</sub> emission from GDP growth, although they are primarily linked. Operational jurisdictive intrusions and involvement, and ecological practices are vital and vigorous to make this modification towards a new prosperous future and technological innovation.

### **3.3.3 Impact of Annual GDP on GDP**

The yearly increase in Gross Domestic Product is one of the most crucial, vital, and important measures of economic success and prosperity, which is typically stated as the percentage change in a nation's GDP over a year. To understand comprehensively, how the annual GDP affects the GDP itself, one must study on how changes in economic activity is affecting the overall production and national income.

The vigorous and robust growth of GDP is indicating the rise in expansion of economic activities and earnings productions. Resultantly, the increase in GDP depends on the higher-level of Investments, government spending and consumptions. This indicates that there is a direct proportional relation between the annual GDP and the GDP. For example, if the GDP of a nation grows at the rate of 5% every year then the GDP should grow by 5% as well (Kuznets, S., 1971).

This direct relation on the other hand also indicates that at the times of slow GDP growth or negative GDP growth may impede the annual GDP growth. The reduction in economic

output and the decline of confidence in consumers and industrial sector and falling of earnings are the common outcomes of economic impedance, recessions are contractions. Consequently, GDP can or may experience a stagnation and general slowdown in economic activity. For instance, during the financial crisis around the globe in 2008-2009, many nations experienced negative GDP growth rates which cost their GDP estimates to decrease (Frankel, J., & Saravelos, G., 2012).

Furthermore, the annual GDP growth is affected by the number of variables including external shocks monetary and fiscal policy changes in structure of economy and state of the world economy. Initiatives, taken by the government, such as monetary easing, infrastructure spending, and tax cuts can help in expansion of GDP, which ultimately are meant to stimulate economic growth. In the same way any commerce, technical, and demographic developments, happened internationally, which are in the favour of a nation can facilitate annual GDP growth (Aisyah, S., Suarmanayasa et al., 2024).

It is very important to keep in mind that there isn't always a linear relationship between the GDP annual and the GDP. This relationship is highly impacted by uncertainties of policy, structural bottlenecks and lag effects. Moreover, the sustainability, inclusivity and environmental impact of growth are factors that must be considered while assessing the trajectory of annual GDP (Khan, N., & Naushad, M., 2020).

### **3.3.4 Impact of Inflation, GDP Deflator on GDP**

To understand the impact of inflation on GDP, as determined by the GDP deflator, requires complete and comprehensive understanding of the dynamics of economic growth and stability. The GDP deflator also known as a pricing indicator tracks down the shift in level of prices generated over time. Following are some points that explain how GDP is impacted by inflation:

At first, it is observed that GDP growth and economic activity of a nation might be boosted by moderate inflation rates. A continual price increase may be able to encourage firms to invest and consumers to spend, that will raise demand and production. This will affect beneficially on GDP as it will deflate to a requisite change in economy where earnings and profits are preserved by purchasing power and consumer confidence to keep up with inflation.

But erratic or high rates of inflation may be detrimental to GDP. Acceleration in inflation after or beyond a certain threshold causes a depression to real earnings, loss of buying powers and skew economic judgment. Test press behaviour of customers may postpone purchases and companies might be reluctant to make investments that will be leading to a decline in consumption and production. Resultantly, these stagnations in economic activity hinders GDP growth or it may even stop.

Furthermore, inefficiency is caused by inflation and social unrest by upsetting the wealth distribution and resources. Increasing interest rates to tighten monetary policy in response to high inflation rates might further stifle economic growth and it will also limit consumer and company access to credit. For the reduction of inflationary pressures, strict monetary policy may result in short term slow growth of GDP.

It is important to know that the factors such as fiscal and monetary policy responses to the structure of the economy and external shocks are different across the country's overtime, so the impact of inflation on GDP may also vary. For instance, if a country's economic structure has a high level of external debt, it may be particularly vulnerable to inflation pressure because of the capital flight and exchange rate depreciation.

Conclusively, where moderate inflation may be able to support GDP growth by stimulating demand and investment, on the other hand a very erratic and volatile inflation rates put obstacles in the performance of economy and its stability. Management of inflation crushers by using strong fiscal and monetary policies is of key importance for promotion of sustainable growth of the economy.

### **3.3.5 Impact of Foreign Direct Investment, Net Flow (Current US \$) on GDP**

Foreign direct investment (FDI) is of great influence on a country's economic environment along with the GDP being one of the major factors. Foreign direct investment is referred for investment that are made or invested by foreign companies in the economy. These foreign investments can impact GDP growth directly or indirectly (Lipsey, R. E., 2003).

Furthermore, it is perceived that FDI may emanate advanced technology, expertise in managerial sector and it may also provide access to global markets. These benefits provided by FDI can help enhance and increase efficiency in productivity and competitiveness in domestic industries, which will be leading towards the GDP growth. For example, a

multinational company may introduce new techniques of production or may be able to introduce new and innovative products which can accelerate growth and expansion in the concerning sectors of economy (Dunning, J. H., & Lundan, S. M., 2008).

Additionally, the contribution of foreign direct investment in the growth of export of a country will help in boosting or accelerating the GDP by increasing the trade activity. For instance, foreign investors may provide an opportunity that is export-oriented or the investor may benefit in expanding the existing export to capitalize on the proportional advantages in the host country. This will help the host country to achieve higher export revenues and favourable values of trade that will contribute to the growth of GDP (Pelinescu, E., & Radulescu, M., 2009).

But it can be observed that FDI does not have same impact on GDP in various nations and industries. FDI's ability and effectiveness in driving and propelling GDP growth is contingent and dependent on various factors. The factors main include institutional quality development in infrastructure regulation of the framework and absorbed capability of a nation. Moreover, they could be negative effects from FDI influence these negative impacts main road and equal distribution of benefits displacement of domestic investment and increase susceptibility to shocks from the outside world (Petrova, E., 2013).

Conclusively, by stimulating investment, raising production and making trade easy, FDI can have a major significant and important effect on GDP. To optimize FDI beneficial benefits on growth and development of the economy, supportive policy development of infrastructure and capacity building institutions are necessary to realize the full potential of FDI. It is reported by the World Bank that a total of 1.38 trillion dollars of inflow is observed in 2019, highlighting and accentuating the significant influence of FDI on the development of the world economy (Sotiriou, A., 2019).

### **3.3.6 Region Wise Impact**

After the COVID-19 pandemic, the profound loss was found in economy of different regions across the globe such as North America, Europe, Asia, Middle East and Latin America specifically. It was also observed that due to the economic disturbance, GDP, fiscal policy, employment rates, sectorial impacts and manufacturing were highly effected. With respected

to the chosen variables and its impact on GDP growth, this research also explores the above-mentioned aspects after the pandemic.

Assessment based on region reveals the disparities in economic impacts. For example, in Europe, most of the revenue was generated from Tourism, European region faced severe economic contraction. In the interim, Germany also felt declination in industrial sector while in Asian region China somehow managed to recover quickly with resilience. On contrary to it, nations with less coordination and harmony faced prolonged economic depression.

In the discussion of this study, the region wise assessment after forecasting the GDP is also explored with respect to the economic indicators, policy implications and sectorial impacts.

### **3.4 DATA PRE-PROCESSING**

For performing training in ML models, the data is prepared well for it. It performs through sifting of economic dataset, outliers and biases. Standardize the economic indicators for uniformity and comparability. Figure 7 below demonstrates the several steps involved in data pre-processing. Firstly, the raw data set is taken and analyzed. After the successful data profiling, the data is sifted and reduced according to the chosen ML models. The chosen variables are attached in Annexure I. After successful training and testing the data, the forecasted or output is validated with the help of quantifying measures. From collecting the data to process it for training, it involves several steps to have a smooth training of models. This study ensures the firm foundation for machine learning analyses.

According to the Figure 3.1, data profiling is the nascent step towards the pre-processing which includes the location or attainment of data. After having the authentic source of data attainment, the data is selected on the basis of desired research input or variables. In this research, data has been sourced via data bank of World Development Indicators (World Development Indicator, 2024). The raw data was extracted in the form of excel sheets. After having the dataset, the desired data is selected and cleansed by filtering the data with “Filter” command in excel.

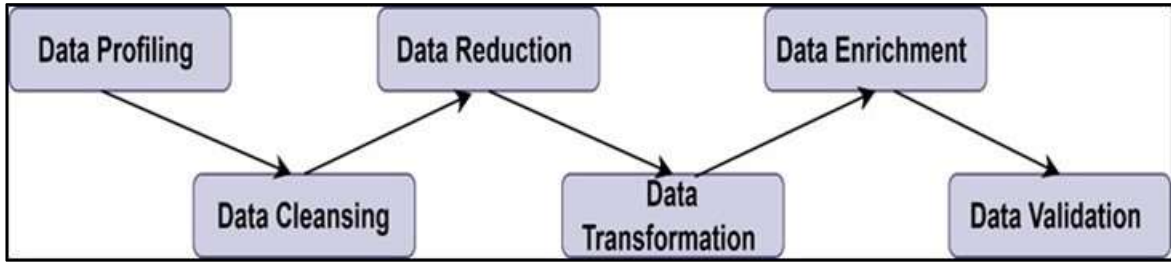


**Figure 3.1:** Steps of Data Pre-processing for Training Purpose.

After appropriate amount of literature review, the data has been reduced as per the chosen machine learning model. Later, the data is transformed and enriched according to the data type exported in MATLAB software. The data is transformed in “double” type for smooth training of models. For validating the data set, the small chunk of data set is trained and performance is checked to observe any random error in the data set.

### **3.5 MACHINE LEARNING MODEL SELECTION**

Adopting an ensemble research design, this research integrates quantitative approaches for a comprehensive economic analysis during the COVID-19 pandemic. The framework demonstrates various economic dimensions, including GDP growth, unemployment rates, and consumer spending patterns, supply chain dynamics, and financial market trends. The schematics includes, machine learning models i.e. AdaBoost, Bayesian Neural Network (BNN), and Linear Regression (LR) models that play a pivotal role in forecasting the global GDP.

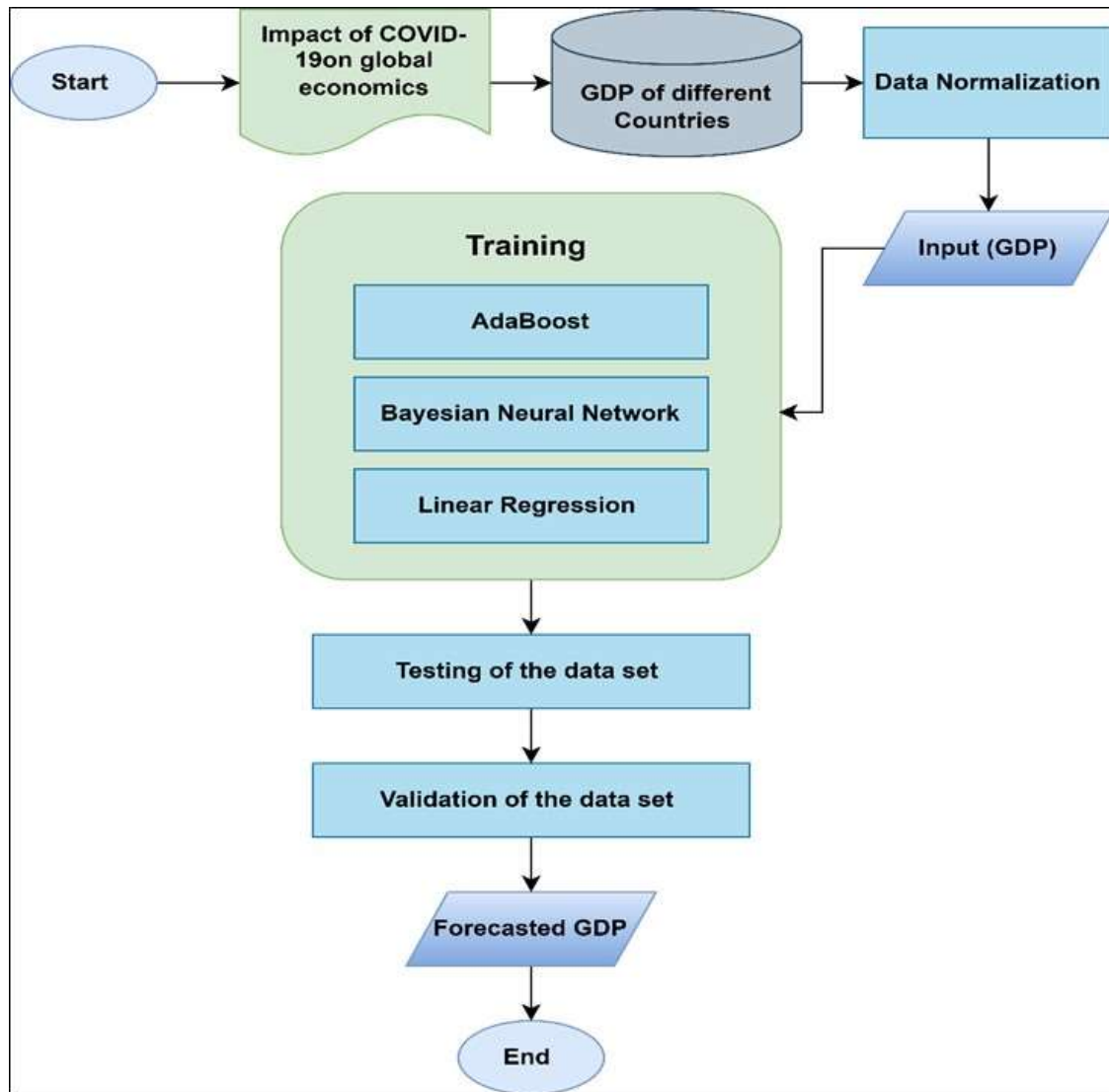


**Figure 3.2:** Proposed Methodology for Forecasting GDP.

While Figure 3.2 shows the proposed methodology for predicting the GDP for economic analysis. Initially, the data is pre-processed as the main purpose is to forecast the GDP. After successful data normalization, the input is generated for training the model. In this study, the shown models are trained individually and then combined with the weighted mean to have an output.

The selected input is first fed to the AdaBoost model to have the first input for the ensemble approach. Afterwards, the BNN model is trained with the same input and then linear regression is trained. The ensemble approach brings these three outputs obtained from i.e. AdaBoost, BNN and LR are treated for the ensemble approach as an input. Later then, the weighted average is taken and the forecasted GDP is obtained.

Finally, the forecasted output is evaluated by the means of quantifying measures i.e. Root Mean Square Error (RMSE), Mean Square Error (MAE) and Mean Absolute Percentage Error (%MAPE). If the error is at its minimum and the accuracy is achieved then the forecasted output can be used for the economic analysis. Otherwise, the input is again trained until the desired output is obtained.

### **3.5.1 Adaptive Boosting**

Collection of information about nation's economic performance and its hopes for the future makes the prediction of GDP crucial and important for economists' investors and politicians alike. Variety of predictive modeling techniques have been used over time to effectively forecast the GDP. One of the Predictive models one of the predictive models that are becoming popular in forecasting economics variables is the algorithm known as adaptive boosting or Ada boost.

Numbers of research have been conducted and investigated to use Adaboost in GDP prediction with encouraging findings. For example, China's GDP growth was predicted in forecasted using Ada boost techniques and other ensemble techniques which outperformed the conventional time series model. (Li, P., & Zhang, J. S.2018). Adaboost was also used anticipate the GDP in the US (Li et al 2018) used at a boost showing how well it captured nonlinear interactions and increase the accuracy of model.

The flexibility of combining various types of predictors, which includes financial data, socio-economic variables, and economic indicators, is one of the key advantages of the Adaboost algorithm (Caporale et al., 2021).

Furthermore, it is seen that economic data frequently exhibit nonlinearity and heteroscedasticity, that is, imbalanced datasets are obtained. So adaptive boosting is well suited for handling imbalanced data set and it may reduce over fitting as well. (Chen et al., 2019)

Basically, Adaptive Boosting is a supervised machine learning which acts as an ensemble learning algorithm, contributes adaptability and robustness to the machine learning models. Its ability to sequentially learn from data, assign weights to instances, and combat over-fitting makes it particularly suitable for the dynamic and complex nature of economic

datasets, especially in the context of predicting GDP during the COVID-19 pandemic (Ying, C et al, 2013).

Adaptive boosting is primarily a combination of weak classifier and adjusts the weights according to the problem statement. The mathematical series of expression of Adaboost is expressed below for better understanding, while Figure 9 shows the architecture of Adaboost.

$$f(x) = \text{signum}(y(x)) \quad (3.1)$$

Where  $f(x)$  shows the string classifier and  $y(x)$  depicts the combination of weak classifier. The process of iterations keeps on rolling until the weak classifiers converts to strong classifier. The weights are generated with their respective classifier and combines to form an output. The mathematical expression of generated weights with respect to their classifier is mentioned below in Equation 2.

$$z^t = 0.5 \ln \left( \frac{1 - \text{total error}}{\text{total error}} \right) \quad (3.2)$$

Where  $z^t$  is the generated weight for respective classifiers.

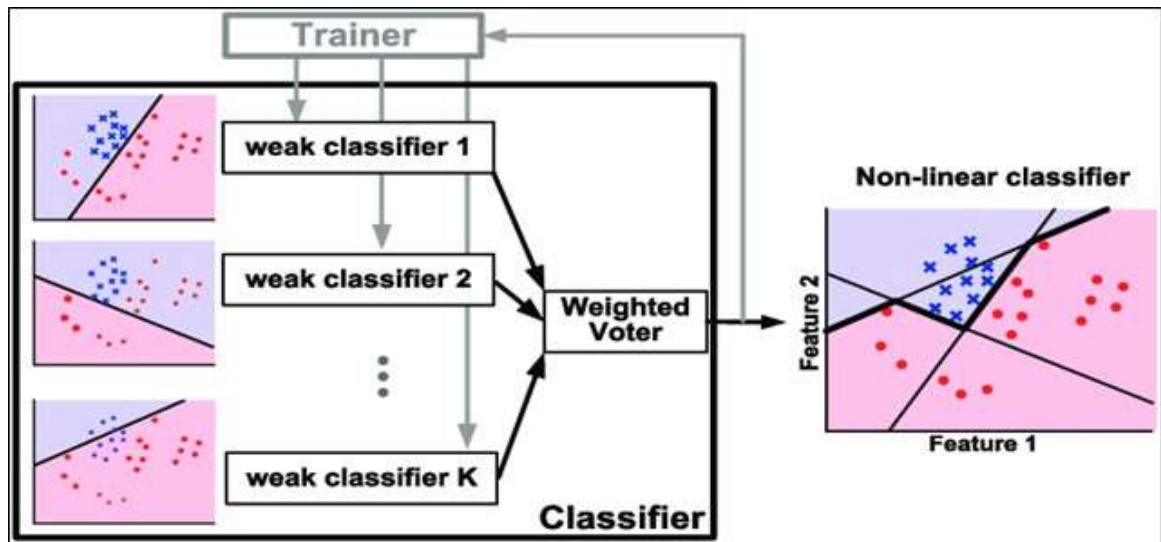


**Figure 3.3:** Adaptive Boosting Classifier.

### 3.5.2 Bayesian Neural Network

Bayesian Neural Networks is a unique kind of neural network contains a function of regularization with probabilistic approach. This is one of the classic training models used in

regression and classification. It is also noted that BNN's are very much flexible in designing the architecture of the network. The basic architecture of BNN is shown below in Figure 3.4.

A number of researches has been conducted and investigated the use of Bayesian neural network in GDP forecast, with very encouraging and promising outcomes. Using a Bayesian Framework that accounts for ambiguities or uncertainties and model misses specification, Soininem, M, 2019 used BNN the project and predict GDP growth in India. Their finding demonstrated that how much better be a prediction at capturing sophisticated relationships and generating precise and reliable forecast then traditional and typical economic models (Soininem, M, 2019).

In a similar manner, Toseafa, E. (2024) used financial factors and macroeconomic metrics as input features to 4C and estimated GDP in the United States using Bayesian Neural Network. The study they conducted revealed and highlighted how BNNs main generate probable forecast enabling politicians and investors to evaluate and critically assess the possibility of several economic conditions and make well informed decisions. (Toseafa, E. 2024)

The potential of Bayesian Neural Network is to deal with small amounts of data size, noisy data, and missing observations common- problems in economics forecasting-is one of its primary benefits that it offers. Studies have shown that be BNNs can be helpful in addressing and overcoming data limitations while improving the prediction accuracy, particularly within the emerging and developing economies (Urrutia et al., 2019)

Deciding the inputs, hidden layers, and adjustment of distributive weights are easy and effortless in BNN (Mohsin, S., Ramli, S.N. and Imdad, M., 2021). The mathematical equation of Bayesian neural network to have an output is illustrated below in Equation 3 and Figure 10 shows the layout of Bayesian neural network.

$$y = w_1(P(y|x)x_1 + w_2(P(y|x)x_2 + \cdots \dots w_n(P(y|x)x_n \quad (3.3)$$

Where y is predicted output,  $x_1$ ,  $x_2$  and  $x_n$  are the input indices while the series of  $w_n$  are the generated weights between input and output with conditional probability.

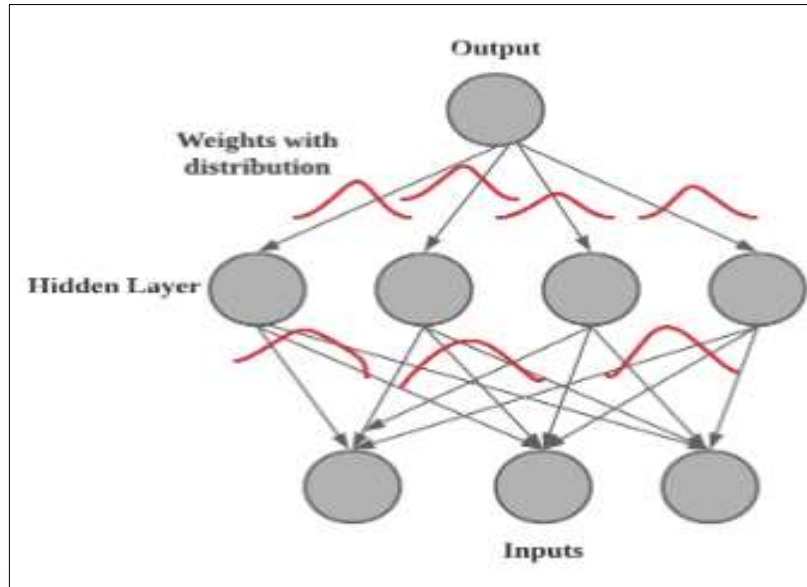


**Figure 3.4:** The Basic Architecture of BNN.

### 3.5.3 Linear Regression

Linear Regression is a straightforward and interpretable model that assumes a linear relationship between the input variables (features) and the (target). Linear Regression provides a simple structural baseline, ensemble methods enhance predictive accuracy by combining the strengths of multiple models. With respect to economic analysis, this simplicity allows for a clear understanding of changes in one variable may affect another, providing valuable insights into economic trends (Gunay, S., Can, G. and Ocak, M., 2021).

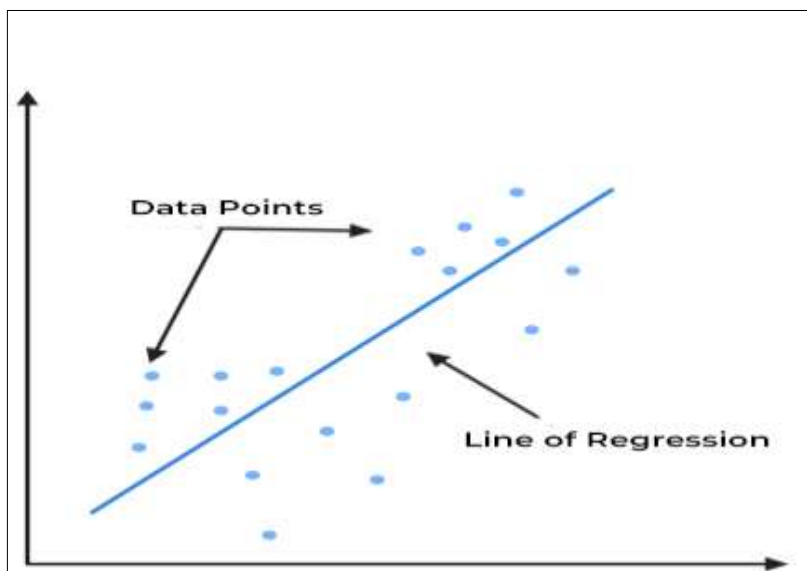


**Figure 3.5:** Basic Diagram of Linear Regression.

The concept of linear regression can be simply taken by the slope-intercept form, which is illustrated below in Equation 4 and Figure 3.5 represents the regression model working.

$$y = mx + c \quad (3.4)$$

Where  $y$  is an output,  $m$  refers to the slope which integrates the input with intercept  $c$ . It best explains the straight line with slope and  $y$ -intercept.

Method of least squares is one of the most commonly employed regression models for GDP forecast. By optimizing the sum of square differences between the recorded and the anticipated GDP values, linear regression evaluates the correlation between the GDP and the variables that are predicted. (Ly, et al, 2019) Linear regression has been used in research like Ly,Z and fellow researcher in 2019 to predict or project GDP growth via macroeconomics indicators as predictors such as government expenditures, investments and consumerism. Linear regression, despite its simplicity, provides information regarding the linear relationship between economic variables and GDP, and offers a baseline model or Framework for GDP projections.

Furthermore, ML regression techniques such as gradient enhancement regression, support vector regression, and random forest regression have demonstrated to be efficient at projecting GDP. These mathematical frameworks are agile and robust in handling massive databases and a variety of variables that can be predicted, and they also utilize the use of complex nonlinear interactions in the data. To forecast GDP growth in China Yoon, J, (2021) used random forest for regression, illustrating how well it incorporates with non-linearity is and improves the accuracy of projection of GDP.

AdaBoost, BNN and LR are chosen for ensemble approach for their self-adaptive nature. They are selected on the basis of hit and trial rule. The chunk of available data set is tested on the numerous machine learning model and then on the basis of quantifying measures the models are selected.

### 3.6 SUMMARY

In summary, the research methodology combines the strengths of ensemble learning, probabilistic modeling, and interpretability to provide a panoramic understanding of economic dynamics during the pandemic. This study aims to contribute perception for

policymakers, economists, and businesses struggling with the challenges faced after the COVID-19 pandemic.



## 4. RESULTS AND FINDINGS

This section of the research reveals the findings and discussion obtained after adopting the proposed methodology. The chapter explores the forecasting of GDP effected after COVID-19 by using combination of different machine learning models i.e. BNN, LR and AdaBoost. In this study, Amalgamation of linear and non-linear machine learning models showcases the comparative analysis between actual and forecasted GDP with behavioral trends and deviation.

Quantifying measures such as Mean Absolute Error (MAE), Mean square Error (MSE) and Root Mean square Error (RMSE) are used to find the accuracy and efficacy of the ensemble approach with individual models.

### 4.1 OUTPUT OBTAINED BY USING BAYESIAN NEURAL NETWORK (BNN)

The graph shown in Figure 4.1 portrays the comparison between actual variables and the forecasted Variables, generated by a Bayesian neural network (BNN) model, over a series of training indices. In the model, where the dotted line is representing the BNN forecasted variables lie very close to the actual GDP variables line specifies that the BNN model is precisely netting and picking up the trends and patterns in the data, showing that the model is forecasting values reliably and accurately.

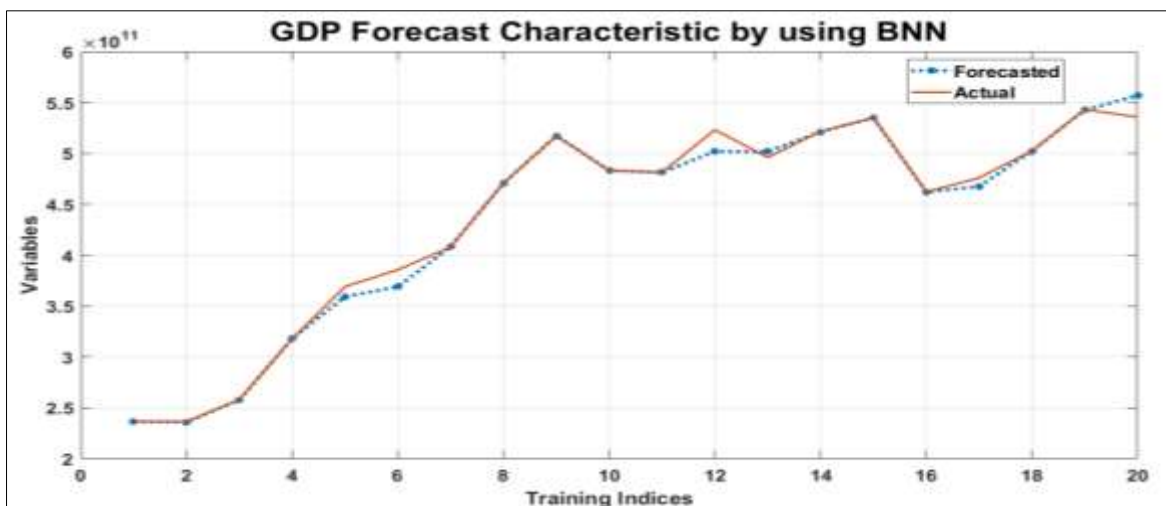


**Figure 4.1:** GDP Forecast Characteristic by using BNN.

As it can be seen clearly from the graph that the divergence rate is very low this indicated that is the BNN model's performance is at high accuracy. The deviation that can be seen in the graphs may indicate that model needs further refinement or it may depict that external factors may not be effectively captured by the model.

## 4.2 OUTPUT OBTAINED BY USING LINEAR REGRESSION

Similar to Figure 4.1, the graph shown in Figure 4.2 renders the association between actual variables and the forecasted Variables, generated by Linear Regression (LR) model, over a series of training indices. The dotted line seen in graph is representing the prophesized values predicted by LR model. It can be visibly perceived from the graph that the predicted points which are showing low error values lies closely to the actual values. However, it can be evidently comprehended that the LR model is showing fluctuations and erratic behavior that is it may not be capturing underlying patterns effectively. The cause of this could be that LR model assumes linear relationship between training indices and target variables, but economic relationships are usually nonlinear. The simplicity of the LR model may hinder its ability to capture underlying complex patterns and nonlinear relationship in the data.

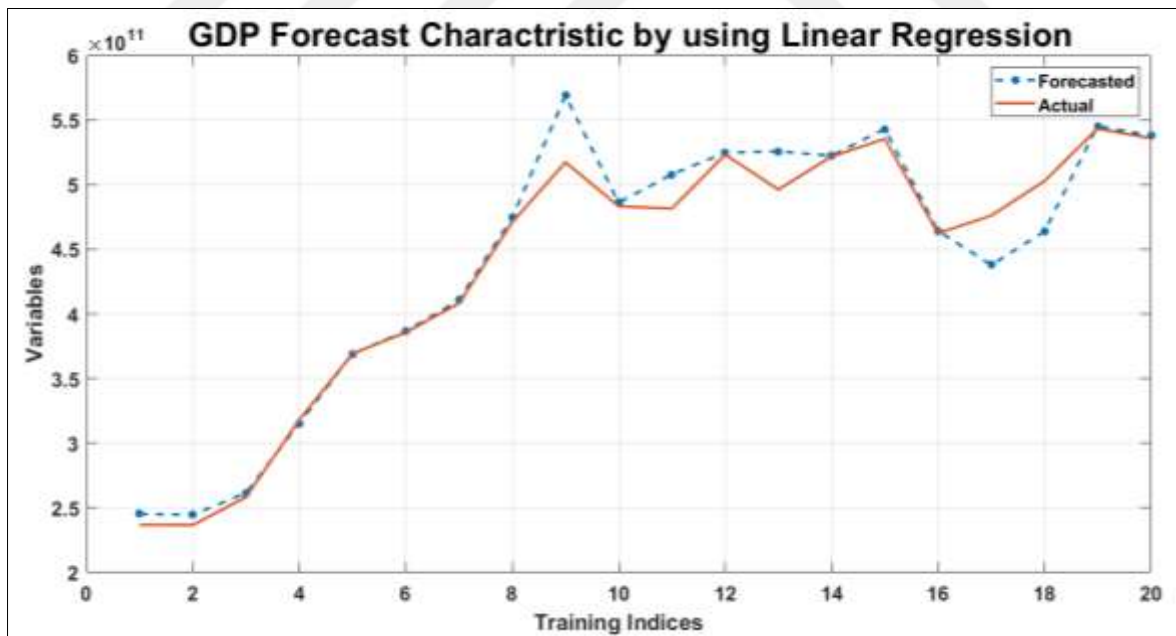


**Figure 4.2:** GDP Forecast Characteristic by using LR.

### 4.3 OUTPUT OBTAINED BY USING ADAPTIVE BOOSTING

Similar to BNN and LR model shown in Figure 4.1 and Figure 4.2 respectively, the graph in Figure 4.3 interpret the contrast between actual variables and the forecasted Variables, generated by Adaptive Boosting (AdaBoost) model. The dotted line perceived in graph is representing the predicted values forecasted by AdaBoost model. A closer alignment between the predicting line and actual graph is displaying that the model is performing well in that specific indices. It can also be grasped clearly from the graph that unlike BNN model, AdaBoost model is showing discrepancies and deviations, this may happen because the AdaBoost model may have inherited limitations in apprehending the complex relationships present in data. The training of Adaboost depends heavily on quality and quantity of data available for training. The discrepancies displayed in data showing that the model is struggling to make accurate Predictions.

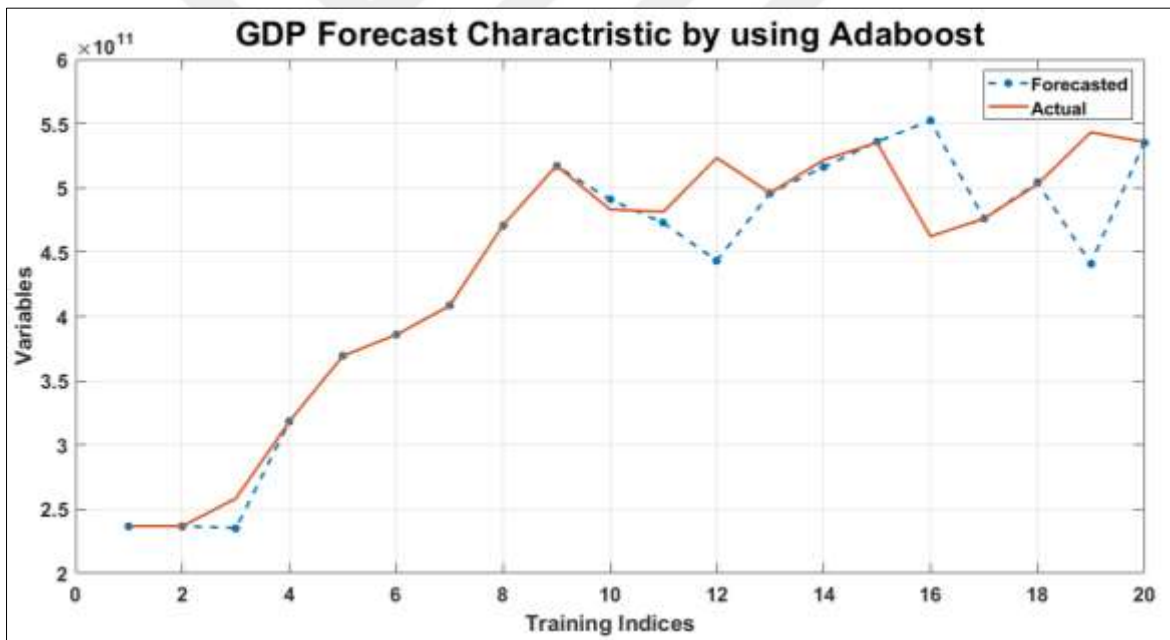


**Figure 4.3:** GDP Forecast Characteristic by using Adaboost.

### 4.4 OUTPUT OBTAINED BY USING ENSEMBLE APPROACH

The ensemble technique is applied on the same series of indices. Like the graphs of aforementioned models, Figure 4.4 shows the graph presenting contrast between actual variables and the forecasted Variables, generated by Ensemble model. The dotted line perceived in graph is representing the anticipated values guessed by Ensemble model. The area where the predicted values align closely to the actual values indicates model is

performing well in those specific points. Ensemble model is showing discrepancies and deviations, this may happen due to the dependency of model on weak learner diversity, quality of data and complexity of model. The model may be struggling with the complex relationship in data.

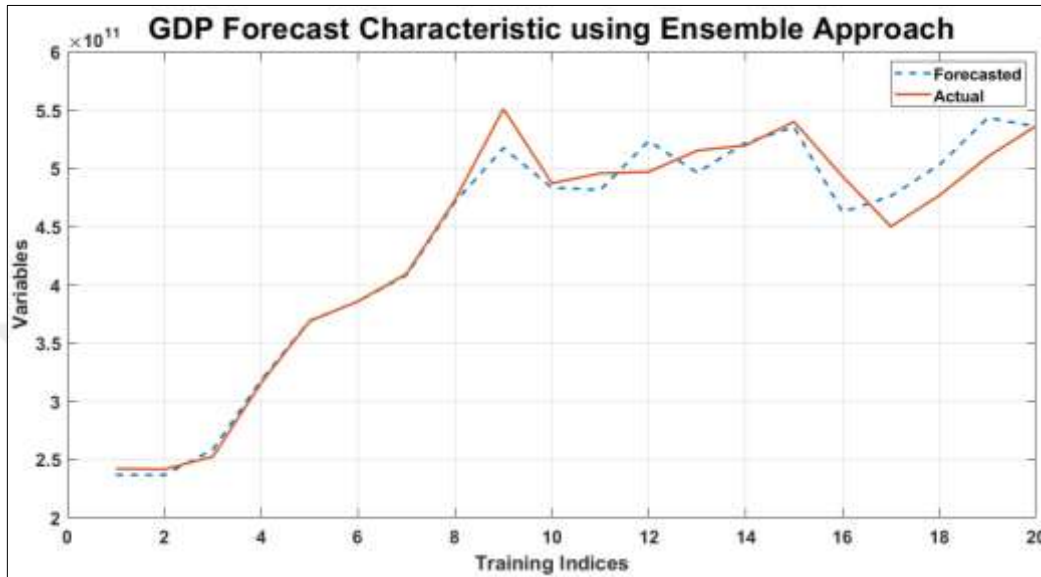


**Figure 4.4:** GDP Forecast using Ensemble Approach.

#### 4.5 ACCURACY MEASUREMENT

Figure 4.5 is showing visual representation of the Mean Absolute Error (MAE) scores for each of already mentioned models. Each sector of the chart tallies MAE of one of these models. The smallest slice of the pie symbolizes the MAE of BNN model, showing that it attained the lowest error. The slice of LR is slightly larger than BNN. Moving forward it is clear that the largest slice is reserved by AdaBoost, accounting the highest error among the four. The leftover slice shows the MAE of Ensemble model, its MAE score is slightly greater than LR but less than AdaBoost model. Generally, the pie chart is providing relative visual comparison of all the mentioned models.

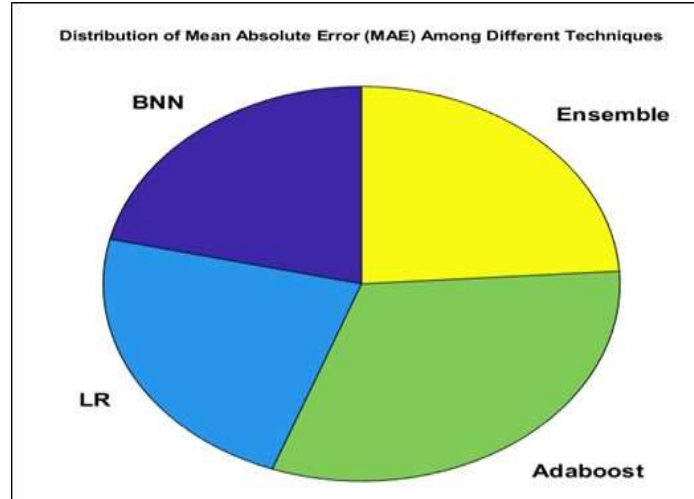


**Figure 4.5:** Distribution of MAE using Different Techniques.

The pie chart in Figure 4.6 shows the Root Mean Square Error (RSME) for each of mentioned models. Each sector of the chart represents RSME of one of these models. It can be visualized that segments of BNN and LR model has equally sized segments representing that both models have lowest error among the four models. The largest sector of the chart represents RSME score of AdaBoost model depicting that the AdaBoost model has highest error. The sector representing Ensemble model's error is showing that its RSME score is greater than BNN, LR but less than AdaBoost model. Generally, the pie chart is presenting comparative visual evaluation of all the mentioned models.

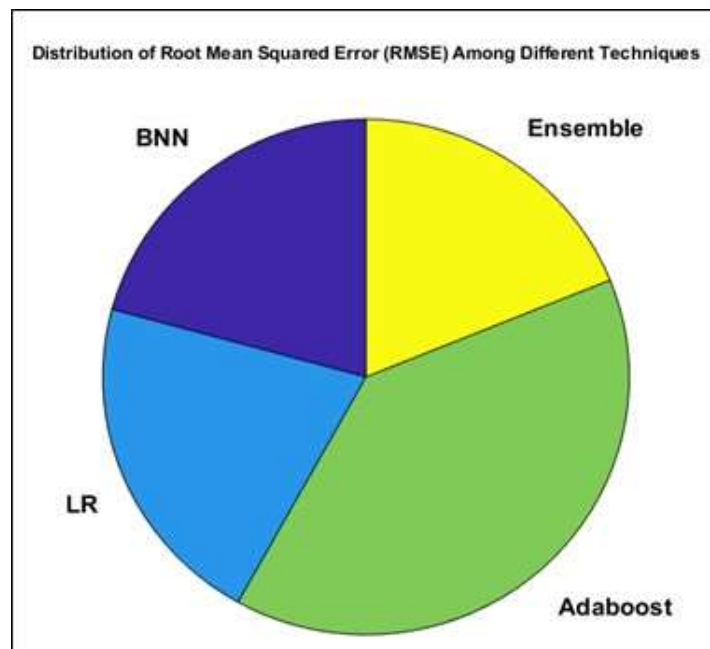


**Figure 4.6:** Distribution of RMSE using Different Techniques.

#### 4.6 COMPARISON OF FORECASTED GDP ACROSS COUNTRIES

A comprehensive in-depth analysis of GDP disparity throughout the G7 G8 and G20 groups is given in Table 4. The actual GDP data along with the forecasted or estimated GDP data is mentioned in the table for comparative analysis.

**Table 4.1:** The Actual GDP Data 2000 Along with Corresponding Forecasted GDP 2020.

| Country   | Group       | Input<br>GDP,2000,<br>(10 <sup>-6</sup> ) | Input<br>GDP,2000 | Forecasted<br>GDP,2020, (10 <sup>-6</sup> ) | Forecasted<br>GDP,2020 |
|-----------|-------------|-------------------------------------------|-------------------|---------------------------------------------|------------------------|
| Australia | G20         | \$ 416,000                                | 4.16E+11          | \$ 297,000                                  | 2.97E+11               |
| Argentina | G20         | \$ 284,204                                | 2.84E+11          | \$ 646,012                                  | 6.46E+11               |
| Brazil    | G20         | \$ 655,448                                | 6.55E+11          | \$ 2,598,150                                | 2.60E+12               |
| Canada    | G7, G8, G20 | \$ 744,773                                | 7.45E+11          | \$ 2,001,750                                | 2.00E+12               |
| China     | G20         | \$ 1,211,330                              | 1.21E+12          | \$ 14,481,500                               | 1.45E+13               |
| Germany   | G7, G8, G20 | \$ 1,950,000                              | 1.95E+12          | \$ 4,239,480                                | 4.24E+12               |
| India     | G20         | \$ 468,000                                | 4.68E+11          | \$ 2,884,440                                | 2.88E+12               |
| Indonesia | G20         | \$ 165,000                                | 1.65E+11          | \$ 1,209,970                                | 1.21E+12               |
| Italy     | G7, G8, G20 | \$ 1,150,000                              | 1.15E+12          | \$ 2,302,490                                | 2.30E+12               |
| Japan     | G7, G8, G20 | \$ 4,970,000                              | 4.97E+12          | \$ 5,359,790                                | 5.36E+12               |

| Country               | Group       | Input<br>GDP,2000,<br>(10 <sup>-6</sup> ) | Input<br>GDP,2000 | Forecasted<br>GDP,2020, (10 <sup>-6</sup> ) | Forecasted<br>GDP,2020 |
|-----------------------|-------------|-------------------------------------------|-------------------|---------------------------------------------|------------------------|
| Mexico                | G20         | \$ 742,000                                | 7.42E+11          | \$ 1,390,000                                | 1.39E+12               |
| Russian<br>Federation | G8, G20     | \$ 260,000                                | 2.60E+11          | \$ 2,185,440                                | 2.19E+12               |
| Saudi Arabia          | G20         | \$ 190,000                                | 1.90E+11          | \$ 915,221                                  | 9.15E+11               |
| South Africa          | G20         | \$ 189,515                                | 1.90E+11          | \$ 915,221                                  | 9.15E+11               |
| South Korea           | G20         | \$ 576,179                                | 5.76E+11          | \$ 1,789,440                                | 1.79E+1                |
| Turkey                | G20         | \$ 274,000                                | 2.74E+11          | \$ 1,040,150                                | 1.04E+12               |
| UK                    | G7, G8, G20 | \$ 1,670,000                              | 1.67E+12          | \$ 3,126,640                                | 3.13E+12               |
| US                    | G7, G8, G20 | \$ 10,300,000                             | 1.03E+13          | \$ 21,142,700                               | 2.11E+13               |
| European Union        | G20         | \$ 7,276,390                              | 7.28E+12          | \$ 17,403,900                               | 1.74E+13               |
| France                | G7, G8, G20 | \$ 1,370,000                              | 1.37E+12          | \$ 3,084,200                                | 3.08E+12               |

The table provide a detailed comparative study or examination of the input GDP data and the anticipated or predicted GDP values for G7, G8, and G20 countries. This research analysis underlines these nations' economics condition situation and expected growth pathways, showcases the importance they have in the world economy.

The most powerful and largest economies in the world are represented by the G7, G8 and G20 groups combined. But each of these groups has unique trades and economic rules which are explained below:

a. G7 Countries

The seven most prosperous economies, that play a very important role in establishing the policies and the trends that impact the global economy, are known as G7 countries. These countries include:

- i. Canada
- ii. France
- iii. Germany
- iv. Italy
- v. Japan
- vi. UK
- vii. US

All of these developed economies possess substantial technological and industrial foundations, and high per capita income, due to which a major and substantial contributions are made to international trade and finance. The substantial and robust institutional frameworks financial stability and innovation and technology define their economies.

b. G8 Countries

The group of G8 countries includes all the countries in G7 along with Russia, which contributes a great deal of natural resources to the table, particularly in the energy sector. The incorporation of Russia to the group or block offers considerable diplomatic, economic,

and financial influence and highlights or accentuates the importance of resources in the realm of global market

c. G20 Countries

Along with the G7 and G8 countries, the G20 group includes wealthy countries along with major developing economies like China, India, Brazil, South Korea and South Africa. The G20 group comprises two-thirds of the global population and more than 80% of the world's GDP (Cilliers, J., 2016). This group spans an extended spectrum of economic, business and financial endeavors all over the world. The ever-increasing importance and relevance of these nations in the development of the world economy and the evolving balance of financial dominance can be seen and reflected in G20's incorporation in emerging economic systems. The substantial and huge populations and rapid growth of GDP in nations like India and China search as driving factors that underline worldwide economic developments.

It can be clearly seen in the table that Germany Italy, the UK and the US showcase their significant and noteworthy contributions in the economy as provided in the dataset, with the input GDP's of \$318 billion, \$385 billion, \$496 billion, and \$523 billion, respectively.

Including Russia along with these nations of G7 countries constitutes a group of G8 countries, which extends and improves the macroeconomic discussion to address the ever growing and fluctuating international market and Geopolitical disputes. Having a \$408 billion GDP, Russia has an enormous and substantial footprint in Europe as well as Asia.

Incorporating the G20 countries, which are composed of 20 main economies of the globe, in the assessment broadens the prospective of the current state of the global economy. In accordance with the statistics, along with the G7 and Russia other G20 members are Australia, Saudi Arabia, Turkey South Africa, South Korea, Brazil, Argentina, India, Indonesia, China Mexico and the European Union. The strong economy of Australia, operated by the natural services and resources, can be seen in its \$236 billion GDP and its forecast at GDP of \$242 billion. The \$470 billion of GDP and the projected \$473 million GDP of Saudi Arabia illustrate the country's persistent attempts to broaden and increase the diversity in the economy. With the predicted GDP of \$487 billion worth of GDP, Turkey, wedged between Asia and Europe, exhibit and highlight the important strategic location of

Turkey in the economy of the region. It also highlights and exhibits its potential for development and growth in the emerging economies and developing markets.

The contrasting analysis of the G7, G8 and G20 countries emphasizes that the different attributes as well as development trajectories of these significant economies can paint an accurate portrait of the current state of the world's economy. In order to manage the intricacies and complexities of international market policy maker, investors, and companies must comprehend numerous economic environments so that they can handle an increasingly globalized and interconnected world economy.

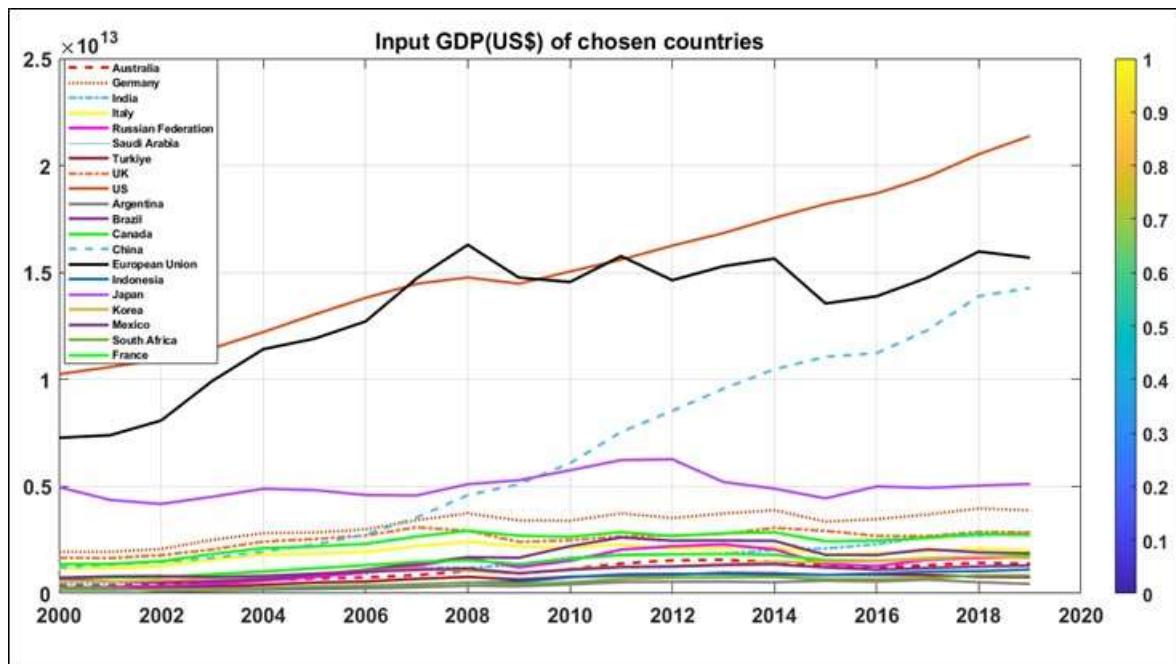


**Figure 4.7:** Trend of GDP (US\$) from 2000 to 2019 of Chosen Countries.

Figure 4.7 reveals the trend of 20 countries as shown in the legend box of the graph. The input for the ML models is taken from 2000 to 2019 of the mentioned 20 countries. The graph is plotted between years and GDP (US\$) corresponding along countries. It is obvious from the graph that every country is having their own trend with respect to years. From 2000 to 2019, few countries are showing increase in their GDP while few are showing the decreasing manner.

While Figure 4.8 is illustrating the forecasted GDP (US\$) from 2020 to 2039 of mentioned countries. As compare to the input GDP, the forecasted GDP is different and showing different trend. Table 4 also demonstrates the input and forecasted GDP across their

respective years. Contrastingly, the forecasted GDP (US\$) shows the projected economic output and triangulated future GDP. It aids in taking subsequent economic measures.

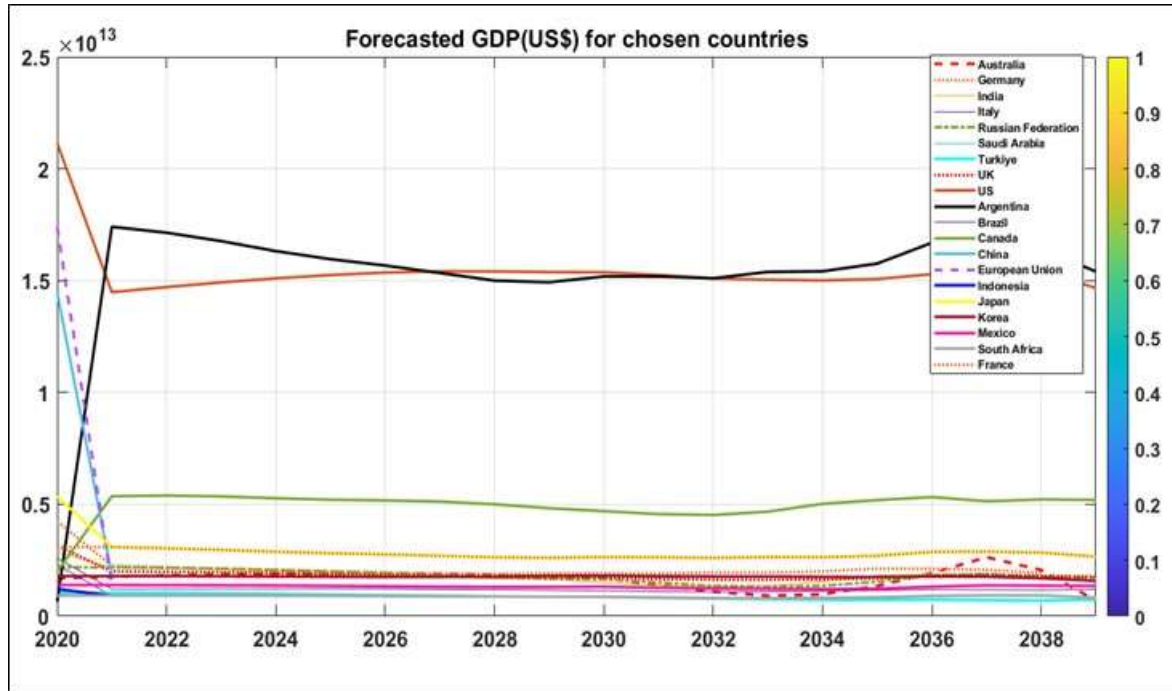


**Figure 4.8:** Trend of Forecasted GDP (US\$) from 2020 to 2039 of Chosen Countries.

The data shown in Annexure 1 is showing the values of variables such as-GNI per Capita (Current International), Carbon Dioxide Emission (metric ton per capita), GDP (Current US \$), GDP Growth Annual, Inflation GDP deflator, Foreign Direct Investment net flow (Current US \$) for different countries from G7, G8 and G20 economic blocks. As shown in Table 4, 20 countries are taken for forecasting their GDP.

#### 4.7 SUMMARY

The discussion presented across Figures 4.3-4.8 elucidates the contrast of actual and forecasted variables generated by the already mentioned models; Bayesian neural network (BNN), Linear Regression (LR), Adaptive Boosting (AdaBoost), Ensemble Approach; on a chain of training indices. Although, all the aforementioned model provide intuitions into GDP forecasting, the BNN model creates very precise forecasted variables and capture complex trends, on the other hand LR, AdaBoost and Ensemble models shows confinements in capturing and seizing underlying complex patterns, underlining the prominence and distinction of BNN model.

Furthermore, the comparative analysis of the economies of different countries of the world, divided in to three different groups; G7, G8 and G20; offers an extensive and in depth understanding of the impact of economies in different regions and how these regions can contribute to the global economy. This in-depth study provides an alleyway for prediction of economy of different countries which can affect the global economy. This study delves into the convolutions and complexities of a number of economies, which can help in scripting policies to move in international market, and to handle the fluctuations that might affect the economy of a country.



## **5. DISCUSSION**

This chapter reveals the discussion on the obtained results from ML models and its impact on COVID-19 on global economies after and before forecasting.

### **5.1 IMPACT OF COVID-19 ON GLOBAL ECONOMIES ATER FORECASTING**

During the pandemic, various factors have been seen affected in terms of global economies. There is surge to forecast the GDP or other variable which is directly affected by the economic inclination. In this study, combination of machine learning algorithms have been chosen to forecast the GDP of G7, G8 and G20 countries. The basic aim of the study is to analyze the impact of COVID-19 after forecasting the GDP till 2039. This section outlines the comparison of input and forecasted GDP of the countries and the regions. Further, the economic indicators, sectoral impact (tourism, healthcare, manufacturing etc.) and policy implications as a result of improvement and changes in GDP due to anti-COVID-19 measures and some pertinent studies from the literature were also discussed:

### **5.2 COMPARISON OF FORECASTED GDP VERSUS INPUT GDP**

The chosen countries for the comparison span multiple region across the globe including Asia, Europe, North America, Oceania and Middle East. The comparative analysis is categorised with respect to G7, G8 and G20 countries. This geographical diversity ensures a comprehensive representation of global economic dynamics and allows for cross-regional comparisons.

#### **5.2.1 G7 Countries**

The G7 countries are considered as the most prosperous economies, due to the stable economic condition these countries play an important role in establishing the trends and policies that impact the global economy. These G7 countries include: Canada, France, and Germany, Italy, Japan, UK and US.

##### **5.2.1.1 Comparison between forecast GDP and input GDP of Canada**

The Canada is one of the largest country with respect to region and the employment rate in Canada is increased from 14.76 million to 20.17 million for the year 2000 to 2023 respectively according to ([www.statista.com](http://www.statista.com)). This show that employment rate is improved

after the COVID-19. Figure 20 shows the GDP of Canada from 2000 to 2019 which indicates that GDP has been increased from 2000 to 2008 and after slight decrease in 2009 it again stabilized from the period 2010 to 2014, further more after a short fall in 2015-16 it again regains the strength. This slope is common in prosperous economic condition. Figure 21 shows the forecasted GDP of Canada from the period of 2020 to 2038 which clearly indicates that the GDP is drastically increased in the year 2020-21 and stabilized from the span of 2021 to 2028 with slight decrease which indicates a mild economic contraction. Form the span of 2030 to 2032 it gradually decreased further which can produce the economic distressed. But from the span of 2033 to 2039 it will regain the economic strength.

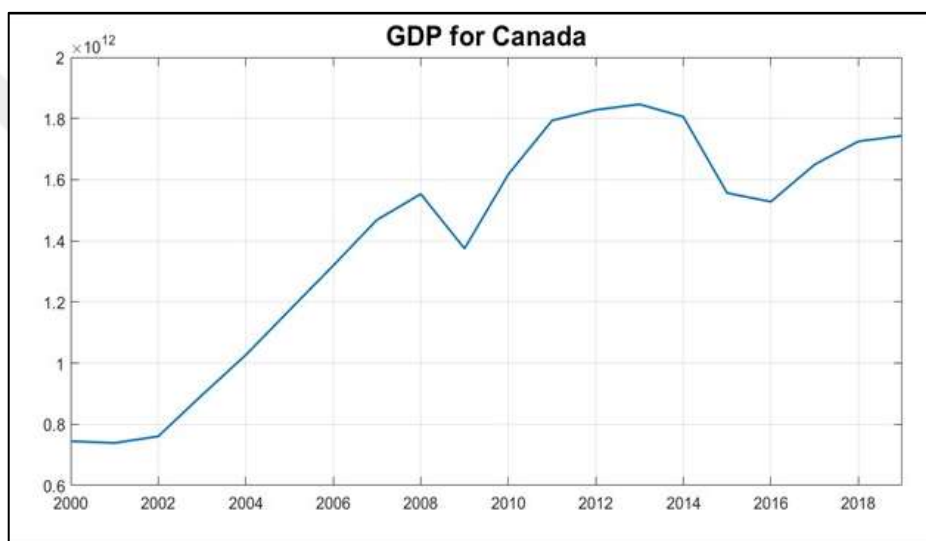


**Figure 5.1:** Input GDP (US\$) of Canada from 2000 to 2019.

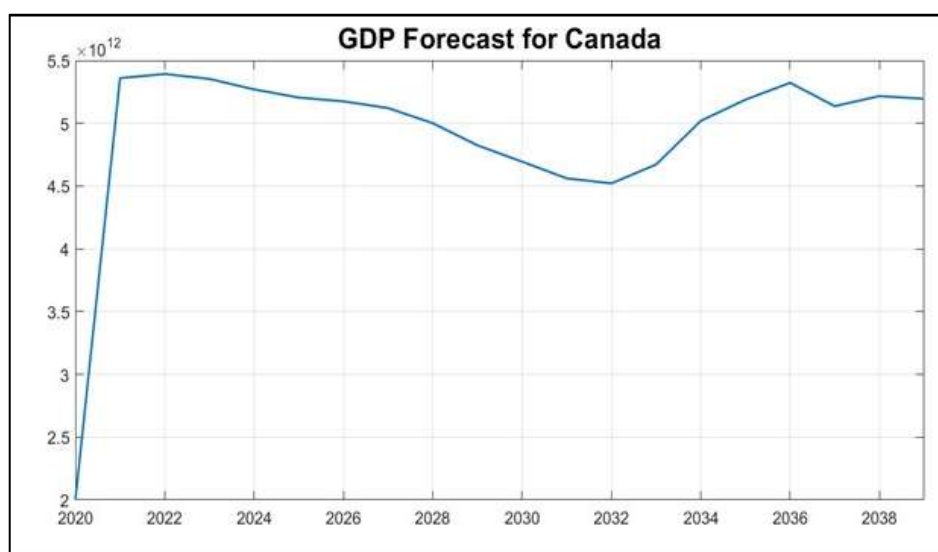


**Figure 5.2:** Forecast GDP (US\$) of Canada from 2020 to 2039.

### 5.2.1.2 Comparison between forecast GDP and input GDP of France

The comparative analysis of input GDP and Forecast GDP of France is shown in figure 20 and Figure 21 respectively. It is illustrated from the graph shown in figure 20 that the GDP of France is gradual increase from the period of 2000 to 2008 which shows the improvement but from the span of 2008 to 2014 there is fluctuation that increases and decreases timely. In the year 2014 to 2015 economic growth is drastically fall down and then regain strength from 2015 to 2018 before the pandemic of COVID-19. Figure 21 shows the forecast GDP from the span of 2020 to 2039 which is quite alarming in the first decade as illustrated in the figure the GDP is drastically decreasing from 2020 to 2029 which shown economic contraction and distress this will cause unemployment rate as well. This fall will stabilize from the period of 2029 to 2034 with slight fluctuation. In the period 2034 to 2037 will again gain strength in the GDP and improve economic growth, but the alarming situation is that it will further decrease from 2038 this will cause economic contraction potentially resulting in higher unemployment and reduced consumer confidence.

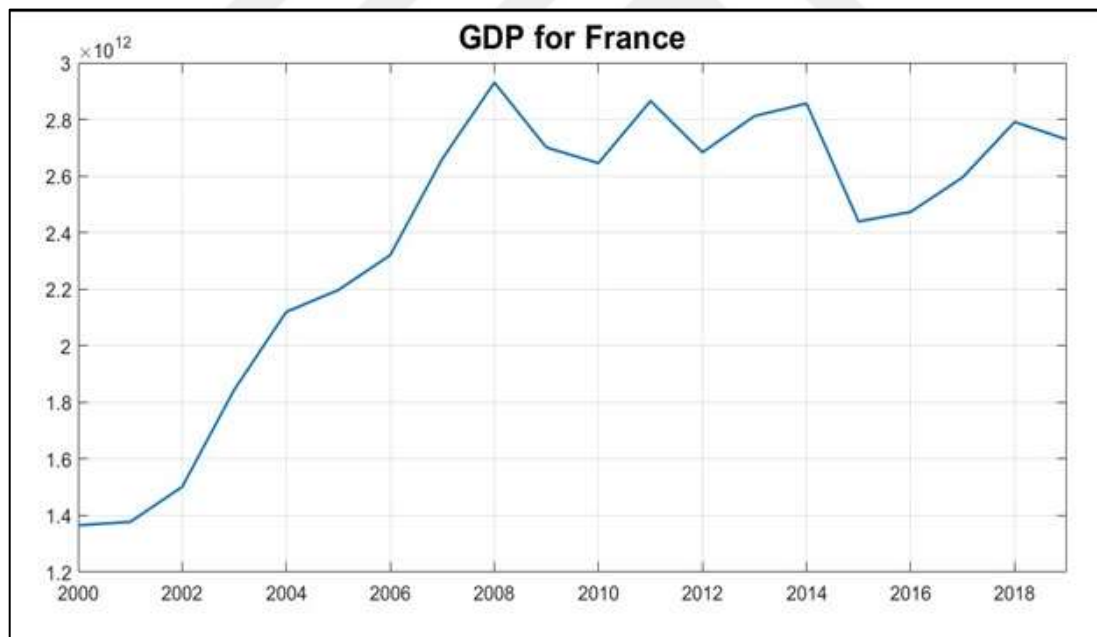


**Figure 5.3:** Input GDP (US\$) of France from 2000 to 2019.

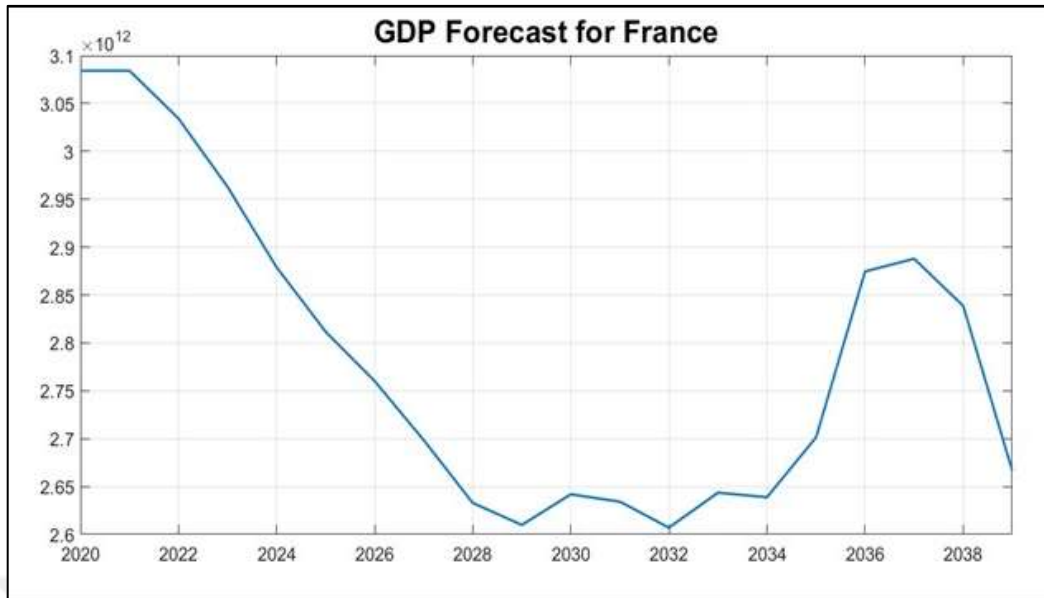


**Figure 5.4:** Forecast GDP (US\$) of France from 2020 to 2039.

#### 5.2.1.3 Comparison between forecast GDP and input GDP of Japan

Japan is most common name in industrial sector and most of the GDP of Japan is based on industrial sector. The GDP of Japan from the span of 2000 to 2007 is stabilized with slight variation, but from 2007 to 2012 its economic growth has been improved drastically. But the downfall in the GDP is evident from the period of 2013 to 2015 which impose distress in economic growth. From 2015 to 2019 it again regains its strength somehow but not effectively. Figure 21 shows the forecast GDP of Japan from the period of 2020 to 2039 which is quit alarming in economic growth for the period of 2020 to 2021 that shows drastic fall of GDP due to possible impact of COVID-19 pandemic. From the span of 2021 to 2035 the economic growth will be normalize with slight decreasing slope, which will improve from 2036 to 2038.

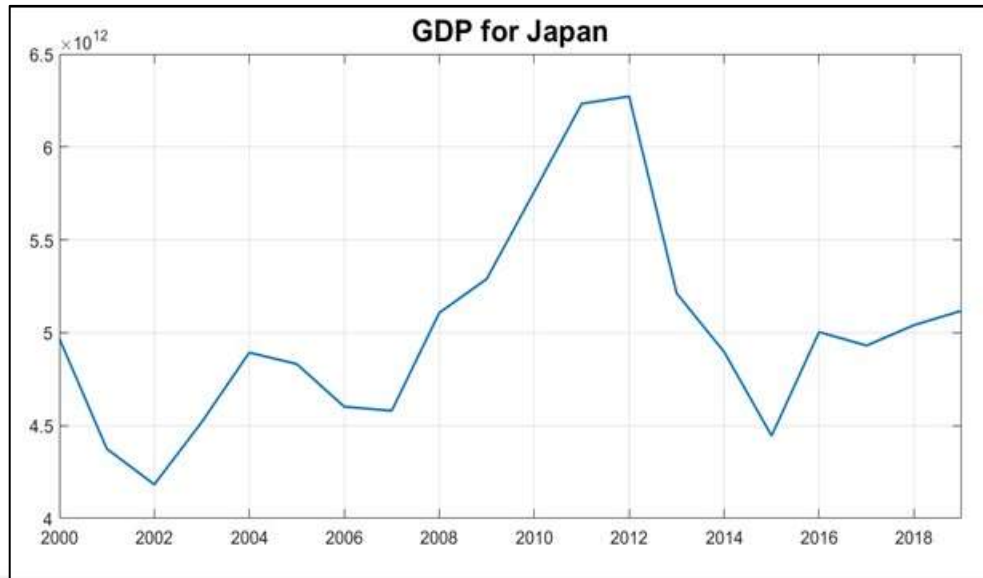


**Figure 5.5:** Input GDP (US\$) of Japan from 2000 to 2019.

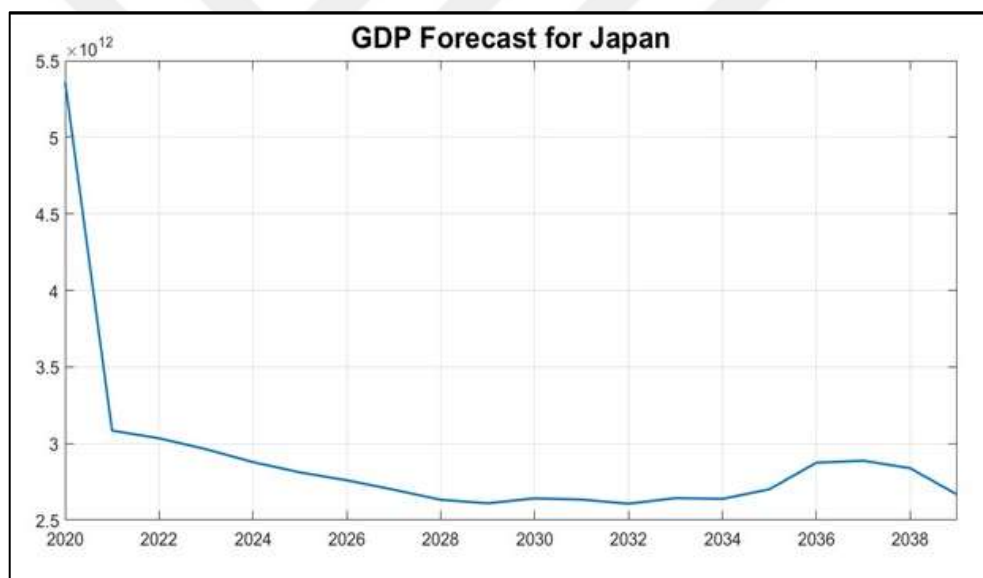


**Figure 5.6:** Forecast GDP (US\$) of Japan from 2020 to 2039.

#### 5.2.1.4 Comparison between forecast GDP and input GDP of UK

UK is considered as one of the prosperous economic country in the world, the most GDP is generated from services sector. Figure 22 and 23 shows the input GDP of UK and Forecast GDP of UK respectively. Figure 22 indicates that the GDP of UK is increasing progressively from the span of 2000 to 2007 and after that there is a certain downfall which hits the economic growth, after 2009 the GDP again gain the growth and improve visibly. But again in 2014 to 2017 it drops at certain level which impact the economy. After COVID-19

pandemic the economy hits very hard as shown in figure 23 there is drastic drop in GDP for the period of 2020 to 21 but it continues to drop with a constant slope till 2033. It is evident from the graph that there is slight improvement in GDP till 2037.

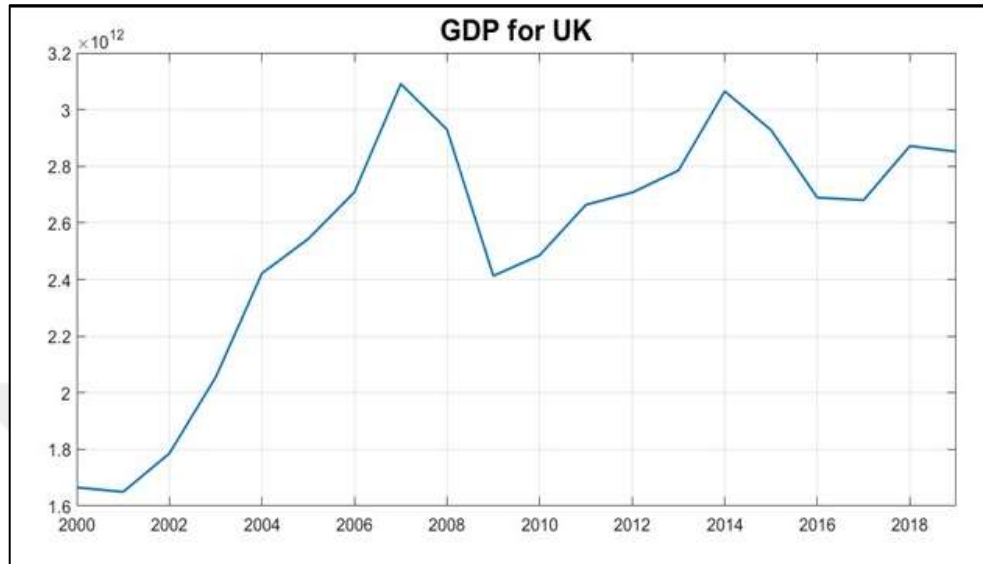


**Figure 5.7:** Input GDP (US\$) of UK from 2000 to 2019.

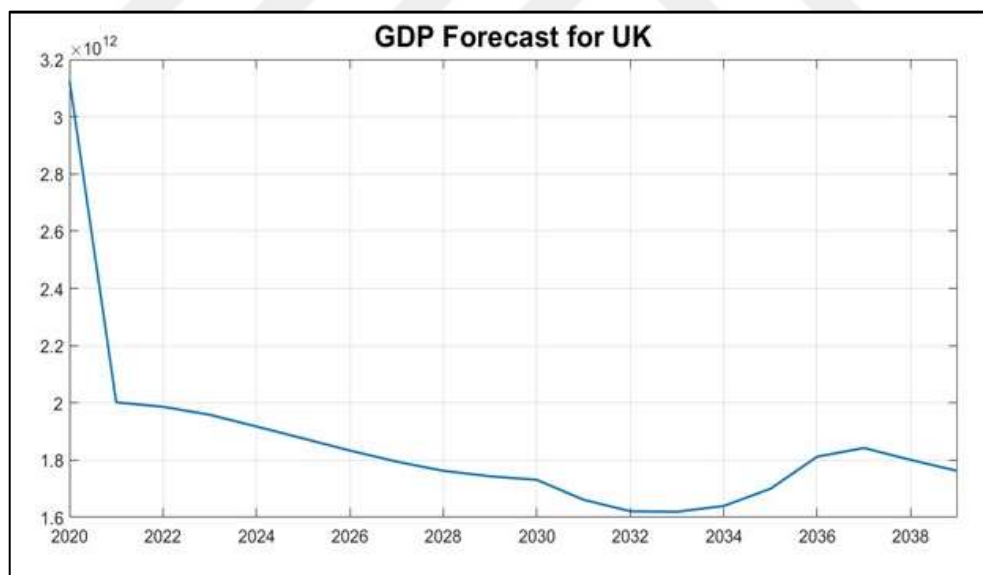


**Figure 5.8:** Forecast GDP (US\$) of UK from 2020 to 2039.

The forecasted GDP of other G7 Countries are attached in Annexure B such as Germany, Italy and US. The GDP of Germany is improved and increase from 2000 to 2008 and from 2008 to 2015 there is visible fluctuation in the GDP which increased and decreased timely and regain the strength from 2015 to 2019 (See Annexure B). The Forecast GDP of the

Germany is fall drastically as the GDP of UK from 2000 to 2001 and slightly decreased with a constant slope till 2034 which will then improve slightly from the span of 2034 to 2036 (See Appendix B). Same as Germany the input GDP of Italy from the period of 2000 to 2019 there is instability in the GDP. The period of 2000 to 2008 is healthier GDP period which improve noticeable, but from 2008 to 2014 there is fluctuating decrease in the GDP which effect the economic growth. And after 2015 till COVID-19 there is some improvement in economic growth (See Appendix B). Furthermore, the input GDP of US is stronger among all the G7 countries as shown in graph (See Appendix B). The graph illustrated that from the span 2000 to 2018 the GDP is increasing progressively with linear slop which indicated a strong economic growth. But the Forecast GDP of the US is almost the same as Germany and Italy as it drastically falls from 2020 to 2021 which increase slightly from 2024 to 2030 and then again decrease from 2030 to 2035. After 2035, it will regain its strength (See Appendix B).

#### 5.2.1.5 Comparison of input GDP and forecasted GDP of G7 countries

Almost all the countries in G7 has gain the increase in GDP from the period 2000 to 2019 as shown in figure 24, but among all the countries US has the highest increase that is continuously increasing with a constant rate throughout the time period which indicates that US has the strongest economic growth. While figure 25 indicates forecasted GDP of G7 countries which indicates that the Canada has the highest GDP among all the countries after the pandemic of COVID-19. The France has the second highest GDP among all.

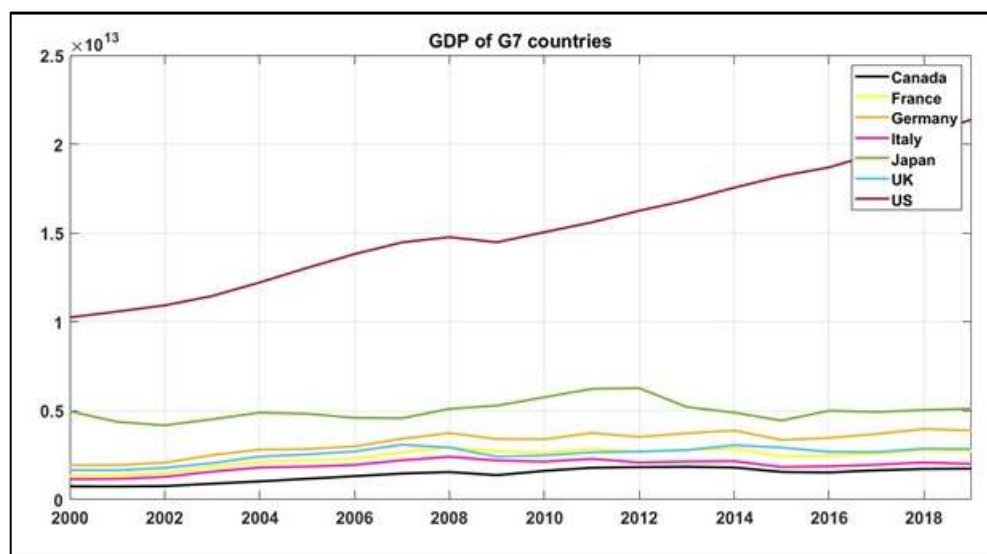


**Figure 5.9:** Input GDP (US\$) of G7 Countries from 2000 to 2019

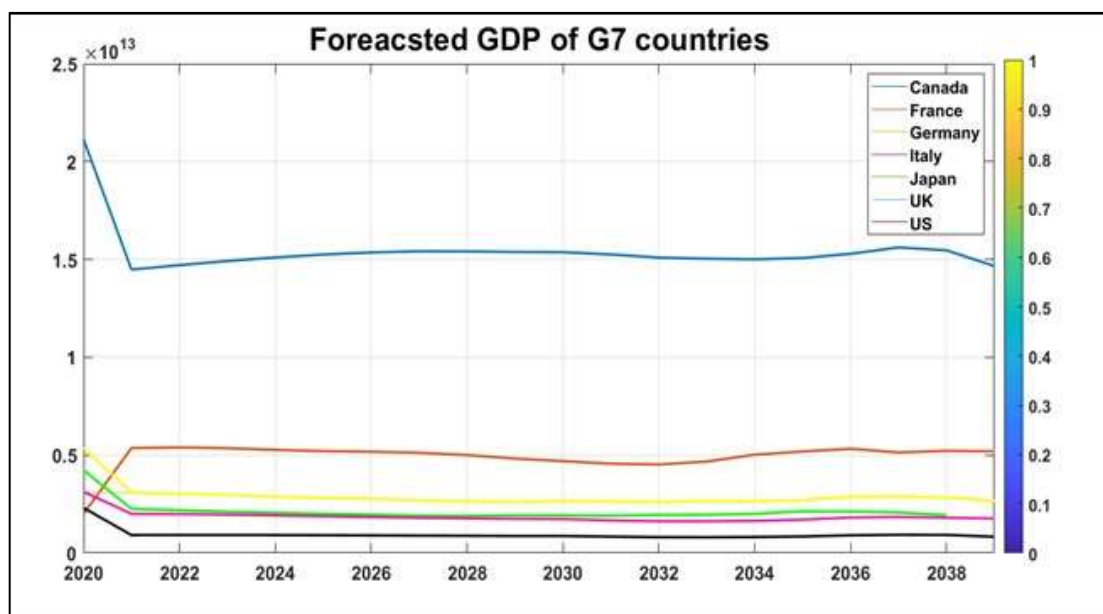


**Figure 5.10:** Forecast GDP (US\$) of G7 Countries 2020 to 2039

### 5.2.2 G8 Countries

The group of G8 countries includes all the countries in G7 along with Russia, which contributes a great deal of natural resources, particularly in the energy sector. The input GDP from the period of 2000 to 2019 of Russia federation is shown in figure 26 which indicates that the economic growth is increasing from the period of 2000 to 2008 but for the period of 2008-2009 it is decline which increase again from the span of 2008 to 2013. After 2013 the GDP fall drastically till 2016 which then increase till the COVID-19 Pandemic. Figure 28 shows the GDP of G8 Countries which include all the G7 countries including Russian Federation. It is evident from the graph that the Russian Federation has the lowest GDP among all the G8 countries. The forecasted GDP of G8 countries is also shown in figure 29 which indicates that Russian Federation has the lowest GDP among all the G8 countries.

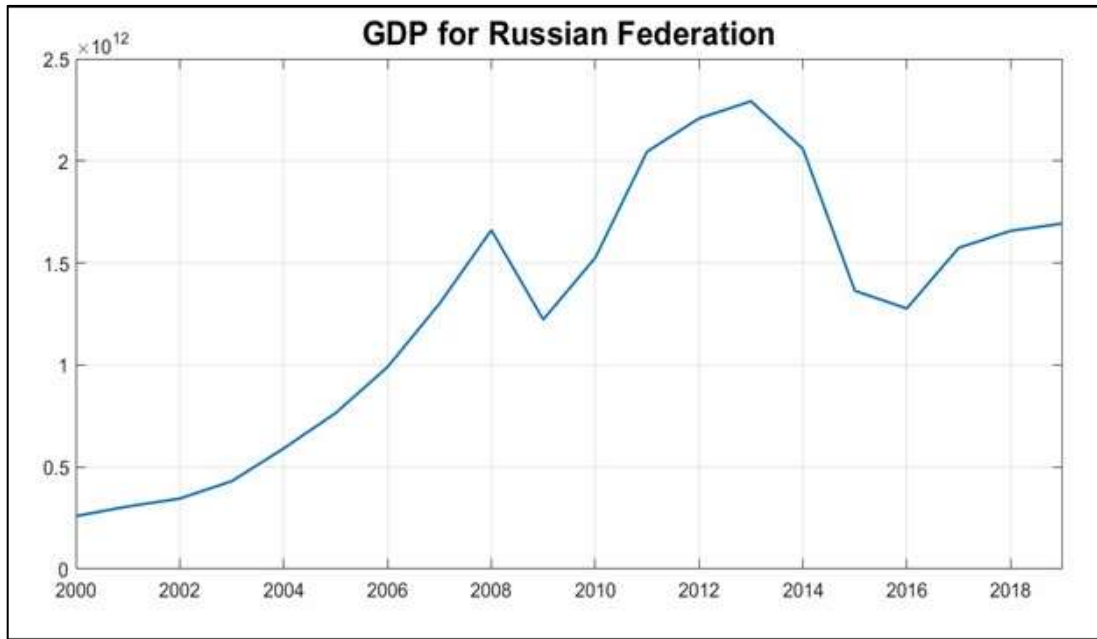


**Figure 5.11:** Input GDP (US\$) of Russian Federation from 2000 to 2019.

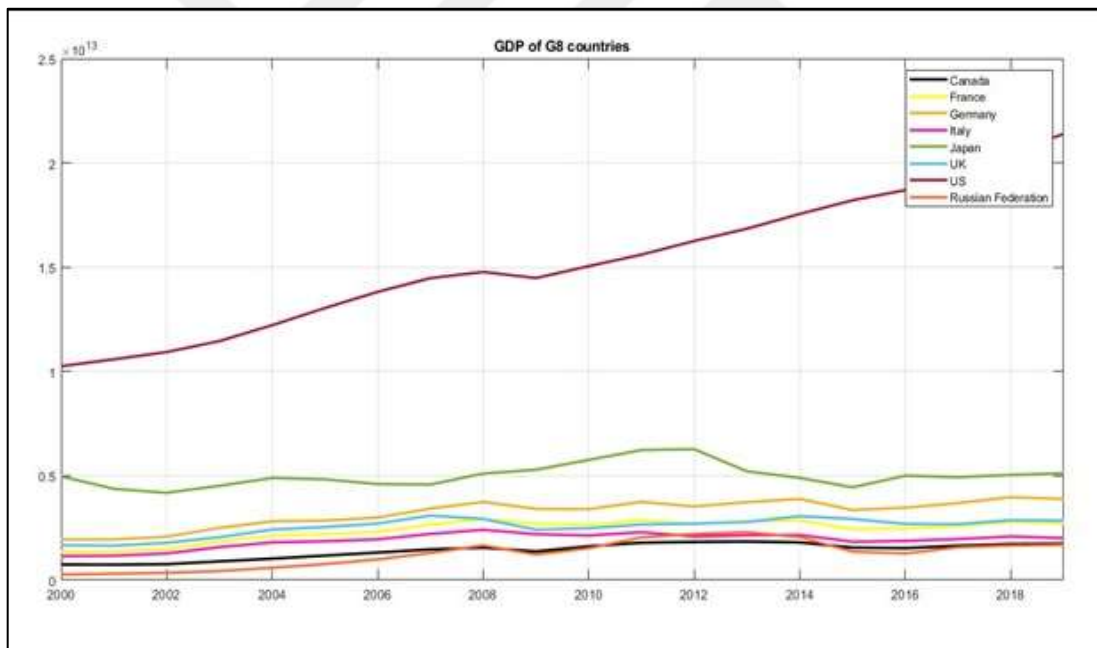


**Figure 5.12:** Input GDP (US\$) of G7 Countries from 2000 to 2019.

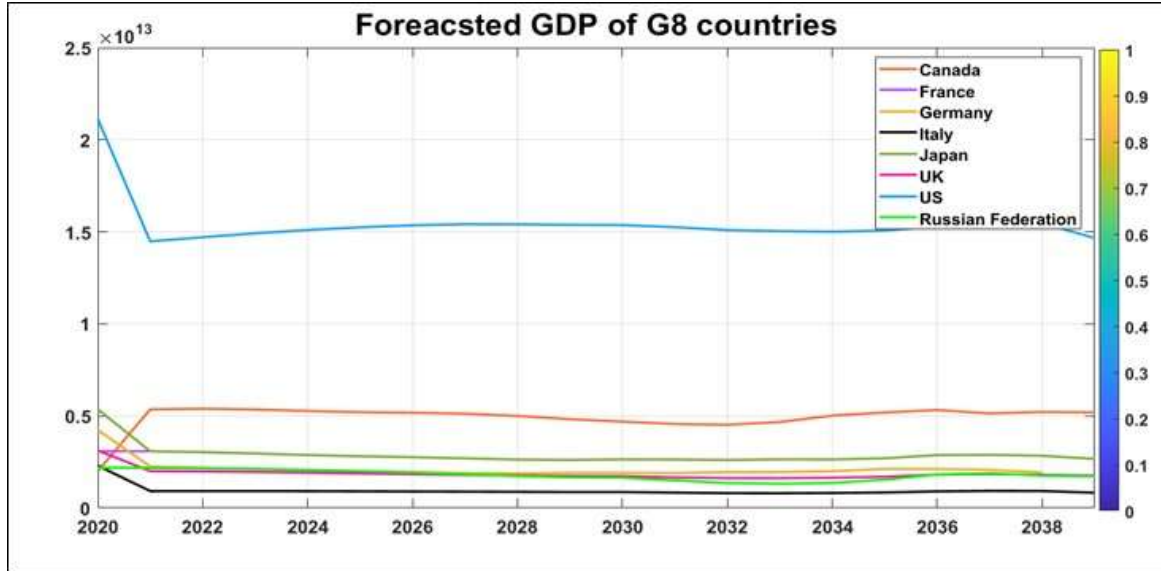


**Figure 5.13:** Forecast GDP (US\$) of G8 Countries 2020 to 2039.

### 5.2.3 G20 Countries

Along with the G7 and G8 countries, the G20 group includes wealthy countries along with major developing economies like China, India, Brazil, South Korea and South Africa.

#### 5.2.3.1 Comparison between forecast GDP and input GDP of China

The input GDP of china from the span of 2000 to 2019 is healthier as it increases with a constant ratio as mention in figure 29 which indicates the good economic growth. After the pandemic of COVID-19 the GDP in decreased from 2020 to 2021 as most the country face the decrease in GDP. But after 2021 the GDP of China approximately remain constant till 2039 as illustrated in figure 30.

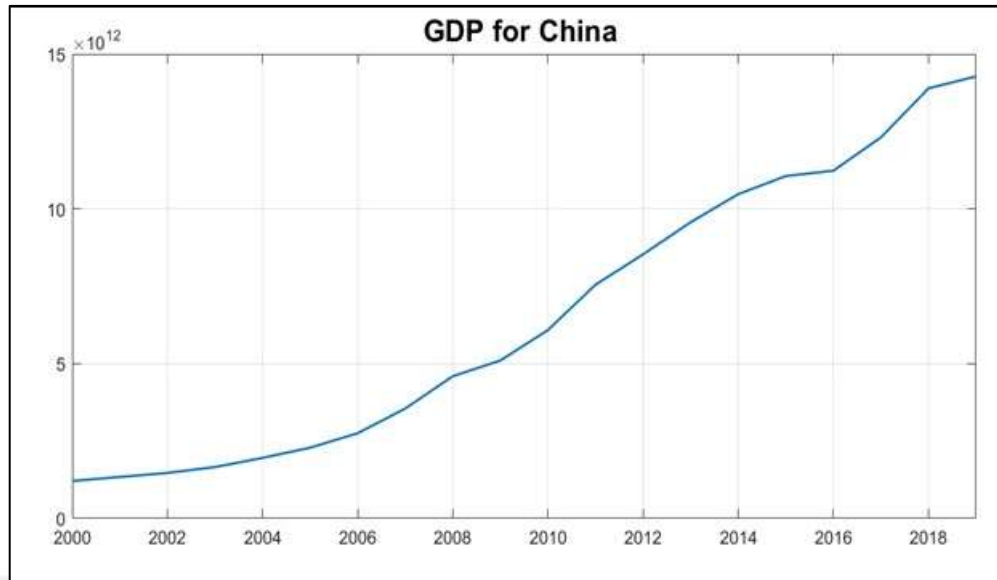


**Figure 5.14:** Input GDP (US\$) of China from 2000 to 2019.

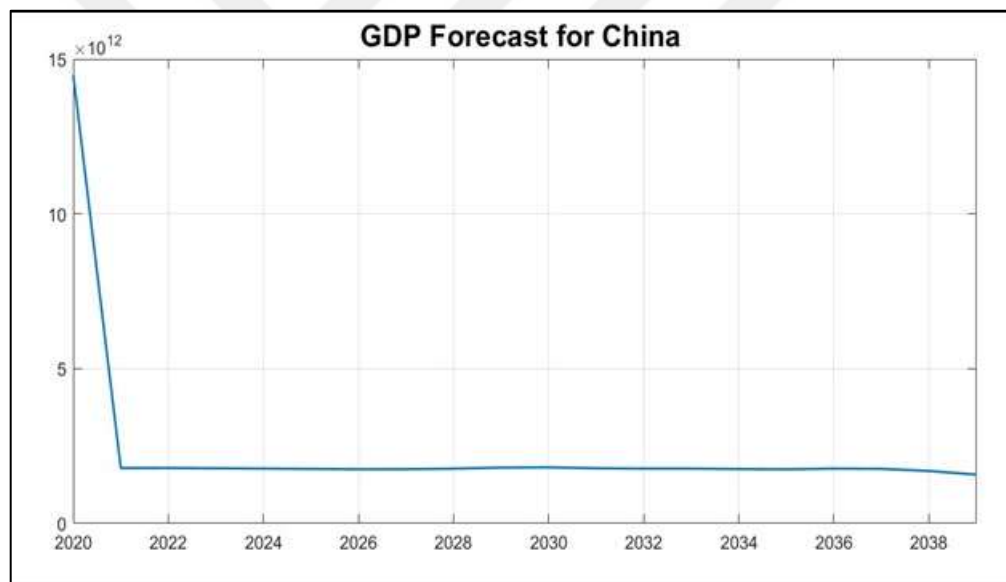


**Figure 5.15:** Forecast GDP (US\$) of China from 2020 to 2039.

### 5.2.3.2 Comparison between forecast GDP and input GDP of Brazil

The GDP of Brazil is also increased from the time span 2000 to 2011 as shown in figure 31 but there is a decrease in GDP from 2011 to 2016 which distress the economic growth. After 2016 till the COVID-19 it increase and stabilize the economic growth of Brazil. Soon after the COVID-19 the GDP falls down till 2021 and then it stabilize with slight fall till 2032 but not distress the economic growth further as mentioned in figure 32. After 2032 it will gain increase in GDP and strengthen the economic growth.

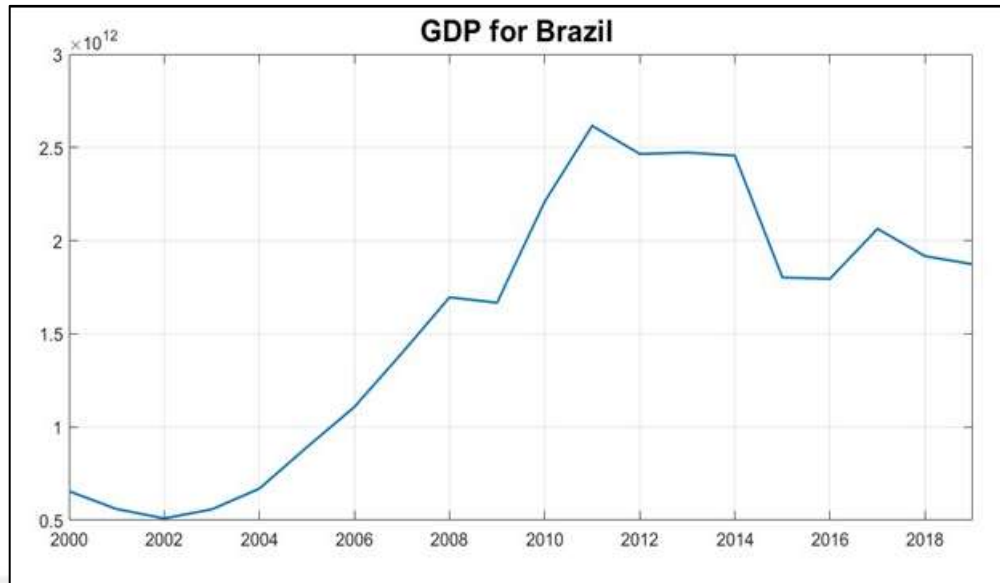


**Figure 5.16:** Input GDP (US\$) of Brazil from 2000 to 2019.

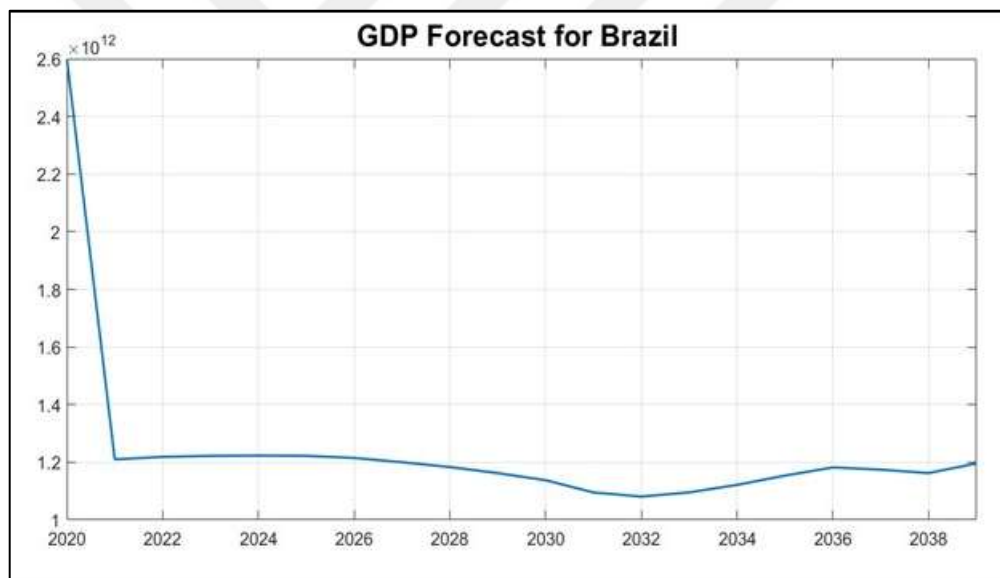


**Figure 5.17:** Forecast GDP (US\$) of Brazil from 2020 to 2039.

### 5.2.3.3 Comparison between forecast GDP and input GDP of South Korea

The GDP of South Korea is strong before the COVID-19 pandemic as mentioned in figure 33 the GDP is increasing from the period 2000 to 2019 but some distress in span of 2007 to 2009. Soon after the pandemic of COVID-19, South Korea manage to stable the GDP growth from 2020 to 2022 but there is economic distress from 2022 till 2026 which regain the stability till 2030 with slight increase as mentioned in figure 34. But after the GDP will fall

from 2030 to 2036 and drastically fall down till 2039. It will increase the unemployment rate and hit the economic health as well.

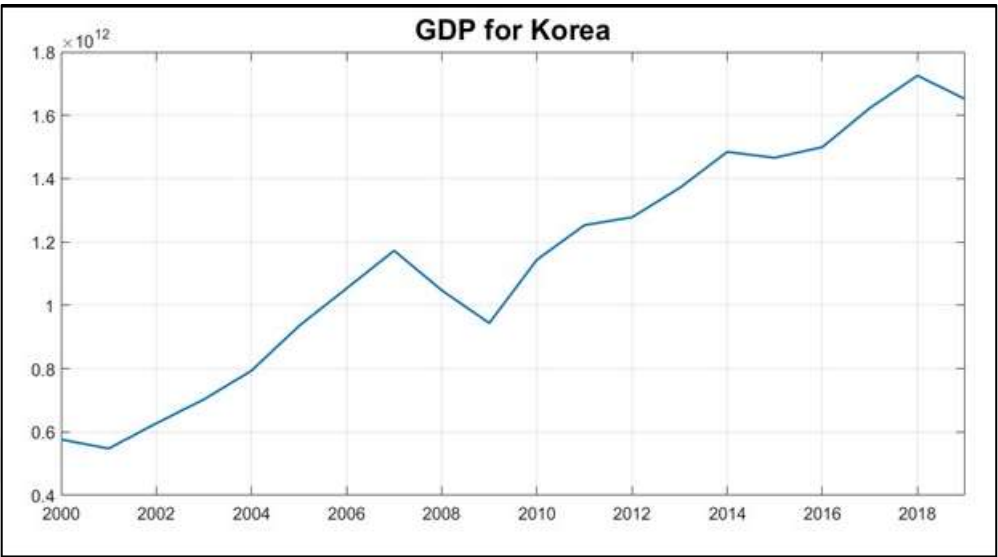


**Figure 5.18:** Input GDP (US\$) of South Korea from 2000 to 2019.

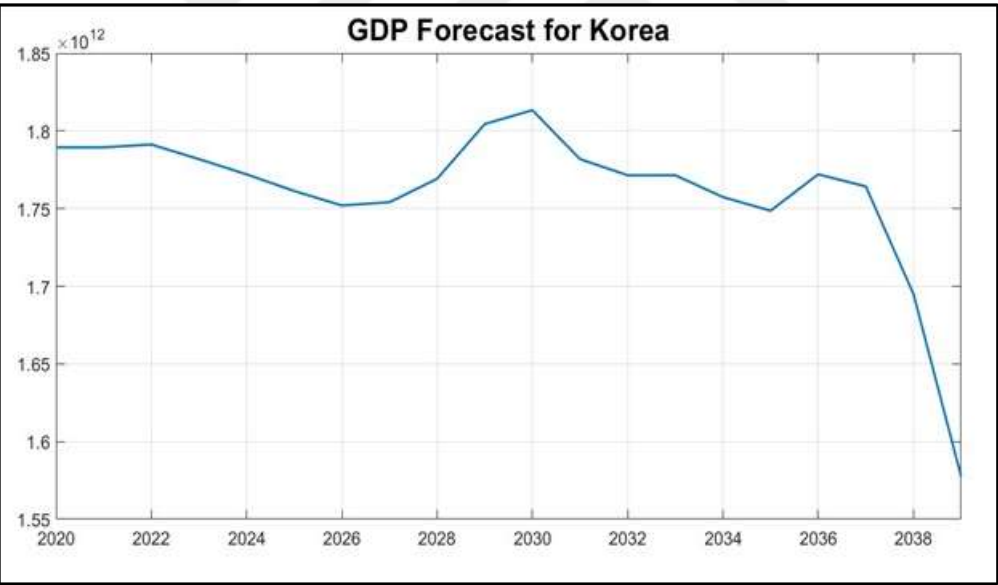


**Figure 5.19:** Forecast GDP (US\$) of South Korea from 2000 to 2019.

#### 5.2.3.4 Comparison between forecast GDP and input GDP of Australia

Figure 35 shows the GDP of Australia from 2000 to 2019 and then compare with forecasted GDP from 2020 to 2039 as mentioned in figure 36. It can be analyzed from the trend that forecasted GDP for Australia will be elevated till 2030 and then can experience an economic

distress somewhere between 2032 and 2034. Furthermore, it can also be taken into consideration that around 2037, it can gain highest GDP among all years.

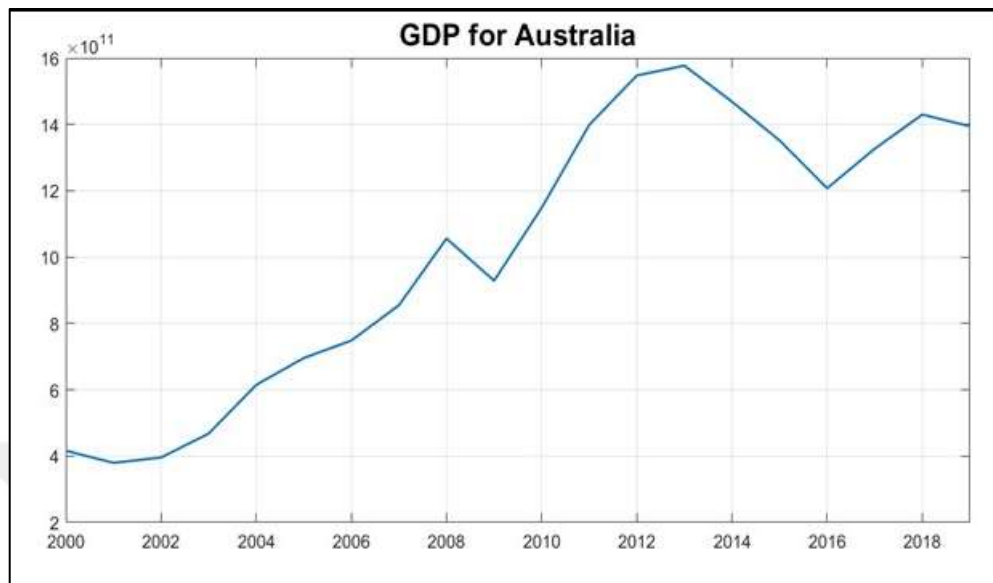


**Figure 5.20:** Input GDP (US\$) of Australia from 2000 to 2019.

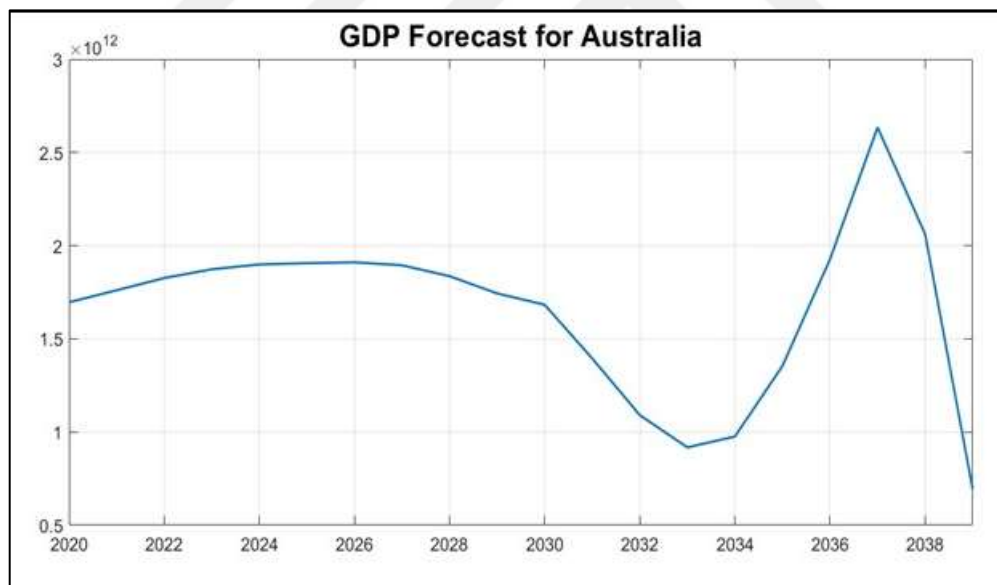


**Figure 5.21:** Forecast GDP (US\$) of Australia from 2020 to 2039.

#### 5.2.3.5 Comparison between forecast GDP and input GDP of other G20 countries

The other G20 group includes wealthy countries along with major developing economies like India, and South Africa are also play important role in world economic. The input GDP of these Countries from the period of 2000 to 2019 and the forecasted GDP is from the span

of 2020 till 2039 is shown in Annexure B. The Comparative analysis of G20 countries is explained further.

### 5.2.3.6 Comparison of input GDP and forecasted GDP of G20 countries

The figure 37 illustrated the comparison of input GDP of G 20 countries as it is visible that US has highest economic growth and increasing GDP from 2000 to 2019. The EU secured second highest GDP among all the countries. The China stand at the third highest GDP. But after the pandemic of COVID-19, US somehow manage to stable the GDP at the highest level after Argentina as mentioned in figure 38. The Canada secure the third highest GDP among all the G20 countries.

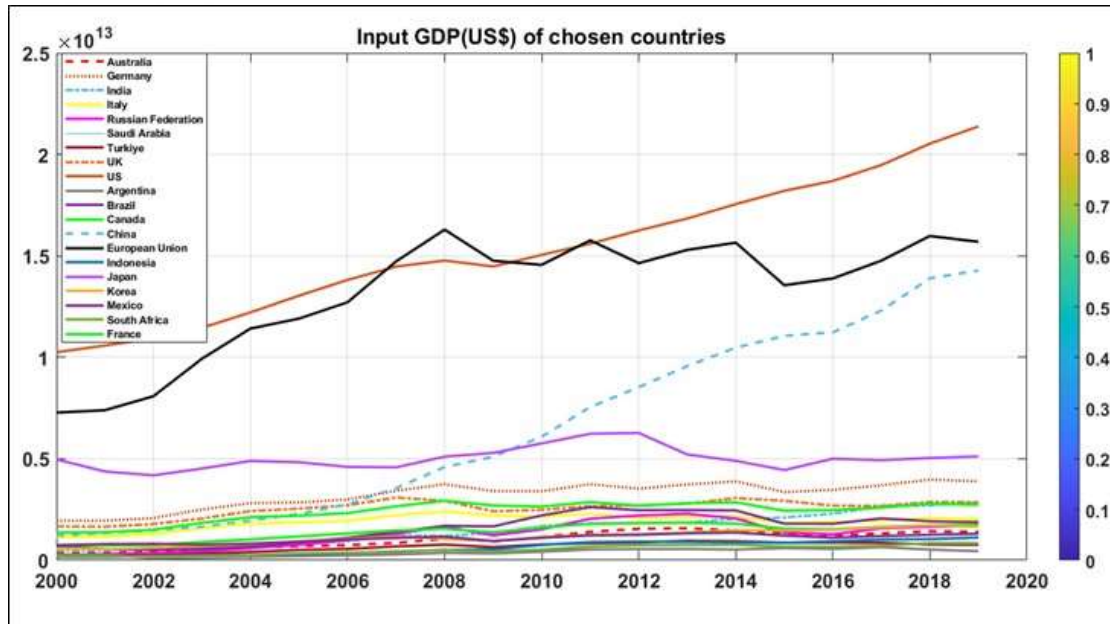


**Figure 5.22:** Input GDP (US\$) of G20 Countries from 2000 to 2019.

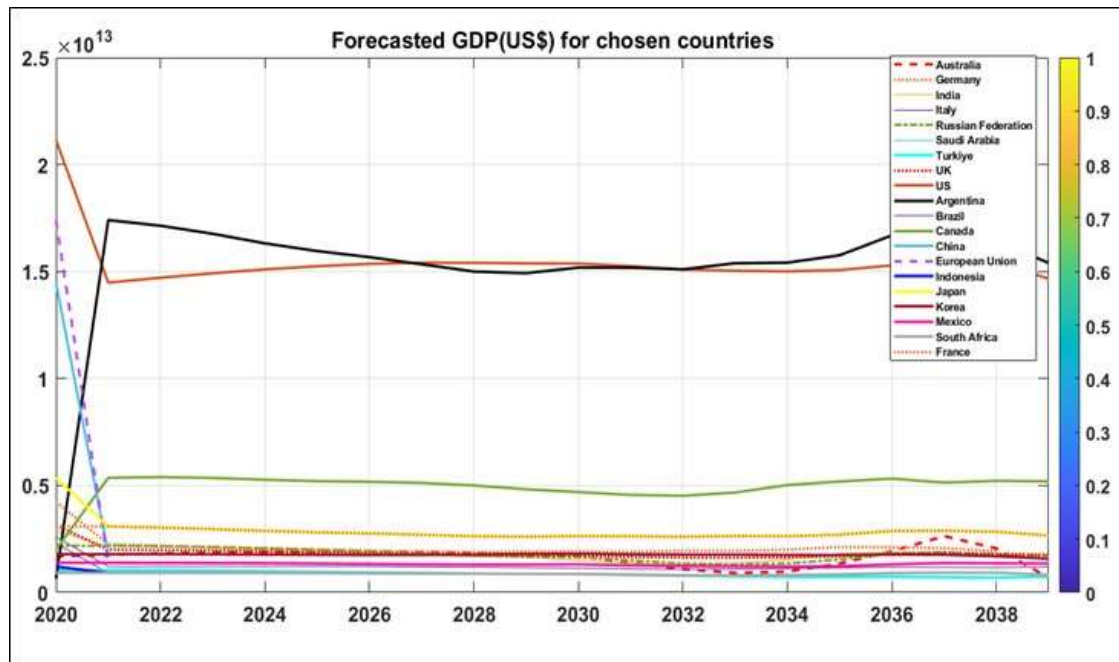


**Figure 5.23:** Forecasted GDP (US\$) of G20 Countries from 2019 to 2039.

### 5.3 REGION WISE COMPARISON

COVID-19 pandemic has had different effects on economies across different sectors, based on different factors such as healthcare infrastructure, economic diversification, policy responses, and sectorial composition. Region specific assessment looks at the different impacts of the pandemic on GDP and economic indicators in significant regions across the globe.

#### 5.3.1 North America

##### 5.3.1.1 Economic indicators

**GDP Growth Rates:** North America, comprising the United States and Canada primarily, experienced severe economic contractions in early 2020, followed by a robust recovery driven by fiscal stimulus and vaccination efforts. GDP forecasts indicate a gradual return to pre-pandemic levels by 2023, with sectors like technology and healthcare leading the recovery.

**Unemployment Rates:** Initial spikes in unemployment were mitigated by government support programs, leading to a steady decline as economic activity resumed.

*Inflation Rates:* The temporary increase in inflation was caused by disruptions in the supply chain and the rise in consumer demand. Forecasts predict supply chains reversing and demand decreasing, and inflation will stabilize.

### ***Policy implications***

*Fiscal Policies:* North American governments implemented extensive fiscal stimulus plans to aid households and businesses, which led to an increase in consumer spending and investment.

*Monetary Policies:* Central banks kept monetary policy flexible, such as asset purchases and interest rate reduction, to promote economic recovery.

### ***Sectorial impact***

*Technology:* Digital services and remote work helped the tech sector grow, which in turn stimulated GDP contributions and job creation.

*Manufacturing:* Manufacturing strategies were needed to cope with the disruptions in global supply chains, restoring initiatives and investments in advanced manufacturing technologies.

## **5.3.2 Europe**

### **5.3.2.1 Economic indicators**

*GDP Growth Rates:* Europe, including countries like France, Germany, Italy, and the United Kingdom, saw varied GDP contractions initially, followed by a recovery shaped by vaccine distribution and economic reopening strategies.

*Unemployment Rates:* Government support programs stabilized unemployment rates, although sectors reliant on tourism and hospitality continued to face challenges.

*Inflation Rates:* Supply chain disruptions and increased consumer demand initially drove inflation. Stabilization is expected as supply chains normalize and demand patterns adjust.

### ***Policy implications***

*Fiscal Policies:* EU countries coordinated fiscal responses, emphasizing recovery funds and structural reforms to support economic resilience post-Brexit and pandemic.

*Monetary Policies:* European Central Bank policies focused on maintaining liquidity and supporting credit availability to aid recovery efforts.

### ***Sectorial impact***

*Tourism:* The tourism sector struggled due to travel restrictions, impacting GDP growth and employment in related industries.

*Healthcare:* Increased investments in healthcare infrastructure and pharmaceuticals bolstered the sector resilience and preparedness for future health crises.

## **5.3.3 Asia**

### **5.3.3.1 Economic indicators**

*GDP Growth Rates:* Asia, including Japan, showed varied recovery paths, with export-driven economies like South Korea and manufacturing giants like China leading the rebound.

*Unemployment Rates:* Policies aimed at retaining jobs and supporting businesses mitigated unemployment spikes, particularly in export-oriented sectors.

*Inflation Rates:* Economic reopening and recovery efforts led to temporary inflationary pressures, which are expected to stabilize as economies normalize.

### ***Policy implications***

*Fiscal Policies:* Governments implemented stimulus measures and investment incentives to stimulate domestic demand and support key industries.

*Monetary Policies:* Central banks adjusted policies to ensure liquidity and maintain financial stability amid global uncertainties.

### ***Sectoral impact***

*Manufacturing:* Asia's manufacturing sector benefited from global demand recovery, although supply chain disruptions initially posed challenges.

*Technology:* Technological advancements and digital transformations accelerated across Asia, driving growth in the tech sector and enhancing economic resilience.

### **5.3.4 Asia-Pacific**

#### **5.3.4.1 Economic indicators**

*GDP Growth Rates:* Asia Pacific nations, led by China, experienced rapid growth due to early containment measures and strong exports. GDP is expected to grow at a steady pace, driven by domestic consumption and technology exports.

*Unemployment Rates:* Technology and e-commerce are key drivers of job growth in different countries. Those with diverse economic bases have resilient labour markets.

*Inflation Rates:* In a few Asian Pacific nations inflation was not as bad as it should have been thanks to relatively stable commodity prices and effective inflation control policies.

#### ***Policy implications***

*Infrastructure Investments:* Governments prioritized infrastructure investments to promote economic growth and improve connectivity, with a particular focus on digital infrastructure.

*Trade Policies:* Asia Pacific nations used regional trade agreements and export-oriented strategies to capitalize on the global trade rebound after a pandemic.

#### ***Sectorial impact***

*Technology:* Asia-Pacific region has become a technology hub thanks to digital transformation and innovation, which has helped to boost its economic strength and competitiveness.

*Manufacturing:* Exports of electronics and automotive industries have accelerated, according to forecasts.

*Healthcare:* Healthcare infrastructure and vaccine production helped the sector stay stable during a pandemic.

### **5.3.5 Latin America**

*Impact of COVID-19:* Latin America, including Brazil, Mexico, and Argentina, struggled with high infection rates and weaker healthcare systems, exacerbating economic downturns. The region faced challenges in commodity exports and domestic demand.

*GDP Forecast:* GDP forecasts for Latin America were initially bleak with significant contractions in 2020. Recovery was slower compared to other regions due to ongoing health challenges and limited fiscal space for extensive stimulus measures.

### **5.3.6 Middle East**

*Impact of COVID-19:* The Middle East experienced varying impacts depending on oil prices, tourism revenues, and economic diversification efforts. Oil-exporting countries faced revenue declines, while non-oil sectors were affected by reduced global demand and travel restrictions.

*GDP Forecast:* GDP forecasts for the Middle East reflected economic contractions in oil-exporting countries, offset to some extent by recovery in non-oil sectors in countries like the UAE and Saudi Arabia. Economic diversification efforts supported resilience in some economies.

*Overall Comparison:* While all regions faced economic challenges due to COVID-19, the severity and pace of recovery varied significantly. North America and East Asia showed quicker rebounds supported by robust fiscal responses and effective vaccine rollouts. Western Europe and Latin America faced slower recoveries due to persistent health challenges and sector-specific vulnerabilities. Sub-Saharan Africa and the Middle East experienced economic contractions, with recovery prospects tied closely to global commodity prices and domestic economic reforms. Understanding these regional dynamics helps in assessing global economic resilience and recovery trajectories post-pandemic.

## **5.4 COMPARISON OF STUDIES**

This section of the chapter compares the aforementioned studies with this research and discusses the impact as tabulated below:

**Table 5.1:** Results in Comparison with Existing Studies.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>The research work conducted by Singh, R (2020) on Impact of COVID-19 on GDP of major economies, the work highlights the need for strong corrective measures by central banks and governments, citing examples of rescue packages announced by the US and Indian governments. To mitigate the economic impact of the COVID 19 pandemic the author recommended that larger rescue packages may be required. The suggested model predicts GDP figures accurately with an error of less than 2%. The results shows a significant decline in economic growth for all countries in the April-June 2020. The main drawback of the study is that the researcher only conduct study to forecast GDP for 8 countries only that will not give the bigger picture in the world economy.</p>                                                                                                                                                                                                        | <p>This work presents the data from the period of 2000 to 2019, per COVID-19 pandemic, which shown the economic growth of the targeted countries which comprise of various regions. The significant of this study is that it predicts the post COVID-19 GDP of various countries around the World till 2039. The study indicates that there is sudden down fall of GDP in most countries after the COVID-19 but after some period the GDP became stabilized for some region but not same for all the countries around the world.</p> |
| <p>The research Oluwatobi, et al. (2022) Work on the impact on Global Economy and steps to turn crisis into opportunities. This work highlights the COVID-19 pandemic impact on the global economy and argues for a shift to a circular economy framework to achieve sustainable development. It suggested for a structural change in life style and work atmospheres by, providing sector-specific recommendations for circular economy solutions to catalyse global economic growth and development. The author recommends that the policy-makers should take steps to rethink and change the atmospheres of living and work atmosphere as well, this will prioritize human well-being and the health of the planet. The main drawback of this suggestion is that re-structuring the policy and living and working pattern may be difficult to adopt by every country. The long-term impact on the economy is not considered by the author that may fail to adopt by every country.</p> | <p>This research focus on the long-term economic growth and the prediction of GDP till 2039. The policy maker of each country, as well as regions may alter the policies according to the future prediction. This will improve the economic growth of the regions as per the factors that effects the GDP of each region. The future prediction of GDP may help to take necessary and precautionary action to stabilize, improve and uplift the GDP of countries according to the present needs.</p>                                 |

**Table 5.1: Results in Comparison with Existing Studies “Table Continued”.**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>The author Kumar, A. et al. (2022) work on the Global Impacts of Pre and Post COVID-19 Pandemic that Focus on Socio-economic Consequences. The research is basically based on the WHO report that emphasizes COVID-19 pandemic has had significant social and economic impacts worldwide, including declines in income, increases in unemployment, and disruptions in various sectors. Preventive actions are necessary to prevent infection spread, save lives, and mitigate economic losses. Behavioural and sociological factors influence individual and collective responses to the pandemic. The future prediction of GDP is not mention by the author. The post pandemic situation is certain but the long-term plan is not mention to cope the pandemic outcome.</p> | <p>This work shows the GDP of various countries and region that show the pre and post COVID-19 pandemic GDP for the period of 2000 to 2039. This work helps the policy makers to take necessary action the will help to uplift the income, produce employment, and improvement in various sectors, take preventive actions that are necessary to prevent infection spread, save lives, and mitigate economic losses. This help to take some concrete measure for the future pandemic if occurs.</p>                       |
| <p>The research Mishra et al. (2020) work on World after COVID-19 and its impact on Global economy. This work suggested that urgent policy measures are needed to control over pandemic and save lives, not only that but also to protect the most vulnerable in our societies from economic crisis and to sustain economic growth and financial stability. It has been suggested that Foreign direct investment (FDI) become a latest factor in order to bring capital, as well as job opportunities, technology and management skills to many developing nations. Some developing countries have seen major benefits from these investments in terms if economic development and rising standards of living.</p>                                                              | <p>This work shows that the major economic stable countries like US, Canada, Russia, and EU are also facing economic burden after the COVID-19 pandemic and the predicted result shows that till 2039 some countries will face economic distress therefore Foreign direct investment (FDI) may not be a long-term solution to stabilize the economy. Each country should take some precautionary measures to become economic stable and which provide job opportunities and improve technology and management skills.</p> |

**Table 5.1:** Results in Comparison with Existing Studies “Table Continued”.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>The author Esmaeili et al. (2020) research on the potential impact of COVID-19 Pandemic on occupational status, work from, and occupational mobility. The work suggested that three occupational related domains that may have greatly affected by pandemic. First domain is occupational supply and demand, second domain is work from home and third domain is increased segmentation of the labor market. It might benefit for some organization but increase unemployment of physical labours.</p>                                                                                                                                                                                                       | <p>This work did not support of the increase unemployment rate through work from home, segmentation of labour market and unbalance the occupational supply and demands. The main focus is to estimate the GDP of various region and identify the factors that can influence the GDP in upcoming years. This work will help to reshape the policies that can reduce unemployment, balance the segmentation of labor market and occupational supply and demand.</p> |
| <p>The researcher Alam et al. (2021) work on forecasting the GDP growth and economic impact of COVID-19. The aim of this article was to effectively measure the impact of COVID-19 on aggregate economic activity in Greece and 7 other Euro countries. This work suggested that the quantile modelling approach improves the ability to adequately explain real GDP growth with standard conditions.</p>                                                                                                                                                                                                                                                                                                       | <p>Comparative to this work the Alam et al. (2021) only target Greece and seven other Euro countries. That will not give a larger picture of economic stress of different regions. On the other hand, this work target countries of different regions that will give the bigger picture of economic condition of different regions. That will impact the world economy and GDP.</p>                                                                               |
| <p>In the post by Daniel Aaronson published by Chicago feds insight entitle with potential jobs impacted by COVID-19. The post indicates that rounded up from 9 to 26 million jobs could be affected due to COVID-19, with their best estimate being around 15 million. The author also clear that this exercise isn't a definitive prediction but rather an attempt to outline the potential scope of the crisis. They suggest that the unemployment rate with their estimate sitting around 15%. The main drawback of the post is that it did not predict the long-term GDP effect on the country economy. Job affected by COVID -19 is only a single factor among different factors that affect the GDP.</p> | <p>This research not only illustrate the GDP of different countries from the time period of 2000 to 2019, but also estimate the forecasted GDP of different countries. That will help to reshape the polices that will reduce the unemployment rate in the countries.</p>                                                                                                                                                                                         |

**Table 5.1:** Results in Comparison with Existing Studies “Table Continued”.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>The researcher Luciano Ciravegna et al. (2021) highlighted that COVID-19 Pandemic has caused a rise in inequality across and between nations and has reversed previous patterns of poverty alleviation, a result that ultimately fuels anti-globalization sentiments. Pandemic has caused populism, nationalism, and the restoration of the interventionist state to the economy, leading to a rise in protectionism. The work emphasizes that there is a great opportunity for IB scholars to engage in meaningful research to improve the world economy.</p>                                                                                                                                                                                   | <p>The causes are well identified by Luciano Ciravegna et al. (2021) but there should be a long-term estimation on the decline phase of GDP. The work highlighted that after the pandemic of COVID-19 the sharp decline occurs from the span of 2020 to 2021 in GDP but how it prevails has not illustrated. On the other hand, this research not only give the illustration of pre-pandemic GDP estimation also give the post pandemic GDP estimation till 2039 that will help to shape the economic strategies.</p> |
| <p>The researcher Tarek Ben Hassen (2020) work on the title GCC Economies in the Wake of COVID-19: Toward Post-Oil Sustainable Knowledge-Based Economies. The work highlights three main objectives the first is outlining the socio-economic landscape of the GCC, assessing how the pandemic accelerated diversification initiatives, and examining the current state of knowledge-based economies in the region. It employs a semi-systematic literature review to underscore the progress in ICT, education, innovation, and entrepreneurship, which have bolstered international competitiveness. Despite these advancements, challenges persist in achieving diversification, stemming from functional, structural, and cultural factors.</p> | <p>In support of the work presented by Tarek Ben Hassen (2020) decreasing the oil price is not the way to control the GDP. There should be a long-term analysis and the safety measures should be taken by the economist to stable the GDP. The knowledge-based economy is one of the ways to improve the GDP and strengthen the economic growth. This work will help to estimate the other factors that will help to improve the economic growth and strengthen the GDP in long term.</p>                            |

## 5.5 SUMMARY

This chapter give the brief discussion about the impact of COVID-19 pandemic on Global Economic after and before Forecasting. The Countries chosen for comparison encompass a wide range of regions worldwide, such as Asia, Europe, North American, Oceanic regions,

and the Middle East. G7, G8 and G20 nations are compared. The GDP of almost all countries in the G7 has grown from 2000 to 2019 but the United States has the highest growth rate and it is continuously increasing, indicating that our economy is experiencing the strongest economic growth. The expected GDP of G7 countries 25 forecasted after the pandemic indicates that the Canada has the highest GDP after the COVID-19 outbreak. While France is the second highest GDP in the world. For the region of G20 countries the US economy and GDP growth has been highest among all G20 countries while EU's GDP was the second highest among all countries. The GDP was stabilized only in US after the COVID-19 outbreak, ranking only second to Argentina. Canada GDP is the third highest among the 20 countries in the world. Russia is the only country in G8 along with the G7 country the Russian Federation has the lowest GDP among all the G8 countries after the pandemic. This session contributes to estimate the forecasted GDP from 2021 to 2039 of various countries and regions. This will help to reshape the policies that will strengthen the GDP.

## **6. CONCLUSION AND FUTURE WORK**

### **6.1 CONCLUSION**

Conclusively, this research has developed a methodology for forecasting the GDP globally during the COVID-19 pandemic using machine learning algorithms. According to the available dataset, which comprises of 20 countries from G7, G8 and G20 block from 2000 to 2019, the forecasted GDP has received as an output of this study. The employment of ML techniques such as AdaBoost, BNN, and LR has built a framework for predicting GDP and understanding the global economy dynamics. The adaptability of AdaBoost, the probabilistic identity of BNN, and the interpretability of LR conjointly contribute to understanding of economic relationships, offering valuable solutions for policymakers and economists.

This methodology plays an important role in the volatile economic arena particularly disturbed after COVID-19, where traditional models didn't perform well. While conversely, LR has become influencing factor to make a linear relationship between GDP and chosen variables. While Adaboost admits data to improve the predictive accuracy by making the combination of weak classifier and forms a strong classifier. Furthermore, the unique property of BNN offers more realistic and probabilistic approach.

From the findings and discussions, it was observed that among all chosen models; BNN performed well and showed high accuracy. It was also found that other models also competed well and showed good accuracy.

### **6.2 FUTURE RECOMMENDATION**

For future prospect, the study aims to enhance the methodology, deepen the understanding of economic dynamics during COVID-19 pandemic, and contribute to build the resilient and adaptive economic systems. Furthermore, the exploration of more advanced ML algorithms such as reinforcement learning algorithms to solve more complex and non-linear economic problems.

Employing high-frequency economic indicators and real-time data trends into the combination of machine learning models could enhance the accuracy and timeliness of GDP forecasts. Exploring the utilization of alternative data sources; such as satellite imagery,

social media sentiment analysis, and mobility trends; may provide valuable insights into economic activity dynamics during times of crisis.

Furthermore, improving the transparency and reliability of GDP forecasts by quantifying measures and providing probabilistic predictions is critical for informed decision-making and risk management. Employing probabilistic ensemble techniques, such as bootstrapping, Bayesian inference, and Monte Carlo simulations, can boost probabilistic forecasts that capture the inherent uncertainty associated with economic forecasting in volatile environments.

In a nutshell, there is vast scope of forecasting GDP by using machine learning models in future prospect to deepen our understanding of the impact of COVID-19 on the global economy and inform evidence-based policy responses. By embracing innovative methodologies, leveraging diverse data sources, and fostering interdisciplinary collaboration, researchers can contribute to more resilient and adaptive economic systems in the face of uncertainty and disruption.

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# APPENDIX A

**Table A.1:** GNI Per Capita (Current International \$).

| Country Name       | Indicator Name                                 | 2000     | 2001     | 2002     | 2003  | 2004     | 2005    | 2006     | 2007     | 2008     | 2009     | 2010     | 2011     | 2012     | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | 2020    | 2021     | 2022     |
|--------------------|------------------------------------------------|----------|----------|----------|-------|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|----------|----------|
| Argentina          | GNI per capita, PPP (current international \$) | 11240    | 10840    | 9480     | 10530 | 10810    | 11980   | 14410    | 16080    | 16910    | 15730    | 17450    | 18770    | 19170    | 19680    | 19250    | 19680    | 19800    | 22910    | 23620    | 22610    | 21700   | 25560    | 28490    |
| Australia          | GNI per capita, PPP (current international \$) | 25780    | 26870    | 28230    | 29270 | 30860    | 31810   | 33490    | 35020    | 36000    | 36900    | 37940    | 40340    | 41560    | 44790    | 45690    | 45350    | 46170    | 47090    | 48670    | 50970    | 52840   | 56780    | 62920    |
| Brazil             | GNI per capita, PPP (current international \$) | 8740     | 8800     | 9190     | 9390  | 10100    | 10640   | 11320    | 12160    | 12960    | 12930    | 13810    | 14600    | 14690    | 15150    | 15270    | 14790    | 13780    | 14030    | 14740    | 15330    | 15430   | 16900    | 18530    |
| Canada             | GNI per capita, PPP (current international \$) | 28590    | 29380    | 30180    | 31550 | 33190    | 35580   | 37510    | 38990    | 39780    | 38200    | 39310    | 40880    | 41540    | 43620    | 45010    | 45990    | 45900    | 47700    | 49140    | 49920    | 48000   | 55310    | 60760    |
| China              | GNI per capita, PPP (current international \$) | 2880     | 3160     | 3500     | 3910  | 4420     | 5020    | 5830     | 6830     | 7630     | 8230     | 9220     | 10200    | 11210    | 11910    | 12720    | 13140    | 13810    | 14730    | 15940    | 17210    | 17750   | 20260    | 22260    |
| European Union     | GNI per capita, PPP (current international \$) | 22026.25 | 23864.69 | 24004.97 | 24521 | 25724.04 | 26741.5 | 29077.11 | 30073.88 | 32276.62 | 31718.83 | 32808.82 | 34455.06 | 34971.59 | 36120.12 | 37095.57 | 38089.82 | 40497.56 | 42620.65 | 44728.65 | 46265.41 | 47009.7 | 52118.13 | 57238.07 |
| France             | GNI per capita, PPP (current international \$) | 26500    | 27390    | 28820    | 28540 | 29460    | 31020   | 33110    | 34800    | 35860    | 35470    | 36730    | 38430    | 38500    | 40410    | 41010    | 41730    | 43830    | 45380    | 47620    | 52340    | 49880   | 55020    | 58610    |
| Germany            | GNI per capita, PPP (current international \$) | 27050    | 28180    | 28870    | 29610 | 31520    | 32060   | 34740    | 36820    | 38160    | 37540    | 39730    | 43630    | 44400    | 46040    | 47950    | 48690    | 51830    | 54340    | 57060    | 60430    | 59560   | 64330    | 69110    |
| India              | GNI per capita, PPP (current international \$) | 2070     | 2180     | 2260     | 2440  | 2660     | 2920    | 3200     | 3590     | 3610     | 3870     | 4170     | 4430     | 4780     | 4970     | 5150     | 5380     | 5790     | 6100     | 6670     | 7110     | 6890    | 7880     | 8990     |
| Indonesia          | GNI per capita, PPP (current international \$) | 4370     | 4710     | 4970     | 5190  | 5490     | 5890    | 6360     | 6870     | 7370     | 7660     | 8210     | 8770     | 9350     | 9670     | 9830     | 9800     | 10040    | 10460    | 11130    | 11750    | 11530   | 12530    | 14050    |
| Italy              | GNI per capita, PPP (current international \$) | 26970    | 27360    | 28610    | 29060 | 29510    | 30180   | 32380    | 34180    | 35300    | 34580    | 35080    | 36510    | 36440    | 36150    | 36200    | 36640    | 40040    | 41810    | 43510    | 46840    | 44770   | 50550    | 55940    |
| Japan              | GNI per capita, PPP (current international \$) | 27680    | 28380    | 29040    | 29870 | 31430    | 32880   | 34530    | 36090    | 36200    | 34390    | 36280    | 37270    | 38640    | 40790    | 41030    | 42510    | 42010    | 42980    | 43750    | 44350    | 43920   | 46440    | 49820    |
| Korea, Rep.        | GNI per capita, PPP (current international \$) | 18410    | 19590    | 21320    | 22020 | 23730    | 25010   | 26810    | 28990    | 29950    | 29460    | 31780    | 32750    | 33910    | 34460    | 35500    | 38020    | 39720    | 41120    | 43220    | 44240    | 45540   | 49140    | 52430    |
| Mexico             | GNI per capita, PPP (current international \$) | 11530    | 11610    | 11690    | 12000 | 12600    | 13110   | 14370    | 14680    | 15570    | 15090    | 15890    | 17170    | 17790    | 17800    | 18530    | 18740    | 19700    | 20060    | 20470    | 20500    | 18850   | 20580    | 23350    |
| Russian Federation | GNI per capita, PPP (current international \$) | 6550     | 7160     | 7880     | 8970  | 10010    | 11540   | 14480    | 16280    | 19600    | 18780    | 19860    | 22130    | 23560    | 25170    | 24910    | 23420    | 23460    | 25130    | 28120    | 30220    | 31010   | 38060    | 39950    |
| South Africa       | GNI per capita, PPP (current international \$) | 7980     | 8250     | 8670     | 9000  | 9630     | 10360   | 11170    | 11820    | 12300    | 12150    | 12520    | 12970    | 12810    | 13240    | 13230    | 13290    | 13370    | 13590    | 13260    | 13360    | 12850   | 13900    | 15010    |
| Turkey             | GNI per capita, PPP (current international \$) | 9580     | 8890     | 9110     | 9420  | 10710    | 11740   | 13440    | 14730    | 15880    | 15380    | 17200    | 19420    | 20470    | 22170    | 23880    | 23570    | 26410    | 27840    | 27900    | 28020    | 28340   | 31230    | 37390    |
| United Kingdom     | GNI per capita, PPP (current international \$) | 26600    | 28070    | 29430    | 30660 | 32320    | 33070   | 34600    | 35200    | 36160    | 34730    | 36500    | 37380    | 37990    | 39250    | 40540    | 41570    | 43050    | 45550    | 46450    | 46860    | 46980   | 55130    | 57750    |
| United States      | GNI per capita, PPP (current international \$) | 36800    | 37710    | 38430    | 39760 | 42070    | 44550   | 47740    | 48300    | 49400    | 47030    | 49050    | 50870    | 53130    | 54580    | 56670    | 58180    | 58870    | 61160    | 64060    | 66290    | 64770   | 71130    | 77550    |
| Saudi Arabia       | GNI per capita, PPP (current international \$) | 36340    | 37970    | 36490    | 40310 | 43860    | 46390   | 47340    | 47650    | 49970    | 47560    | 48540    | 53810    | 55280    | 54410    | 54860    | 48630    | 45730    | 47110    | 49340    | 47390    | 40580   | 48590    | 55400    |

Table A.2: CO2 Emissions (Metric Tons Per Capita).

| Country Name       | Indicator Name                         | 2000     | 2001     | 2002     | 2003     | 2004     | 2005     | 2006     | 2007     | 2008     | 2009     | 2010     | 2011     | 2012     | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | 2020     |
|--------------------|----------------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Argentina          | CO2 emissions (metric tons per capita) | 3.567918 | 3.341877 | 3.100489 | 3.334891 | 3.655085 | 3.735717 | 3.924627 | 4.083151 | 4.152375 | 3.848348 | 4.099844 | 4.281028 | 4.264111 | 4.34275  | 4.209112 | 4.301914 | 4.201816 | 4.070112 | 3.975651 | 3.74203  | 3.40518  |
| Australia          | CO2 emissions (metric tons per capita) | 17.83732 | 17.93073 | 18.12321 | 17.89454 | 18.36887 | 18.27947 | 18.29275 | 18.45474 | 18.23929 | 18.1572  | 17.97375 | 17.66106 | 17.40562 | 16.79459 | 16.15575 | 16.19846 | 16.32033 | 16.14915 | 15.8657  | 15.59905 | 14.77614 |
| Brazil             | CO2 emissions (metric tons per capita) | 1.7835   | 1.792112 | 1.780651 | 1.701853 | 1.778441 | 1.775663 | 1.777478 | 1.847976 | 1.939215 | 1.789328 | 2.026806 | 2.110628 | 2.271418 | 2.413447 | 2.514592 | 2.365361 | 2.16126  | 2.185487 | 2.064361 | 2.05077  | 1.94523  |
| Canada             | CO2 emissions (metric tons per capita) | 16.75747 | 16.33144 | 16.72041 | 17.20836 | 16.79419 | 17.02757 | 16.59321 | 17.38063 | 16.55943 | 15.50451 | 15.79454 | 15.98827 | 15.73682 | 15.84081 | 15.85218 | 15.64991 | 15.42182 | 15.54419 | 15.63665 | 15.05275 | 13.99937 |
| China              | CO2 emissions (metric tons per capita) | 2.650409 | 2.774762 | 2.964821 | 3.434036 | 3.945155 | 4.467686 | 4.910776 | 5.306388 | 5.43079  | 5.79882  | 6.33542  | 6.901347 | 7.0452   | 7.320155 | 7.304713 | 7.145132 | 7.10548  | 7.22616  | 7.593193 | 7.645486 | 7.756138 |
| European Union     | CO2 emissions (metric tons per capita) | 7.83538  | 7.95761  | 7.920361 | 8.099947 | 8.079666 | 8.011893 | 8.005333 | 7.888365 | 7.680031 | 7.101275 | 7.282944 | 7.081678 | 6.934679 | 6.744306 | 6.40209  | 6.517123 | 6.525933 | 6.571147 | 6.415993 | 6.101852 | 5.50607  |
| France             | CO2 emissions (metric tons per capita) | 6.126515 | 6.141052 | 6.004364 | 6.052956 | 6.02632  | 6.026578 | 5.842388 | 5.670765 | 5.56404  | 5.314137 | 5.350408 | 5.127105 | 5.152358 | 5.127899 | 4.614807 | 4.675935 | 4.703476 | 4.747217 | 4.570517 | 4.440165 | 3.95882  |
| Germany            | CO2 emissions (metric tons per capita) | 10.09937 | 10.23961 | 10.10301 | 10.13876 | 9.950446 | 9.729463 | 9.88648  | 9.527523 | 9.617458 | 8.971731 | 9.453389 | 9.299003 | 9.451289 | 9.624229 | 9.08528  | 9.087345 | 9.072972 | 8.858345 | 8.537043 | 7.927188 | 7.252121 |
| India              | CO2 emissions (metric tons per capita) | 0.885078 | 0.883747 | 0.892243 | 0.905457 | 0.95547  | 0.984261 | 1.036354 | 1.123599 | 1.180361 | 1.278874 | 1.338034 | 1.396878 | 1.498204 | 1.527674 | 1.642465 | 1.631323 | 1.639914 | 1.704927 | 1.795595 | 1.752384 | 1.576093 |
| Indonesia          | CO2 emissions (metric tons per capita) | 1.310938 | 1.39128  | 1.388515 | 1.496673 | 1.510802 | 1.495369 | 1.572351 | 1.67182  | 1.580832 | 1.62826  | 1.702306 | 1.92542  | 1.92545  | 1.770402 | 1.891428 | 1.887564 | 1.848304 | 1.948574 | 2.126837 | 2.245286 | 2.071659 |
| Italy              | CO2 emissions (metric tons per capita) | 7.662108 | 7.662629 | 7.772184 | 8.064421 | 8.189341 | 8.173814 | 8.025944 | 7.880787 | 7.564925 | 6.718921 | 6.836875 | 6.880355 | 6.327652 | 5.752878 | 5.387443 | 5.563294 | 5.488244 | 5.437912 | 5.37894  | 5.311031 | 4.732373 |
| Japan              | CO2 emissions (metric tons per capita) | 9.337724 | 9.220202 | 9.46887  | 9.504764 | 9.449564 | 9.512764 | 9.331294 | 9.593603 | 9.048953 | 8.609231 | 9.03801  | 9.495701 | 9.827856 | 9.94495  | 9.564306 | 9.26805  | 9.166714 | 9.063591 | 8.761979 | 8.478401 | 8.031496 |
| Korea Rep.         | CO2 emissions (metric tons per capita) | 9.514045 | 9.640541 | 9.657782 | 9.686601 | 10.10574 | 9.982484 | 10.07162 | 10.34626 | 10.49694 | 10.68065 | 11.60783 | 11.9848  | 11.93853 | 11.89004 | 11.58872 | 11.91489 | 12.0162  | 12.19149 | 12.21646 | 11.82528 | 10.99003 |
| Mexico             | CO2 emissions (metric tons per capita) | 3.874146 | 3.811392 | 3.824988 | 3.95034  | 3.983826 | 4.089801 | 4.194183 | 4.220761 | 4.189727 | 4.037594 | 4.113211 | 4.19099  | 4.202414 | 4.056055 | 3.882355 | 3.925368 | 3.920323 | 3.862759 | 3.587489 | 3.612165 | 3.040766 |
| Russian Federation | CO2 emissions (metric tons per capita) | 10.66766 | 10.73578 | 10.77264 | 11.1304  | 11.11271 | 11.23185 | 11.56387 | 11.61127 | 11.59565 | 10.83211 | 11.3254  | 11.88456 | 11.70207 | 11.377   | 11.20821 | 11.05201 | 10.88743 | 11.0352  | 11.49657 | 11.79719 | 11.23228 |
| South Africa       | CO2 emissions (metric tons per capita) | 6.076553 | 6.783733 | 6.939514 | 7.338956 | 7.824764 | 7.704298 | 7.672712 | 7.948359 | 8.44665  | 7.902049 | 8.217612 | 7.880054 | 8.034649 | 8.116435 | 8.191153 | 7.607189 | 7.54459  | 7.683708 | 7.667377 | 7.688908 | 6.687663 |
| Turkiye            | CO2 emissions (metric tons per capita) | 3.37507  | 3.039265 | 3.159687 | 3.277514 | 3.313431 | 3.420478 | 3.751129 | 4.118808 | 4.042199 | 4.002087 | 4.071715 | 4.292989 | 4.387019 | 4.190395 | 4.426835 | 4.51829  | 4.747838 | 5.203879 | 5.08692  | 4.828561 | 4.88564  |
| United Kingdom     | CO2 emissions (metric tons per capita) | 9.014528 | 9.222025 | 8.944233 | 9.104093 | 9.05309  | 8.955401 | 8.908613 | 8.651031 | 8.33782  | 7.490594 | 7.889567 | 7.044843 | 7.344251 | 7.0761   | 6.43347  | 6.159376 | 5.824508 | 5.553291 | 5.405128 | 5.175947 | 4.601142 |
| United States      | CO2 emissions (metric tons per capita) | 20.4638  | 20.17154 | 19.44553 | 19.50651 | 19.59762 | 19.46927 | 18.94592 | 19.04291 | 18.27849 | 16.80868 | 17.43174 | 16.60419 | 15.78976 | 16.11118 | 16.04092 | 15.56002 | 15.14988 | 14.83225 | 15.22252 | 14.67338 | 13.03283 |
| Saudi Arabia       | CO2 emissions (metric tons per capita) | 11.58631 | 11.50485 | 12.03405 | 12.30315 | 12.67399 | 12.9231  | 13.21499 | 13.43244 | 14.0375  | 14.27221 | 15.16889 | 15.3814  | 15.97882 | 15.98992 | 16.82524 | 17.25779 | 16.7951  | 16.07779 | 15.0655  | 14.70302 | 14.26659 |

Table A.3: GDP Current \$.

| Country Name       | Indicator Name     | 2000               | 2001               | 2002               | 2003               | 2004               | 2005               | 2006               | 2007               | 2008               | 2009               | 2010               |
|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Argentina          | GDP (current US\$) | 284,203,750,000    | 288,696,750,000    | 97,724,004,252     | 127,586,979,492    | 164,657,930,453    | 198,737,095,012    | 222,257,260,817    | 287,230,508,431    | 361,598,097,110    | 332,976,494,578    | 423,627,422,092    |
| Australia          | GDP (current US\$) | 416,167,815,093    | 379,629,301,675    | 395,788,996,012    | 467,739,079,790    | 614,659,980,083    | 695,692,898,677    | 748,417,562,770    | 855,007,458,585    | 1,056,112,407,190  | 928,762,122,698    | 1,148,890,200,292  |
| Brazil             | GDP (current US\$) | 655,448,231,984    | 559,983,634,799    | 509,795,279,807    | 558,233,745,652    | 669,289,424,806    | 881,633,839,653    | 1,107,626,541,711  | 1,397,114,496,471  | 1,655,855,083,552  | 1,666,996,438,681  | 2,208,837,452,214  |
| Canada             | GDP (current US\$) | 744,773,415,992    | 738,981,792,355    | 760,649,344,098    | 895,540,646,635    | 1,026,690,228,278  | 1,173,108,598,779  | 1,319,464,809,591  | 1,468,820,407,783  | 1,552,989,690,722  | 1,374,652,142,157  | 1,617,343,674,966  |
| China              | GDP (current US\$) | 1,211,331,651,880  | 1,339,400,897,153  | 1,470,557,654,804  | 1,660,280,548,871  | 1,955,346,788,738  | 2,285,561,149,904  | 2,752,118,657,222  | 3,550,327,803,025  | 4,594,336,785,752  | 5,101,691,124,358  | 6,087,191,746,739  |
| European Union     | GDP (current US\$) | 7,276,390,991,857  | 7,399,612,739,233  | 8,083,519,004,562  | 9,932,133,486,285  | 11,418,900,352,971 | 11,910,068,707,012 | 12,712,635,610,430 | 14,727,519,982,191 | 16,295,383,915,395 | 14,762,732,194,093 | 14,556,037,351,406 |
| France             | GDP (current US\$) | 1,365,639,680,792  | 1,377,657,339,281  | 1,501,409,382,971  | 1,844,544,799,037  | 2,119,633,181,634  | 2,196,945,232,436  | 2,320,536,221,305  | 2,660,591,246,212  | 2,930,303,780,828  | 2,700,887,366,932  | 2,645,187,882,117  |
| Germany            | GDP (current US\$) | 1,947,981,991,012  | 1,945,790,973,803  | 2,078,484,517,475  | 2,501,640,388,482  | 2,814,353,869,359  | 2,946,864,211,175  | 2,994,703,642,024  | 3,425,578,382,922  | 3,745,264,093,617  | 3,411,261,212,652  | 3,399,667,820,000  |
| India              | GDP (current US\$) | 468,394,937,256    | 485,441,014,539    | 514,937,940,874    | 607,699,283,436    | 709,148,514,816    | 820,381,595,511    | 940,259,888,794    | 1,216,736,438,842  | 1,198,895,139,015  | 1,341,888,016,984  | 1,675,615,194,469  |
| Indonesia          | GDP (current US\$) | 165,021,012,078    | 160,446,947,785    | 195,660,611,165    | 234,772,463,824    | 254,836,875,295    | 285,868,619,196    | 364,570,515,618    | 432,216,737,775    | 510,228,634,991    | 539,580,085,616    | 755,094,157,622    |
| Italy              | GDP (current US\$) | 1,146,676,894,210  | 1,168,023,426,056  | 1,276,769,338,449  | 1,577,621,707,051  | 1,806,542,988,546  | 1,858,217,147,204  | 1,949,351,719,390  | 2,213,102,482,751  | 2,408,655,348,719  | 2,199,928,904,119  | 2,136,099,955,237  |
| Japan              | GDP (current US\$) | 4,968,359,075,957  | 4,374,711,694,081  | 4,182,846,045,874  | 4,519,561,646,254  | 4,893,116,006,657  | 4,881,467,035,390  | 4,601,683,122,650  | 4,579,750,900,355  | 5,106,679,115,127  | 5,289,493,117,994  | 5,759,071,689,013  |
| Korea Rep.         | GDP (current US\$) | 576,179,387,820    | 547,656,279,895    | 627,246,933,730    | 702,714,855,194    | 793,175,561,887    | 994,901,071,333    | 1,053,216,909,888  | 1,172,614,086,540  | 1,047,339,010,225  | 943,944,876,219    | 1,143,672,441,150  |
| Mexico             | GDP (current US\$) | 742,061,329,643    | 796,064,590,656    | 810,666,116,505    | 765,549,967,889    | 819,459,227,375    | 917,571,853,446    | 1,020,685,057,699  | 1,102,355,554,789  | 1,161,553,459,895  | 943,437,415,099    | 1,105,424,238,889  |
| Russian Federation | GDP (current US\$) | 259,710,142,197    | 306,602,070,621    | 345,470,394,418    | 430,347,420,185    | 591,016,630,732    | 764,015,973,481    | 989,932,071,553    | 1,299,703,478,482  | 1,660,348,058,303  | 1,222,645,900,056  | 1,524,916,715,224  |
| South Africa       | GDP (current US\$) | 151,752,757,215    | 135,429,905,903    | 129,087,556,612    | 191,018,966,309    | 255,806,908,595    | 288,867,217,197    | 303,658,675,364    | 339,077,117,254    | 316,131,258,616    | 329,754,080,647    | 417,363,822,802    |
| Turkiye            | GDP (current US\$) | 274,294,623,164    | 201,753,123,807    | 240,249,071,871    | 314,595,571,146    | 408,865,430,200    | 506,314,717,662    | 557,076,157,773    | 681,321,124,296    | 770,449,132,861    | 649,286,324,628    | 776,967,266,306    |
| United Kingdom     | GDP (current US\$) | 1,665,334,876,883  | 1,649,827,283,567  | 1,785,729,516,067  | 2,054,422,857,143  | 2,421,252,082,387  | 2,543,180,000,000  | 2,708,441,582,337  | 3,090,510,204,082  | 2,929,411,764,706  | 2,412,840,006,232  | 2,485,482,596,185  |
| United States      | GDP (current US\$) | 10,250,947,997,000 | 10,581,929,774,000 | 10,929,112,355,000 | 11,556,442,041,000 | 12,217,193,198,000 | 13,039,199,193,000 | 13,815,586,948,000 | 14,474,226,905,000 | 14,769,857,911,000 | 14,478,064,934,000 | 15,048,964,444,000 |
| Saudi Arabia       | GDP (current US\$) | 189,514,410,223    | 194,137,517,725    | 189,605,920,241    | 215,807,655,244    | 258,742,263,029    | 328,459,700,124    | 376,900,135,721    | 415,964,583,059    | 519,796,738,631    | 429,097,899,279    | 528,207,298,530    |

Table A.3: GDP Current \$ “Table Continued”.

| Country Name       | Indicator Name     | 2011               | 2012               | 2013               | 2014               | 2015               | 2016               | 2017               | 2018               | 2019               | 2020               | 2021               | 2022               |
|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Argentina          | GDP (current US\$) | 590,563,121,000    | 545,492,767,000    | 553,005,400,500    | 536,319,673,700    | 594,719,186,400    | 557,531,300,600    | 643,620,339,200    | 524,480,982,300    | 447,734,689,600    | 385,700,508,400    | 487,900,572,600    | 621,133,380,400    |
| Australia          | GDP (current US\$) | 1,398,701,321,000  | 1,507,649,336,700  | 1,577,301,940,200  | 1,498,597,690,000  | 1,351,763,461,100  | 1,207,530,901,570  | 1,246,602,100,817  | 1,429,733,686,106  | 1,394,671,325,601  | 1,301,381,544,900  | 1,559,033,796,200  | 1,691,565,646,600  |
| Brazil             | GDP (current US\$) | 2,494,565,213,977  | 2,462,277,830,012  | 2,477,883,955,700  | 2,456,640,717,499  | 1,802,712,706,905  | 1,795,660,402,600  | 2,063,144,977,334  | 1,916,693,888,038  | 1,879,238,205,106  | 1,476,407,131,194  | 1,649,612,118,000  | 1,920,095,779,033  |
| Canada             | GDP (current US\$) | 1,793,326,620,175  | 1,820,566,481,520  | 1,846,597,414,835  | 1,825,749,878,440  | 1,556,638,136,217  | 1,527,994,741,507  | 1,649,166,544,244  | 1,725,319,197,783  | 1,749,725,183,879  | 1,655,684,730,000  | 2,007,477,101,464  | 2,161,483,369,422  |
| China              | GDP (current US\$) | 7,551,545,703,518  | 8,551,185,580,696  | 9,570,471,111,948  | 10,475,524,944,300 | 11,061,972,885,955 | 11,233,313,702,899 | 12,310,951,339,901 | 13,489,497,667,906 | 14,779,968,506,243 | 14,607,744,662,001 | 17,820,499,508,851 | 17,963,071,479,105 |
| European Union     | GDP (current US\$) | 15,765,045,884,120 | 16,641,587,697,977 | 15,294,685,548,007 | 15,651,155,795,806 | 13,553,666,666,876 | 13,288,514,162,749 | 14,765,549,459,855 | 15,980,982,271,825 | 15,659,432,719,570 | 15,388,137,424,002 | 17,315,210,527,336 | 16,746,544,871,112 |
| France             | GDP (current US\$) | 2,865,151,541,944  | 2,669,671,765,967  | 2,811,676,933,299  | 2,855,594,488,500  | 2,439,884,642,163  | 2,472,964,344,587  | 2,595,151,065,198  | 2,793,668,078,717  | 2,728,870,246,706  | 2,647,403,691,598  | 2,999,355,919,171  | 2,779,092,294,506  |
| Germany            | GDP (current US\$) | 3,719,314,991,001  | 3,527,143,188,785  | 3,733,004,645,458  | 3,389,591,051,004  | 3,357,965,193,352  | 3,469,852,463,946  | 3,480,049,152,508  | 3,974,443,355,000  | 3,889,177,589,255  | 3,807,727,161,914  | 4,270,569,934,690  | 4,082,468,480,798  |
| India              | GDP (current US\$) | 1,823,051,829,901  | 1,827,637,390,787  | 1,865,721,977,681  | 2,039,126,479,218  | 2,103,983,360,066  | 2,294,736,885,683  | 2,661,479,248,735  | 2,702,489,641,707  | 2,835,646,256,636  | 2,671,339,405,987  | 3,119,306,839,142  | 3,416,645,826,653  |
| Indonesia          | GDP (current US\$) | 687,963,104,553    | 917,089,813,333    | 941,514,067,708    | 889,014,755,514    | 860,014,132,686    | 931,871,364,038    | 1,005,628,744,160  | 1,041,277,153,189  | 1,119,099,871,350  | 1,059,054,641,668  | 1,186,505,155,737  | 1,319,100,220,408  |
| Italy              | GDP (current US\$) | 2,294,991,296,900  | 2,086,957,566,822  | 2,141,914,424,289  | 2,142,008,615,897  | 1,826,627,711,064  | 1,877,071,687,634  | 1,961,796,179,334  | 2,109,139,242,367  | 2,011,310,198,827  | 1,897,461,635,592  | 2,155,360,298,998  | 2,044,737,165,408  |
| Japan              | GDP (current US\$) | 6,233,347,172,911  | 6,270,625,368,105  | 5,212,324,881,166  | 4,956,594,405,533  | 4,441,690,651,964  | 5,008,677,687,544  | 4,930,837,349,151  | 5,040,880,999,325  | 5,117,999,859,017  | 5,055,307,093,502  | 5,034,620,794,585  | 4,256,410,760,714  |
| Korea, Rep.        | GDP (current US\$) | 1,553,268,597,501  | 1,270,046,536,287  | 1,370,621,553,211  | 1,484,080,516,272  | 1,466,028,366,206  | 1,499,677,823,810  | 1,623,074,189,502  | 1,725,373,486,825  | 1,651,422,922,488  | 1,644,312,831,906  | 1,818,432,106,880  | 1,673,916,469,027  |
| Mexico             | GDP (current US\$) | 1,239,013,703,266  | 1,255,110,714,742  | 1,327,436,570,361  | 1,254,507,717,464  | 1,213,244,467,528  | 1,112,232,497,289  | 1,190,721,475,959  | 1,256,300,882,984  | 1,205,211,479,662  | 1,101,791,118,380  | 1,312,557,121,916  | 1,465,864,085,286  |
| Russian Federation | GDP (current US\$) | 2,045,917,513,368  | 2,208,793,539,878  | 2,293,470,073,346  | 2,093,410,589,885  | 1,363,882,182,198  | 1,276,736,365,081  | 1,574,199,340,069  | 1,667,310,773,461  | 1,659,115,002,708  | 1,493,075,984,362  | 1,836,892,755,546  | 2,240,421,427,459  |
| South Africa       | GDP (current US\$) | 458,393,484,811    | 434,003,465,086    | 407,886,613,586    | 381,188,869,776    | 346,709,790,459    | 323,586,509,674    | 381,448,816,655    | 405,360,773,893    | 388,330,821,271    | 398,291,386,006    | 420,117,812,464    | 405,270,860,959    |
| Turkiye            | GDP (current US\$) | 633,785,289,684    | 680,555,685,452    | 697,791,010,008    | 938,594,619,917    | 864,113,101,469    | 889,656,061,593    | 864,988,492,854    | 774,972,199,728    | 761,005,946,788    | 710,338,484,175    | 819,865,259,610    | 907,118,495,553    |
| United Kingdom     | GDP (current US\$) | 2,463,305,834,928  | 2,707,089,736,615  | 2,784,853,192,234  | 3,054,708,247,911  | 2,927,911,140,917  | 2,688,116,566,300  | 2,880,148,073,325  | 2,871,340,347,582  | 2,851,407,164,828  | 2,697,806,592,294  | 3,144,506,156,619  | 3,089,077,722,400  |
| United States      | GDP (current US\$) | 15,593,728,123,000 | 16,219,712,310,000 | 16,884,390,943,000 | 17,510,630,174,000 | 18,206,000,141,000 | 18,856,116,841,000 | 19,477,236,549,000 | 20,519,187,312,000 | 21,230,976,119,000 | 21,060,473,613,000 | 23,315,080,160,000 | 25,493,700,000,000 |
| Saudi Arabia       | GDP (current US\$) | 676,615,577,213    | 742,482,580,948    | 753,864,433,420    | 786,616,546,120    | 669,484,381,329    | 665,996,879,684    | 714,594,684,952    | 846,483,791,843    | 838,564,705,256    | 734,271,883,545    | 871,156,115,900    | 1,006,571,517,285  |

Table A.4: GDP Growth Annual %.

| Country Name       | Indicator Name        | 2000     | 2001     | 2002     | 2003     | 2004     | 2005     | 2006     | 2007     | 2008     | 2009     | 2010     | 2011     | 2012     | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | 2020     | 2021     | 2022     |
|--------------------|-----------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Argentina          | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | -0.789   | -4.40884 | -10.8946 | 8.837041 | 9.029573 | 8.85166  | 8.047152 | 9.007651 | 4.057233 | -5.91853 | 10.1254  | 6.003952 | -1.02642 | 2.405324 | -2.51262 | 2.73116  | -2.08033 | 2.818303 | -2.6174  | -2.00086 | -9.90048 | 10.71801 | 4.95637  |
| Australia          | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 3.921518 | 2.02127  | 3.979534 | 3.096687 | 4.224322 | 3.154139 | 2.755298 | 3.773393 | 3.586228 | 1.892574 | 2.226538 | 2.489872 | 3.91841  | 2.686198 | 2.607401 | 2.20181  | 2.779143 | 2.318709 | 2.906663 | 2.181109 | -0.33469 | 2.11831  | 4.268946 |
| Brazil             | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 4.387949 | 1.388956 | 3.053461 | 1.140829 | 5.739665 | 3.202132 | 3.961389 | 0.659871 | 5.094195 | -0.12581 | 7.528226 | 3.974423 | 1.921176 | 3.004823 | 0.503956 | -3.54576 | -3.27392 | 1.322869 | 1.783567 | 1.220778 | -3.7676  | 4.88885  | 2.90531  |
| Canada             | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 5.138539 | 1.875088 | 2.992355 | 1.806085 | 3.092364 | 3.210454 | 2.637944 | 2.049305 | 0.995406 | -2.91509 | 3.090806 | 3.137194 | 1.755661 | 2.325814 | 2.873467 | 0.648971 | 1.038551 | 3.033835 | 2.742963 | 1.908432 | -5.08823 | 5.286957 | 3.819866 |
| China              | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 8.490093 | 8.335733 | 9.133531 | 10.03803 | 10.11362 | 11.39459 | 12.72096 | 14.23086 | 9.650679 | 9.398726 | 10.63587 | 9.550832 | 7.863736 | 7.736615 | 7.425764 | 7.041329 | 6.848762 | 6.947201 | 6.749774 | 5.965001 | 2.238638 | 8.449469 | 2.989094 |
| European Union     | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 3.900525 | 2.175909 | 1.110751 | 0.988251 | 2.592306 | 1.924742 | 3.494445 | 3.156121 | 0.641226 | -4.34871 | 2.224595 | 1.907842 | -0.70201 | -0.0829  | 1.600279 | 2.309219 | 1.971766 | 2.845052 | 2.066127 | 1.809002 | -5.65123 | 6.010882 | 3.445962 |
| France             | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 3.323669 | 1.983721 | 1.133531 | 0.823161 | 2.829753 | 1.66322  | 2.449324 | 2.424736 | 0.234946 | -2.87331 | 1.949438 | 2.192701 | 0.313135 | 0.576327 | 0.956183 | 1.112912 | 1.095464 | 2.29142  | 1.863066 | 1.842972 | -7.54046 | 6.43521  | 2.454738 |
| Germany            | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 2.912503 | 1.681468 | -0.19797 | -0.70012 | 1.175088 | 0.731707 | 3.816442 | 2.976455 | 0.959809 | -5.69384 | 4.179882 | 3.925193 | 0.418498 | 0.437591 | 2.209543 | 1.491992 | 2.23     | 2.680231 | 0.981233 | 1.075472 | -3.82677 | 3.16382  | 1.806209 |
| India              | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 3.840991 | 4.823966 | 3.803975 | 7.880081 | 7.922397 | 7.923431 | 8.060733 | 7.680815 | 3.086698 | 7.881889 | 8.497585 | 5.241315 | 5.456389 | 6.386106 | 7.410228 | 7.996254 | 8.256305 | 6.795383 | 6.453851 | 3.871437 | -5.83105 | 9.050278 | 7.239693 |
| Indonesia          | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 4.920068 | 3.643466 | 4.899475 | 4.780369 | 5.030674 | 5.692571 | 5.500592 | 6.345022 | 6.013704 | 4.628881 | 6.223854 | 6.169784 | 6.030051 | 5.517264 | 5.006668 | 4.876322 | 5.033069 | 5.069786 | 5.174292 | 5.019288 | -2.06551 | 3.703055 | 5.308595 |
| Italy              | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 3.786935 | 1.951372 | 0.25349  | 0.138627 | 1.423594 | 0.817849 | 1.79064  | 1.487073 | -0.96201 | -5.28094 | 1.713296 | 0.707333 | -2.98031 | -1.84107 | -0.00455 | 0.778304 | 1.293463 | 1.667853 | 0.923811 | 0.483188 | -8.97419 | 8.31376  | 3.724549 |
| Japan              | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 2.764648 | 0.386103 | 0.041961 | 1.551725 | 2.186116 | 1.803301 | 1.37235  | 1.483969 | -1.22429 | -5.69324 | 4.097918 | 0.02381  | 1.374751 | 2.0051   | 0.296206 | 1.50627  | 0.753827 | 1.675332 | 0.643391 | -0.40217 | -4.14712 | 2.55932  | 0.954737 |
| Korea, Rep.        | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 9.060833 | 4.8524   | 7.725149 | 3.147291 | 5.197391 | 4.308543 | 5.264327 | 5.799548 | 3.012985 | 0.792699 | 6.804825 | 3.885688 | 2.402531 | 3.164709 | 3.02454  | 2.809103 | 2.948882 | 3.159636 | 2.907404 | 2.243978 | -0.70942 | 4.304735 | 2.612672 |
| Mexico             | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 5.02384  | -0.45085 | -0.23859 | 1.185545 | 3.565441 | 2.113247 | 4.805014 | 2.077864 | 0.945332 | -6.29525 | 4.971335 | 3.444045 | 3.553211 | 0.851102 | 2.505764 | 2.702323 | 1.772493 | 1.871729 | 1.972082 | -0.27815 | -8.65159 | 5.83783  | 3.888231 |
| Russian Federation | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 10.00007 | 5.100051 | 4.89992  | 7.299952 | 7.199948 | 6.399965 | 8.200068 | 8.499978 | 5.199969 | -7.79999 | 4.5      | 4.300029 | 4.024086 | 1.755422 | 0.736267 | -1.97272 | 0.19369  | 1.82579  | 2.807245 | 2.198076 | -2.65365 | 5.61429  | -2.06971 |
| South Africa       | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 4.2      | 2.7      | 3.700374 | 2.949075 | 4.55456  | 5.277052 | 5.603806 | 5.360474 | 3.191044 | -1.53809 | 3.039733 | 3.166556 | 2.396232 | 2.485468 | 1.413826 | 0.664552 | 1.157947 | 1.556784 | 0.269936 | -5.96366 | 4.703062 | 1.910406 |          |
| Turkey             | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 6.93324  | -5.75001 | 6.447722 | 5.785206 | 9.795356 | 8.992305 | 6.947988 | 5.043508 | 0.815005 | -4.82315 | 8.427104 | 11.20011 | 4.788493 | 8.468817 | 4.939715 | 6.084487 | 3.329084 | 7.501997 | 3.013138 | 0.818626 | 1.85984  | 11.43938 | 5.533469 |
| United Kingdom     | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 4.318727 | 2.578741 | 1.791986 | 3.146573 | 2.426497 | 2.738942 | 2.386775 | 2.620331 | -0.22573 | -4.61496 | 2.238689 | 1.145102 | 1.512937 | 1.792322 | 3.195782 | 2.220258 | 1.921063 | 2.65307  | 1.403792 | 1.641611 | -10.3539 | 8.674904 | 4.346561 |
| United States      | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 4.077139 | 0.954339 | 1.893948 | 2.786709 | 3.852553 | 3.48322  | 2.782811 | 2.010508 | 0.122188 | -2.59989 | 2.708857 | 1.548955 | 2.280688 | 1.84875  | 2.287776 | 2.70637  | 1.667472 | 2.241921 | 2.945385 | 2.294439 | -2.7678  | 5.945485 | 1.93635  |
| Saudi Arabia       | GDP growth (annual %) |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |
|                    | GDP growth (annual %) | 5.625416 | -1.21074 | -2.81917 | 11.2406  | 7.93842  | 5.57385  | 2.788402 | 1.84713  | 6.248773 | -2.03925 | 5.039493 | 10.99376 | 5.427394 | 2.850343 | 4.027651 | 4.690145 | 2.363075 | -0.0897  | 2.762244 | 0.83228  | -4.54139 | 4.326105 | 8.880736 |

Table A.5: Inflation GDP deflator %.

| Country Name       | Country Code | Indicator Name                     | 2000     | 2001      | 2002     | 2003     | 2004     | 2005     | 2006     | 2007     | 2008     | 2009      | 2010      | 2011     | 2012     | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | 2020     | 2021     | 2022     |
|--------------------|--------------|------------------------------------|----------|-----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Argentina          | ARG          | Inflation, GDP deflator (annual %) | 1.07287  | -1.09577  | 30.5552  | 10.4957  | 18.36335 | 10.31751 | 13.74105 | 14.93993 | 23.17116 | 15.37765  | 20.91512  | 23.70347 | 22.31488 | 23.9488  | 40.28297 | 26.57999 | 41.11938 | 26.00658 | 42.03367 | 49.19558 | 40.08309 | 53.8045  | 69.47124 |
| Australia          | AUS          | Inflation, GDP deflator (annual %) | 2.520751 | 4.630718  | 2.840307 | 2.98562  | 3.232263 | 3.825509 | 5.115389 | 4.93598  | 4.569822 | 4.949161  | 1.151859  | 6.200399 | 1.805164 | -0.16378 | 1.404839 | -0.62292 | -0.65577 | 3.651233 | 1.87881  | 3.463723 | 2.113825 | 3.078774 | 7.123076 |
| Brazil             | BRA          | Inflation, GDP deflator (annual %) | 5.608065 | 8.225094  | 9.798112 | 14.09107 | 7.752061 | 7.431225 | 6.774274 | 6.439038 | 8.776553 | 7.313483  | 8.423338  | 8.31692  | 7.943127 | 7.504665 | 7.84671  | 7.566175 | 8.105604 | 8.671365 | 4.493534 | 4.274159 | 6.4725   | 11.38406 | 8.283206 |
| Canada             | CAN          | Inflation, GDP deflator (annual %) | 4.374199 | 1.573677  | 1.257523 | 3.49737  | 3.280874 | 3.118639 | 2.570173 | 3.300546 | 3.996316 | -2.32492  | 2.848638  | 3.244455 | 1.218444 | 1.740738 | 1.941199 | -0.86765 | 0.716978 | 2.571015 | 1.651118 | 1.54071  | 1.07081  | 7.66485  | 7.65382  |
| China              | CHN          | Inflation, GDP deflator (annual %) | 2.062793 | 2.047049  | 0.602099 | 2.603178 | 6.951993 | 3.905744 | 3.926549 | 7.749686 | 7.795346 | -0.203953 | 6.88138   | 8.07864  | 2.331218 | 2.16337  | 1.031064 | -0.00294 | 1.407546 | 4.232882 | 3.499748 | 1.2867   | 0.492494 | 4.55327  | 2.248974 |
| European Union     | EUU          | Inflation, GDP deflator (annual %) | 3.329755 | 3.660305  | 3.274542 | 2.18841  | 2.709358 | 2.548105 | 2.89974  | 2.965345 | 3.253235 | 1.678839  | 0.929246  | 1.617107 | 1.675127 | 1.279887 | 0.981646 | 1.138249 | 0.874115 | 1.464064 | 2.007492 | 2.294651 | 1.928572 | 2.868806 | 6.482598 |
| France             | FRA          | Inflation, GDP deflator (annual %) | 1.55329  | 2.008334  | 2.067405 | 1.839366 | 1.626875 | 1.936341 | 2.155327 | 2.556637 | 2.367074 | 0.066621  | 1.069697  | 0.94796  | 1.161825 | 0.778101 | 0.576944 | 1.138249 | 0.523559 | 0.521377 | 0.992225 | 1.276592 | 2.839876 | 1.42948  | 2.947217 |
| Germany            | DEU          | Inflation, GDP deflator (annual %) | -0.48939 | 1.304955  | 1.378126 | 1.321254 | 1.115596 | 0.405207 | 0.397181 | 1.770273 | 0.90933  | 1.841881  | 0.645276  | 1.089484 | 1.064489 | 1.939392 | 1.87794  | 1.653679 | 1.327751 | 1.503739 | 2.007492 | 2.130709 | 1.872586 | 3.016588 | 5.268325 |
| India              | IND          | Inflation, GDP deflator (annual %) | 3.64497  | 3.215616  | 3.715884 | 3.867798 | 5.775413 | 5.671903 | 8.400338 | 6.944418 | 9.10937  | 7.040365  | 10.52803  | 8.73338  | 7.994386 | 6.186504 | 3.331757 | 2.279588 | 3.137975 | 3.989258 | 3.88424  | 2.405517 | 4.746549 | 8.538525 | 8.225889 |
| Indonesia          | IDN          | Inflation, GDP deflator (annual %) | 20.44746 | 14.29572  | 5.898052 | 5.487129 | 8.550727 | 14.33179 | 14.08742 | 11.53858 | 18.14975 | 8.274751  | 15.76429  | 7.465934 | 3.753879 | 4.96599  | 5.443175 | 3.980243 | 2.458024 | 4.292678 | 3.618314 | 1.598488 | -0.40165 | 6.002471 | 9.567844 |
| Italy              | ITA          | Inflation, GDP deflator (annual %) | 1.792298 | 3.033392  | 3.274342 | 3.147808 | 2.670184 | 2.105558 | 2.124654 | 2.478995 | 2.400703 | 1.678839  | 0.436361  | 1.607127 | 1.547301 | 1.14761  | 0.913241 | 0.931864 | 1.13453  | 0.726343 | 1.068132 | 0.938114 | 1.579171 | 1.277861 | 2.976401 |
| Japan              | JPN          | Inflation, GDP deflator (annual %) | -1.33626 | -1.08488  | -1.39098 | -1.6077  | -1.12477 | -1.19402 | -0.86202 | -0.70524 | -0.91153 | -0.56396  | -1.88074  | -1.62208 | -0.75609 | -0.35438 | 1.886235 | 2.111289 | 0.419944 | -0.07435 | -0.00024 | 0.624803 | 0.94145  | -0.18006 | 0.33388  |
| Korea, Rep.        | KOR          | Inflation, GDP deflator (annual %) | 1.021765 | 3.478499  | 3.03314  | 3.449933 | 3.12738  | 1.044001 | -0.2232  | 2.419196 | 2.826302 | 3.808644  | 2.737497  | 1.281864 | 1.251808 | 1.018544 | 0.906897 | 3.183596 | 1.986039 | 2.222781 | 0.482949 | -0.83933 | 1.563747 | 2.762932 | 1.275523 |
| Mexico             | MEX          | Inflation, GDP deflator (annual %) | 10.69796 | 6.473009  | 5.502324 | 4.779667 | 8.117443 | 5.884983 | 6.107154 | 6.127792 | 6.310832 | 5.243482  | 4.372964  | 5.669634 | 4.542213 | 1.703883 | 4.368369 | 3.225429 | 6.075386 | 6.567395 | 5.2045   | 4.637561 | 4.841333 | 4.407044 | 6.719924 |
| Russian Federation | RUS          | Inflation, GDP deflator (annual %) | 37.69793 | 16.479162 | 15.65191 | 13.65714 | 20.5515  | 19.27943 | 15.12041 | 13.84274 | 18.0352  | 1.970613  | 14.19111  | 24.46809 | 8.807888 | 5.320139 | 7.490071 | 7.249736 | 2.844223 | 5.349815 | 9.997977 | 3.26133  | 0.898246 | 18.99052 | 15.80471 |
| South Africa       | ZAF          | Inflation, GDP deflator (annual %) | 9.182191 | 7.800475  | 11.53796 | 6.595764 | 6.042172 | 5.59701  | 6.064637 | 8.245765 | 7.850332 | 8.665042  | 6.128452  | 5.539056 | 4.865208 | 5.844111 | 5.386546 | 5.545528 | 6.952172 | 5.473322 | 3.993295 | 4.613525 | 5.259588 | 6.500128 | 4.759404 |
| Turkiye            | TUR          | Inflation, GDP deflator (annual %) | 49.38078 | 52.97976  | 37.57462 | 23.28818 | 12.42751 | 7.085416 | 9.756106 | 6.199758 | 12.04615 | 5.446449  | 7.009204  | 8.200847 | 7.427673 | 6.28011  | 7.389519 | 7.844917 | 8.130478 | 10.98242 | 16.51228 | 13.86774 | 14.78938 | 28.97302 | 96.03611 |
| United Kingdom     | GBR          | Inflation, GDP deflator (annual %) | 1.143888 | 1.505349  | 2.122738 | 2.392776 | 2.620096 | 2.933328 | 2.708634 | 2.252515 | 3.40328  | 1.89112   | 1.583741  | 2.189185 | 1.338304 | 2.117064 | 1.317778 | 0.660991 | 1.964798 | 1.856341 | 1.922052 | 2.115733 | 5.083623 | -0.12043 | 5.152302 |
| United States      | USA          | Inflation, GDP deflator (annual %) | 2.265548 | 2.252932  | 1.556531 | 1.973599 | 2.684408 | 3.133634 | 3.085683 | 2.702527 | 1.917933 | 0.540395  | 1.202792  | 2.077714 | 1.870396 | 1.75095  | 1.868991 | 1.000542 | 1.002335 | 1.899661 | 2.404059 | 1.799331 | 1.304912 | 4.497792 | 7.740723 |
| Saudi Arabia       | SAU          | Inflation, GDP deflator (annual %) | 10.94792 | -1.64654  | 5.958847 | 2.316559 | 11.05648 | 20.14961 | 11.57736 | 8.435399 | 17.6898  | -15.7132  | 17.719131 | 15.42027 | 3.994036 | -1.19689 | -2.247   | -16.5815 | -2.81698 | 7.431458 | 15.22151 | -1.75482 | -8.46318 | 14.11416 | 16.68691 |

**Table A.6:** Foreign Direct Investments, Net Inflows.

| Country              | Year                                               | 2000      | 2001      | 2002      | 2003       | 2004      | 2005      | 2006      | 2007      | 2008      | 2009      | 2010       | 2011      | 2012      | 2013      | 2014      | 2015       | 2016      | 2017      | 2018       | 2019      | 2020      | 2021       |             |
|----------------------|----------------------------------------------------|-----------|-----------|-----------|------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|-----------|------------|-----------|-----------|------------|-----------|-----------|------------|-------------|
| Algeria              | Foreign Direct Investment<br>Million of current US | 114034.28 | 238105.80 | 214931.00 | 135210.000 | 412971.00 | 535250.00 | 559297.76 | 640787.72 | 979551.20 | 401158.75 | 1123270.33 | 112839.94 | 153551.97 | 982181.88 | 516335.92 | 1129294.01 | 318029.42 | 115868.42 | 1178788.88 | 884877.88 | 488427.75 | 614848.208 | 1548347.796 |
| Andorra              | Foreign Direct Investment<br>Million of current US | 148259.18 | 187105.81 | 146521.81 | 838246.70  | 429072.21 | 259144.25 | 325100.75 | 444000.07 | 621000.31 | 389974.93 | 359586.62  | 652825.59 | 579285.25 | 544029.94 | 610401.36 | 468200.68  | 429072.70 | 489070.40 | 688800.50  | 307612.81 | 614477.86 | 208157.51  | 7108582.28  |
| Brazil               | Foreign Direct Investment<br>Million of current US | 319471.70 | 112084.27 | 145888.85 | 818181.87  | 881881.48 | 154898.88 | 184885.58 | 449481.84 | 507148.71 | 344897.10 | 823897.48  | 824772.21 | 928838.21 | 752102.25 | 871588.27 | 842815.88  | 742827.00 | 888849.15 | 788274.70  | 882141.51 | 327112.37 | 444585.88  | 7148518.88  |
| Canada               | Foreign Direct Investment<br>Million of current US | 683035.55 | 103080.81 | 144842.37 | 718177.79  | 1452545   | 252228.94 | 643038.8  | 128481.8  | 128481.8  | 670888.78 | 841085.86  | 988888.87 | 341021.81 | 153100.00 | 428788.8  | 488888.8   | 187182.88 | 281088.88 | 187182.88  | 281088.88 | 591188.8  | 591188.8   | 498888.88   |
| China                | Foreign Direct Investment<br>Million of current US | 428300.00 | 475000.00 | 510718.87 | 574014.87  | 881271.11 | 881888.88 | 881888.88 | 158388.88 | 175148.81 | 131818.81 | 168148.81  | 281088.81 | 281088.81 | 281088.81 | 281088.81 | 281088.81  | 281088.81 | 281088.81 | 281088.81  | 281088.81 | 281088.81 | 281088.81  | 281088.81   |
| Czechia              | Foreign Direct Investment<br>Million of current US | 618871.18 | 388210.75 | 285258.82 | 285258.82  | 188258.82 | 218258.82 | 881888.88 | 188188.88 | 188188.88 | 188188.88 | 188188.88  | 188188.88 | 188188.88 | 188188.88 | 188188.88 | 188188.88  | 188188.88 | 188188.88 | 188188.88  | 188188.88 | 188188.88 | 188188.88  | 188188.88   |
| Denmark              | Foreign Direct Investment<br>Million of current US | 423800.00 | 514035.95 | 555548.64 | 423006.78  | 568553.11 | 657028.78 | 789351.76 | 817788.36 | 677788.36 | 677788.36 | 677788.36  | 677788.36 | 677788.36 | 677788.36 | 677788.36 | 677788.36  | 677788.36 | 677788.36 | 677788.36  | 677788.36 | 677788.36 | 677788.36  | 677788.36   |
| Egypt                | Foreign Direct Investment<br>Million of current US | 384710.10 | 510000.00 | 500000.00 | 318000.00  | 543300.00 | 788000.00 | 108000.00 | 788000.00 | 788000.00 | 788000.00 | 788000.00  | 788000.00 | 788000.00 | 788000.00 | 788000.00 | 788000.00  | 788000.00 | 788000.00 | 788000.00  | 788000.00 | 788000.00 | 788000.00  | 788000.00   |
| France               | Foreign Direct Investment<br>Million of current US | 280079.12 | 544894.37 | 518820.81 | 648150.08  | 248845.57 | 595125.15 | 874419.22 | 948788.87 | 389788.87 | 389788.87 | 389788.87  | 389788.87 | 389788.87 | 389788.87 | 389788.87 | 389788.87  | 389788.87 | 389788.87 | 389788.87  | 389788.87 | 389788.87 | 389788.87  | 389788.87   |
| Germany              | Foreign Direct Investment<br>Million of current US | 280079.12 | 544894.37 | 518820.81 | 648150.08  | 248845.57 | 595125.15 | 874419.22 | 948788.87 | 389788.87 | 389788.87 | 389788.87  | 389788.87 | 389788.87 | 389788.87 | 389788.87 | 389788.87  | 389788.87 | 389788.87 | 389788.87  | 389788.87 | 389788.87 | 389788.87  | 389788.87   |
| Greece               | Foreign Direct Investment<br>Million of current US | 384710.10 | 510000.00 | 500000.00 | 318000.00  | 543300.00 | 788000.00 | 108000.00 | 788000.00 | 788000.00 | 788000.00 | 788000.00  | 788000.00 | 788000.00 | 788000.00 | 788000.00 | 788000.00  | 788000.00 | 788000.00 | 788000.00  | 788000.00 | 788000.00 | 788000.00  | 788000.00   |
| India                | Foreign Direct Investment<br>Million of current US | 45925.26  | 29720.87  | 145838.4  | 38530.8    | 188000.78 | 48925.26  | 48925.26  | 48925.26  | 48925.26  | 48925.26  | 48925.26   | 48925.26  | 48925.26  | 48925.26  | 48925.26  | 48925.26   | 48925.26  | 48925.26  | 48925.26   | 48925.26  | 48925.26  | 48925.26   | 48925.26    |
| Italy                | Foreign Direct Investment<br>Million of current US | 112000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Japan                | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Kenya                | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Malaysia             | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Mexico               | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Netherlands          | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Nigeria              | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Poland               | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Romania              | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| South Africa         | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Sweden               | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Taiwan               | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| Thailand             | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| United Kingdom       | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| United States        | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |
| United Arab Emirates | Foreign Direct Investment<br>Million of current US | 118000.00 | 140000.00 | 172500.00 | 851000.00  | 201000.00 | 381000.00 | 681000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00 | 881000.00 | 881000.00  | 881000.00   |

Table A.7: Input and Output GDP \$.

| Year | Input (GDP US\$) |               |              |               |                    |               |              |              |               |              |               |               |                |                  |              |
|------|------------------|---------------|--------------|---------------|--------------------|---------------|--------------|--------------|---------------|--------------|---------------|---------------|----------------|------------------|--------------|
|      | Australia        | Germany       | India        | Italy         | Russian Federation | South Africa  | Turkey       | UK           | US            | Argentina    | Brazil        | Canada        | China          | European Union   | France       |
| 2000 | 416.67815393     | 1.9473919102  | 463.3439726  | 1146.67694210 | 239.70142197       | 38.51430123   | 274.2943134  | 1.6653946688 | 10.2504971000 | 84.46075000  | 65.4421394    | 744.7345532   | 1211.33161330  | 1.770.330.91.857 | 1650.1012078 |
| 2001 | 3736230165       | 1.94679737308 | 465.41410439 | 1176.6733449  | 36.60270761        | 38.6550024    | 240.491071   | 1.7672916767 | 10.5012971000 | 86.46075000  | 559493439     | 728.90179255  | 1339.400797151 | 1.770.330.91.857 | 1650.1012078 |
| 2002 | 39570866012      | 2.0704851745  | 514.9719484  | 1216.6733449  | 36.4049449         | 36.4049449    | 240.491071   | 1.7672916767 | 10.5012971000 | 86.46075000  | 559493439     | 728.90179255  | 1339.400797151 | 1.770.330.91.857 | 1650.1012078 |
| 2003 | 4672397073       | 2.501403842   | 607.6992646  | 1577.6170751  | 43.94740135        | 215.80765244  | 314.55573748 | 2.0544257148 | 11.2771491000 | 112.49149100 | 5979573807    | 885.406465    | 1660.26054871  | 1.770.330.91.857 | 1650.1012078 |
| 2004 | 61465930083      | 2.6433308939  | 709.14651486 | 1683.2174704  | 794.0519748        | 326.459700124 | 506.31471762 | 2.5413800000 | 13.0341919000 | 198.37105402 | 891.33333333  | 1176.0638073  | 2285.96149494  | 1.770.330.91.857 | 1650.1012078 |
| 2005 | 6569729967       | 2.8468411175  | 802.38139531 | 1833.2174704  | 794.0519748        | 326.459700124 | 506.31471762 | 2.5413800000 | 13.0341919000 | 198.37105402 | 891.33333333  | 1176.0638073  | 2285.96149494  | 1.770.330.91.857 | 1650.1012078 |
| 2006 | 7464756270       | 2.994704604   | 940.2598874  | 1949.511939   | 9893207353         | 376.90135712  | 557.051773   | 2.7084438237 | 13.6515849000 | 22.5736047   | 1107.6264171  | 1319.56408254 | 2751.11657222  | 1.770.330.91.857 | 1650.1012078 |
| 2007 | 8550074585       | 3.4257383292  | 126.76348942 | 2213.0148251  | 129.70347842       | 415.9433035   | 68.2124296   | 3.0910120402 | 14.4742819000 | 20.5020941   | 1397.14466471 | 1468.0204078  | 3350.37030025  | 1.770.330.91.857 | 1650.1012078 |
| 2008 | 10561124719      | 3.7659409367  | 134.88801694 | 2199.9280419  | 122.6630005        | 420.9789739   | 646.28234628 | 2.4012400612 | 14.4742819000 | 30.20764078  | 1466.9643681  | 1374.65142157 | 510.69112438   | 1.770.330.91.857 | 1650.1012078 |
| 2009 | 9287612258       | 3.4126121652  | 134.88801694 | 2199.9280419  | 122.6630005        | 420.9789739   | 646.28234628 | 2.4012400612 | 14.4742819000 | 30.20764078  | 1466.9643681  | 1374.65142157 | 510.69112438   | 1.770.330.91.857 | 1650.1012078 |
| 2010 | 114890000292     | 3.39966720000 | 165.6151949  | 2133.09955237 | 124.9167524        | 538.20728050  | 75.76726606  | 2.4854053438 | 15.0495444000 | 42.6742789   | 2208.83714524 | 1.6743497466  | 6007.19174673  | 1.770.330.91.857 | 1650.1012078 |
| 2011 | 13987032300      | 3.7463149161  | 182.0518291  | 2294.9493689  | 206.9273738        | 676.657177    | 83.76528894  | 2.6650554328 | 15.5997412000 | 50.58122100  | 2461.652377   | 1793.2658315  | 7351.5470315   | 1.770.330.91.857 | 1650.1012078 |
| 2012 | 15474993333      | 3.527418176   | 182.0518291  | 2294.9493689  | 206.9273738        | 676.657177    | 83.76528894  | 2.6650554328 | 15.5997412000 | 50.58122100  | 2461.652377   | 1793.2658315  | 7351.5470315   | 1.770.330.91.857 | 1650.1012078 |
| 2013 | 15770304000      | 3.733046456   | 186.715781   | 2414.9149049  | 232.4707936        | 753.864540    | 97.73912008  | 2.784532034  | 16.841995000  | 52.054052    | 2472.1935343  | 1466.5974255  | 957.6711184    | 1.770.330.91.857 | 1650.1012078 |
| 2014 | 14689769006      | 3.8880910510  | 209.1264928  | 2209.2438385  | 206.9273738        | 676.657177    | 83.76528894  | 2.6650554328 | 15.5997412000 | 50.58122100  | 2461.652377   | 1793.2658315  | 7351.5470315   | 1.770.330.91.857 | 1650.1012078 |
| 2015 | 15174894333      | 3.357418176   | 182.0518291  | 2294.9493689  | 206.9273738        | 676.657177    | 83.76528894  | 2.6650554328 | 15.5997412000 | 50.58122100  | 2461.652377   | 1793.2658315  | 7351.5470315   | 1.770.330.91.857 | 1650.1012078 |
| 2016 | 12073800579      | 3.4693346346  | 2294.7658683 | 1877.0718834  | 127.7633081        | 665.9978934   | 869.62381333 | 2.8891065630 | 16.651044000  | 57.5320263   | 1756.9340253  | 1527.941407   | 11233.3179308  | 1.770.330.91.857 | 1650.1012078 |
| 2017 | 13268821047      | 3.694945158   | 2261.4742735 | 1961.9367934  | 157.9139308        | 646.8073194   | 778.0719378  | 2.8710719378 | 16.651044000  | 57.5320263   | 1756.9340253  | 1527.941407   | 11233.3179308  | 1.770.330.91.857 | 1650.1012078 |
| 2018 | 14293736816      | 3.7944463510  | 2702.9394170 | 2091.9342637  | 1657.2307344       | 946.8073194   | 778.0719378  | 2.8710719378 | 16.651044000  | 57.5320263   | 1756.9340253  | 1527.941407   | 11233.3179308  | 1.770.330.91.857 | 1650.1012078 |
| 2019 | 129467123361     | 3.8881773825  | 2857.0625616 | 2101.30219827 | 1689.15102708      | 883.8470525   | 778.0719378  | 2.8710719378 | 16.651044000  | 57.5320263   | 1756.9340253  | 1527.941407   | 11233.3179308  | 1.770.330.91.857 | 1650.1012078 |

## APPENDIX B

**Table B.1:** GDP Data Plots for Different Countries.

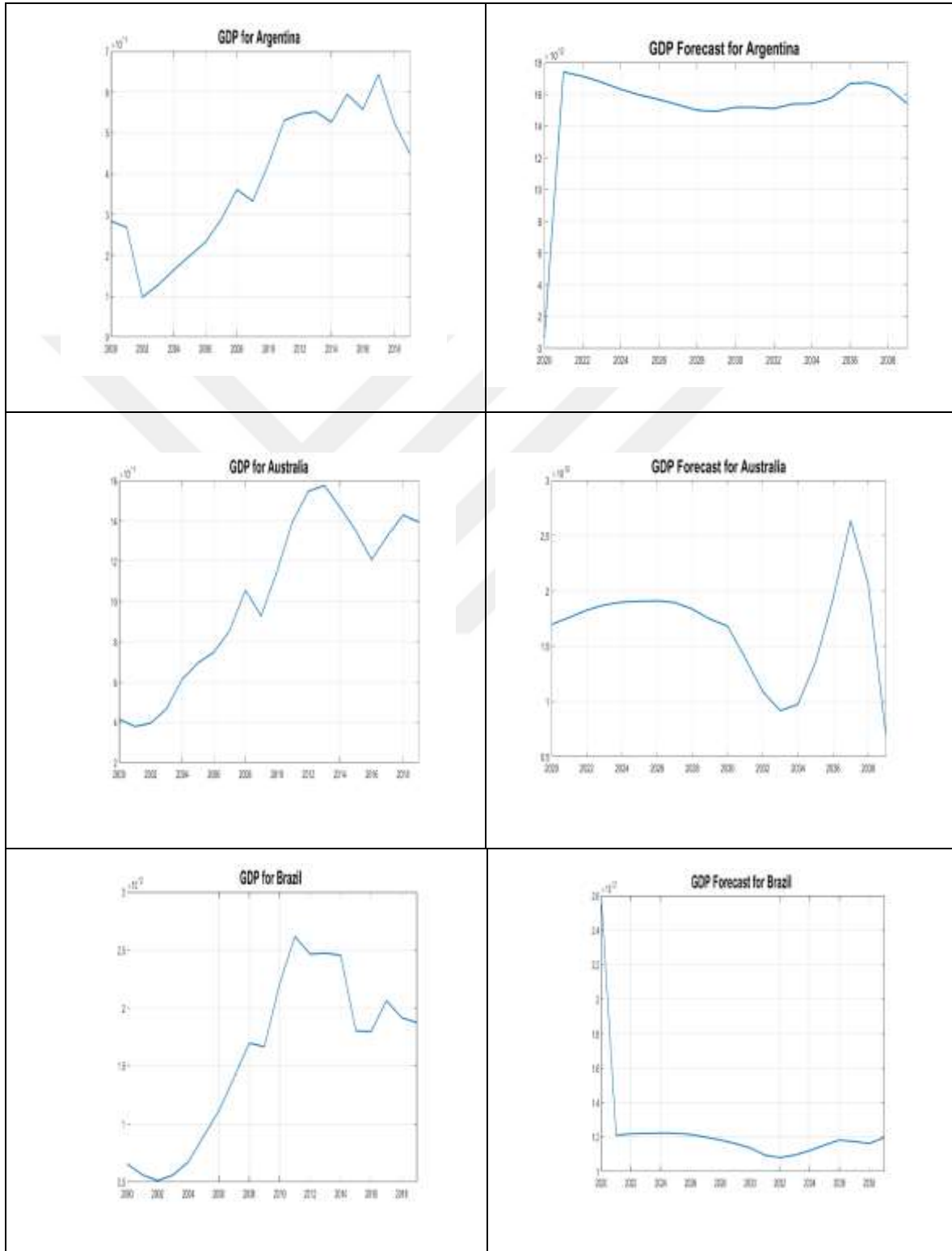


**Table B.1:** GDP Data Plots for Different Countries “Table Continued”.

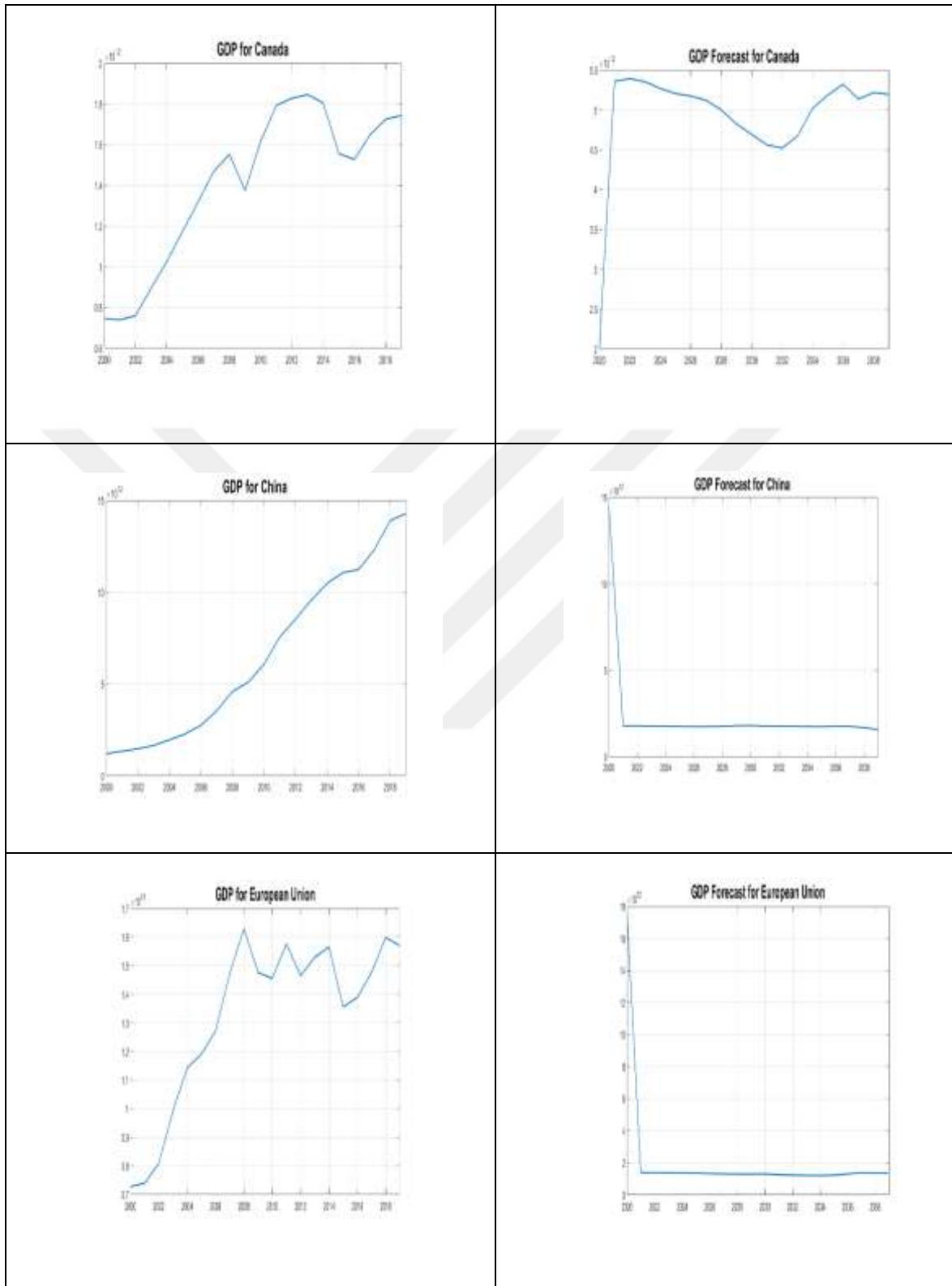


**Table B.1:** GDP Data Plots for Different Countries “Table Continued”.

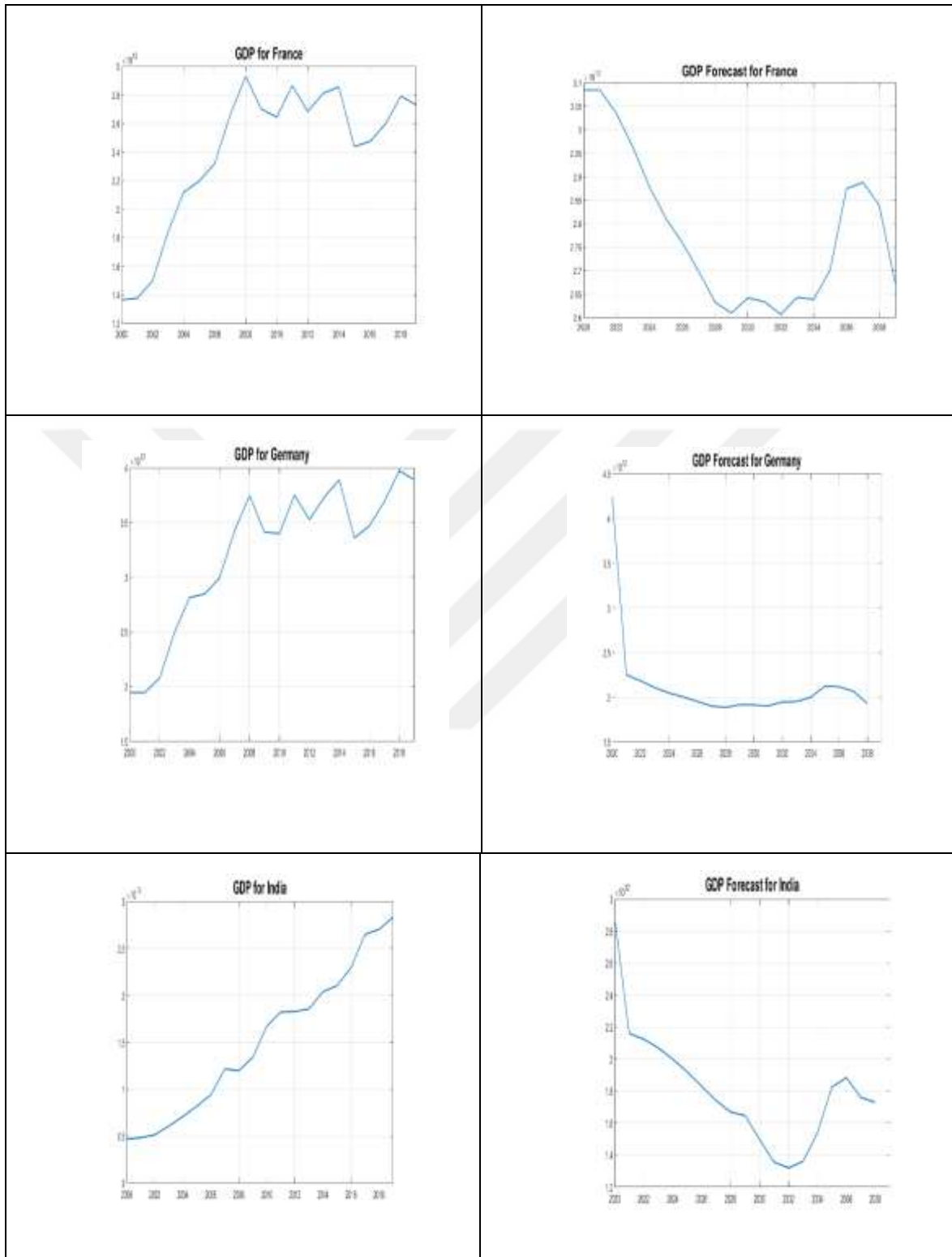


**Table B.1:** GDP Data Plots for Different Countries “Table Continued”.

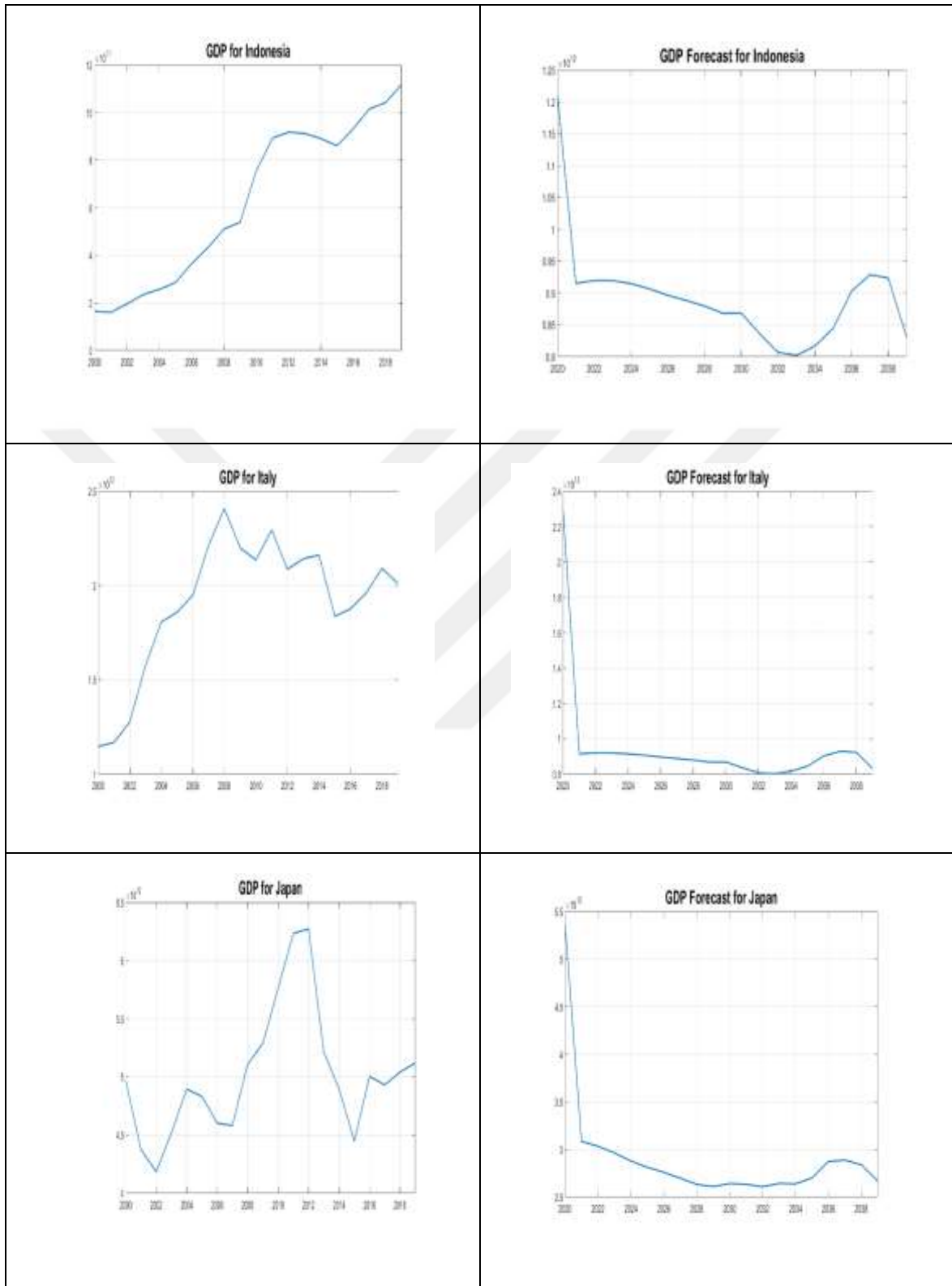


**Table B.1:** GDP Data Plots for Different Countries “Table Continued”.

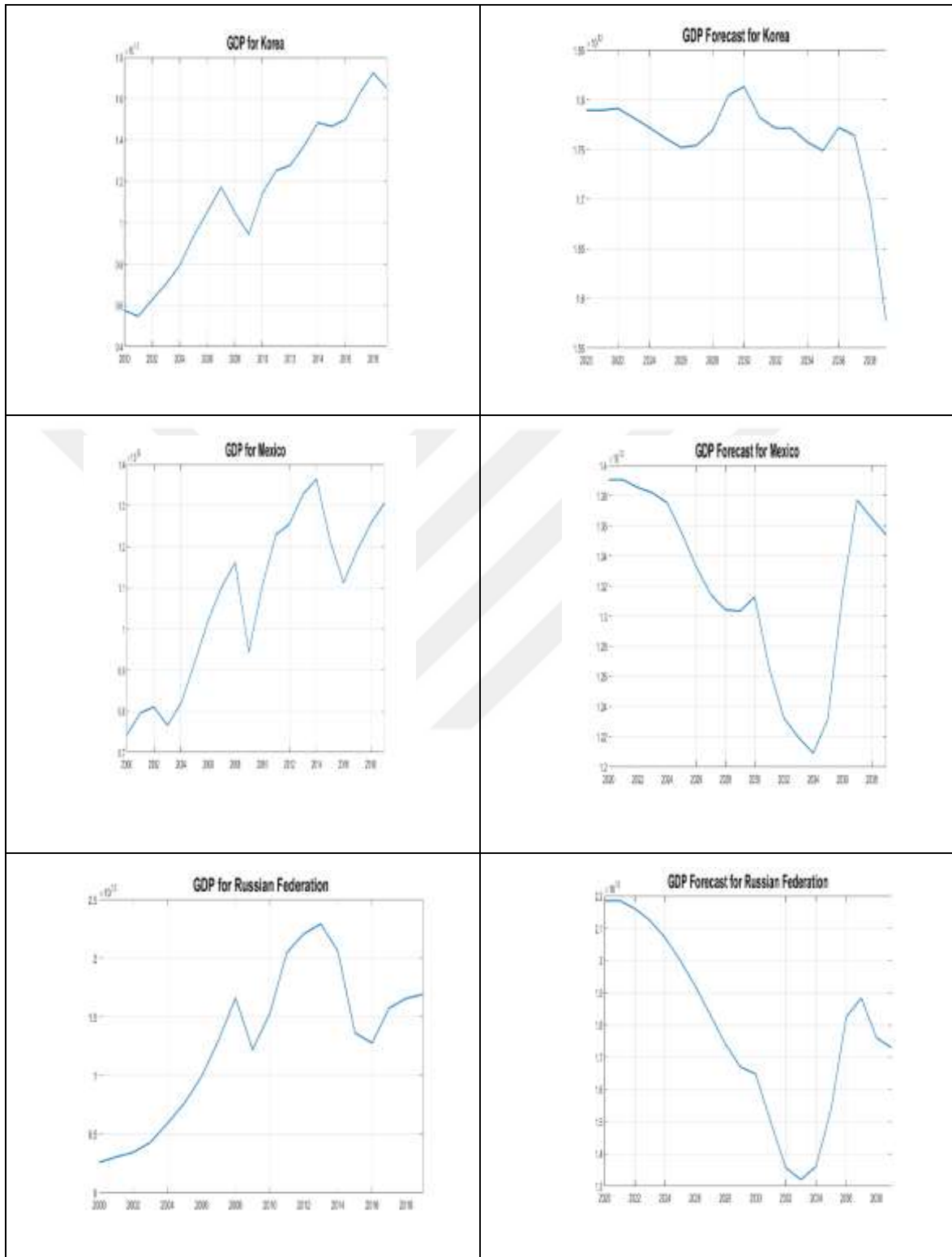


**Table B.1:** GDP Data Plots for Different Countries “Table Continued”.

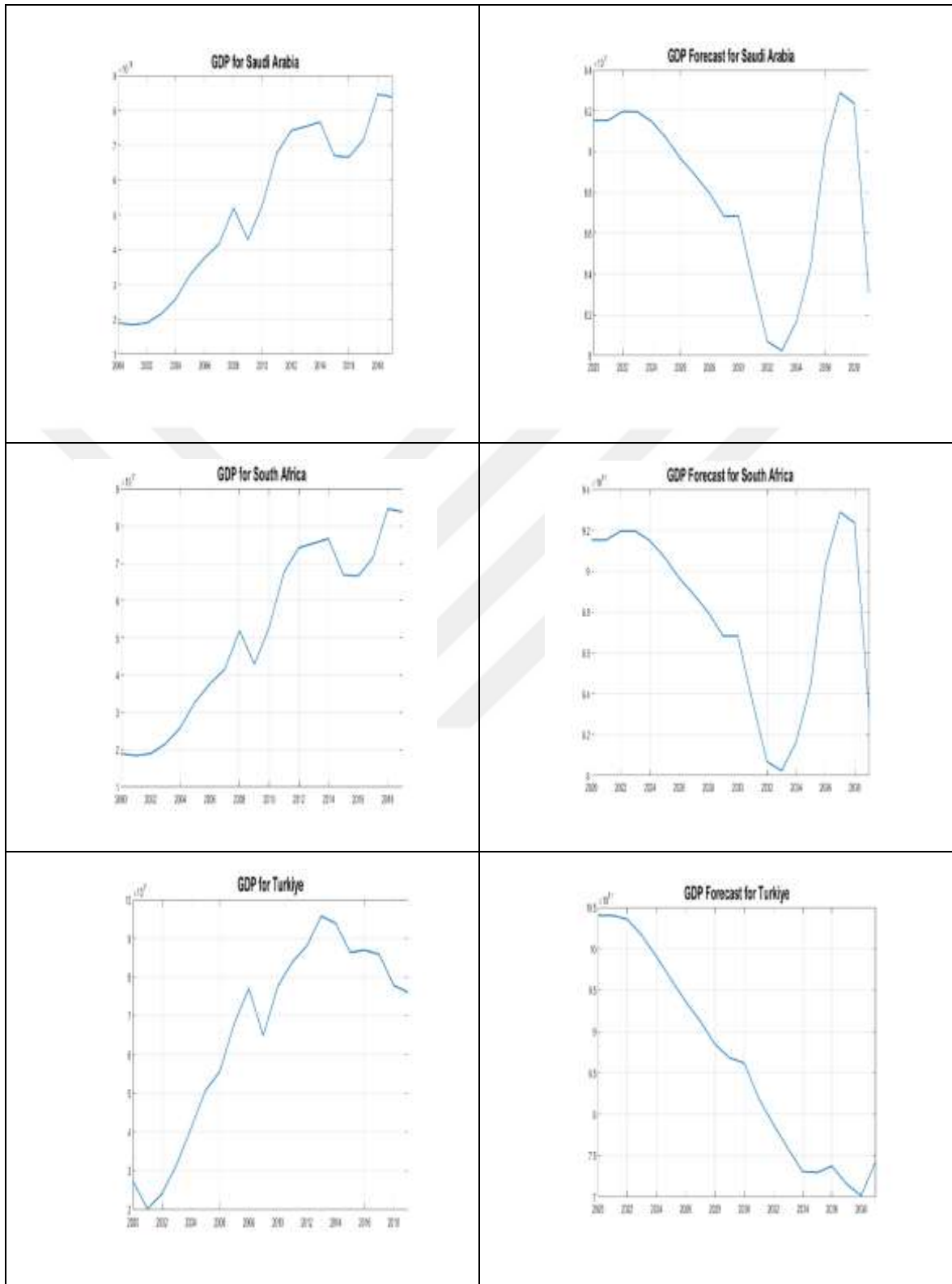


**Table B.1:** GDP Data Plots for Different Countries “Table Continued”.

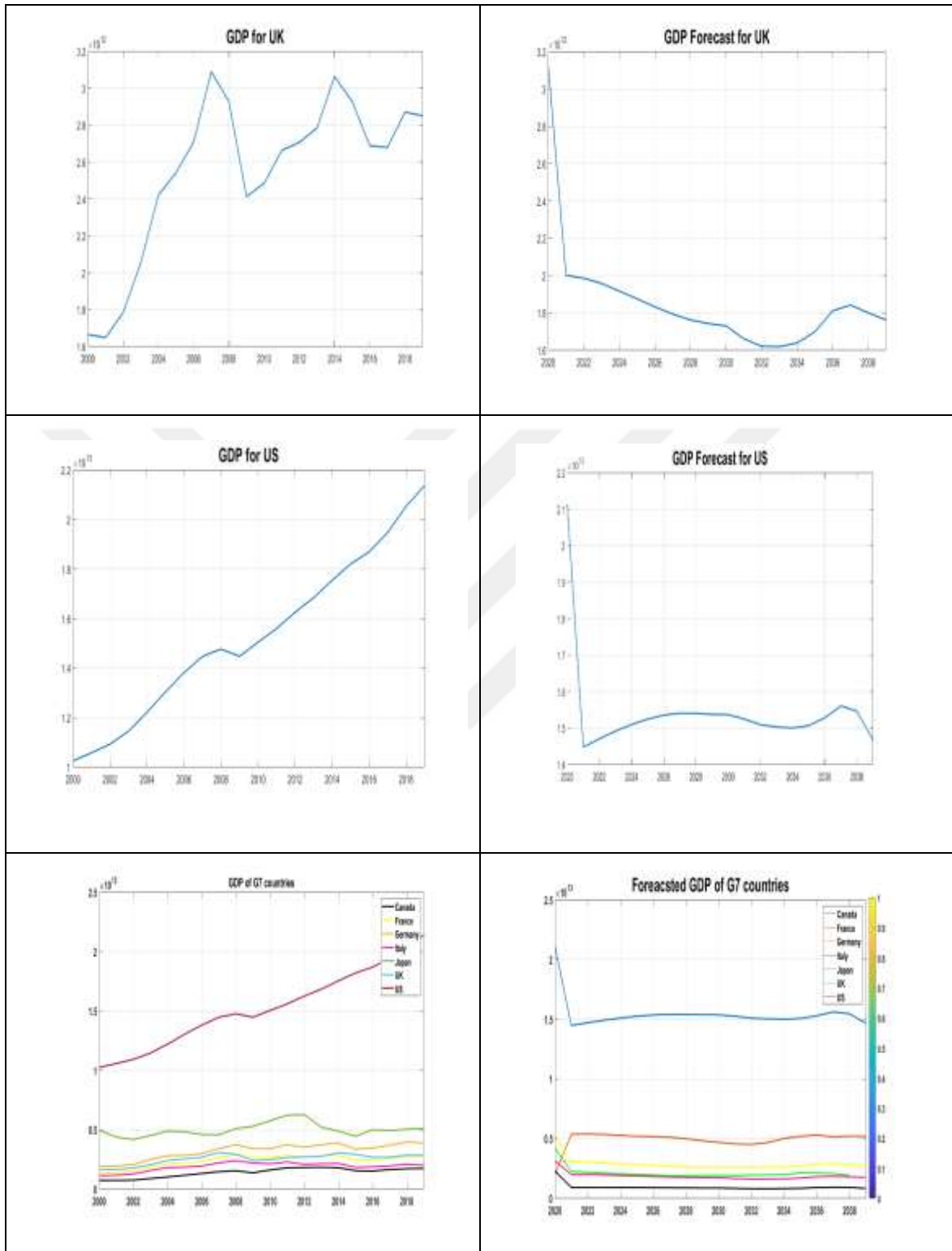


**Table B.1:** GDP Data Plots for Different Countries “Table Continued”.

