ECONOMY WIDE IMPACT OF FLOOD DAMAGES TO PHYSICAL INFRASTRUCTURE IN PAKISTAN: CGE APPROACH

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CERTIFICATE

This is to certify that this thesis entitled: "**Economy Wide Impact of Flood Damages to Physical Infrastructure in Pakistan (CGE Approach)**" submitted by **Ms. Amna Shakeel** accepted in its present form by the School of Public Policy, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Environmental Economics.

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Dedication

This thesis is dedicated to:

Allah, my creator, my master, who always bless me beyond expectations.

My Beloved prophet, Muhammad, who taught us the purpose of life.

My homeland Pakistan, The Paradise on Earth.

My father who have inspired my life and never gave up on me.

My Mom who always taught me to ask Allah for help and stay patient.

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My siblings, who make me laugh and particularly Maryam who stands by me when things look dull and bleak.

My friends, the sign of love and support.

And all the people in my life who touched my heart.

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"Sometimes our light goes out but is blown into flame by another human being. Each of us owes deepest thanks to those who have rekindled this light."

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ABSTRACT

Scientific research has predicted that the likelihood of flooding will increase in many countries particularly in Asia, due to rise in sea level and frequency of weather events as a consequence of climate change. For better future development of coastal cities and flood plains, countries need to know the cost and damages that accompany floods and how to minimize them. In Pakistan researchers have often focused on direct costs of floods neglecting the indirect losses from flood damages due to disruption of economic activity. As many of businesses depend upon physical infrastructure hence, they bear great losses when physical infrastructure is damaged by floods.

This study follows a CGE approach using a static GTAP model to identify the sectors which are most affected when physical infrastructure is lost. We apply our model to all the provinces in Pakistan, considering a scenario where 39% of the physical infrastructure is lost in all the provinces due to 2014 floods. The simulation results show that loss to GDP is about -22% as compare to no flood scenario. Real export is found to be reduced by approximately -56% and welfare is decreased by US$ -50,275.8 million if physical infrastructure is damaged. Major losses in terms of output have accrued to key sectors including heavy manufacturing, light manufacturing, other services and transport & communication as all of them are highly dependent upon physical infrastructure.

Keywords: Flood Damages, Physical Infrastructure, CGE, GTAP

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List of Abbreviations

CGE:	Computable General Equilibrium
DPTAX:	Tax Revenues
EM-DATE	Emergency Event Database
GDP:	Gross Domestic Product
GEMPACK	General Equilibrium Modeling Package
GOVEXP:	Government Expenditure
GTAP	Global Trade Analysis Project
I-O Tables:	Input- Output Tables
IPCC:	Intergovernmental Panel on Climate Change
MTAX:	Import Tax Revenue
NETINV	Net Investment
NDMA	National Disaster Management Authority
PRIVEXP:	Private Household Expenditure
PTAX:	Tax on production of commodity i
ROW:	Rest OF the World
SAM:	Social Accounting Matrix

SAVE: Savings

VDFA: Value of Domestic Firm's Purchases evaluated at Agent's price

VDGA: Value of Domestic Government's Purchases evaluated at Agent's price

VDPA: Value of Domestic private household's Purchases evaluated at Agent's price

VDPM: Value of Domestic private Household's Purchases evaluated at Market price

VIMS: Value of Imports of commodity I at Destination Price

VIWS: Imports of commodity I valued at world price (CIF)

VOA: Value of Output at Agent's Price

VOM: Value of Output at Market price

VXMD: Value of Exports of commodity i at Exporter's domestic price

VXWD: Value of Exports of commodity at World Price (FOB) included

CHAPTER 1
INTRODUCTION

1.1 Introduction

Climate variability has significantly increased the risk of flooding both regionally and globally since 1970. In Asia, floods are considered to be the most devastating natural calamity among other disasters because more than half of the damages occur due to floods in Asia. It has been a concern in the region, as the sum of flood events occurred in Southeast Asia and South Asia count for 28% of the total floods recorded in EM-DAT Database (Mediodia et al., 2013).[1] New report about natural disasters by center for research on epidemiology of disasters shows that floods are responsible for 24% of the total deaths due to natural disasters in 2018 (CRED, 2018). According to Climate Risk Index, Pakistan is listed as 8th among the top ten countries which are going to be worst affected by climate change (Eckstein et al. 2019).

Pakistan has a broad diversity in ecosystems, socio-economic zones, geography, and climate. The country is bestowed with natural resources including mineral deposits, natural gas and but it is still a developing country in terms of environmental protection, economic growth and development. The economy of Pakistan is semi-industrialized which has recently been developed to a service-based economy from an agriculture economy. The pace of economic growth of the country is slow and nearly 25% of its population is still poor (Mujahid et al., 2016).

[1] The Emergency Events Database (EM-DAT) is a free public database containing global data on the incidence of disasters and effects of over 20,000 technological and natural disasters from 1900 till date. The main objective of the database is to help by giving data instruments for humanity-based action at both national & continental levels.

Global risk analysis company, Maple croft has also placed Pakistan at 16th position in the list of countries at extreme risk and vulnerable to climate change (Salman et al., 2018). Majority of the country's population live in the coastal areas of River-Indus which make them vulnerable to floods particularly in the months of July and August. Floods of 2010-2014 have caused greater economic losses to the country both in terms of fatalities and physical infrastructure (Paulikas et al., 2015).

Floods of 2010 and 2014 also proved to be highly catastrophic to the country in the whole history of floods in Pakistan (Economic survey 2010-2011, 2103-2014). The former caused a massive destruction of houses, took about more than 1,700 lives, and affected 20 million people and about 20% of the land area. Essential infrastructure such as buildings, roads, bridges and markets were also damaged severely. While the flood of 2014 occurred as consequence of monsoonal spell which brought unexpected amount of rain fall in the watershed regions of river Chenab and Jhelum that serve as tributaries of River-Indus. This flood caused huge destruction in Azad Jammu and Kashmir and about 16 districts of Punjab province including Chiniot, Gujrat, Jhang, Hafiz Abad, Gujranwala, Mandi Baha Uddin, Khanewal, Khushab, Jhelum, Muzaffargarh, Bahawalpur, Multan, Sargodha, Narowal, Sialkot and Sheikhu Pura (Rehman et al., 2017). The flood was also accompanied by land sliding in Gilgit Baltistan province. Approximately 101,515 houses in Punjab and 28,365 houses in Azad Jammu & Kashmir were affected. Further losses were recorded in livestock, livelihoods, housing, crops, and physical infrastructure of the community. Sectoral damages are shown in Table 1 which reveals that major losses accrued to physical infrastructure followed by housing and crops respectively.

1.1.1 Table 1: Damages caused by 2014 floods

Sectors	**Damages (US$ billion)**	**Damages (in %age)**
Physical Infrastructure	0.17	39.09
Houses	0.13	28.67
Crops	0.11	24.85
Livelihoods	0.03	6.24
Disaster Risk Resilience	0.003	0.8
Livestock	0.002	0.53
Totalxx	0.44	100
Source: NDMA Annual assessment report on flood damages and recovery needs (2014)		

The nature of floods vary according to the geography of the country but in Pakistan, fluvial floods have proved to be the most devastating as the terrain of the Indus plain is flat, economically developed and densely populated (Tariq et al., 2014). The risks and damages associated with floods also vary among countries and regions. However, the effects of floods depend on country's economic activities. For example, supply and demand shocks change the production composition and shift the terms of trade leading towards a negative growth regime. Flood damages to physical infrastructure are usually followed by subsequent economic impacts in terms of employment, loss of income, inflation, production losses, loss of GDP, reducing level of public welfare, low exports, food insecurity, high rehabilitation and reconstruction costs, high government expenditures as well as adversely affecting the country's balance of payment (Rehman et al., 2017).

But as a matter of fact, majority of researchers in Pakistan focus on the effects of climate variability on crops and agriculture and the direct cost of floods, but they ignore the fact that climate change is a macro-prudential phenomenon having far reaching and economy-wide consequences. Hence, there is a need to examine how climate induced disasters particularly floods, affect various sectors of the economy indirectly when physical infrastructure of the country is lost, which is the basic motivation for this research work.

Assessing economic impacts of floods are difficult and complex and various methodologies have been used in the mainstream literature. Direct costs and damages from floods are usually measured through engineering or econometric approaches. Whereas, to measure indirect effects of floods on the entire economy, input-output tables and computable general equilibrium models are used as they comprehensively cover the sectoral dimensions of the impacts. Both types of model class have their own advantages and limitations (Jhan, 2015).

Computable General equilibrium models are comprised of equations of demand and supply functions which are solved simultaneously to obtain equilibrium prices and factor allocation. Usually CGE models use Cobb-Douglas or more generally CES type of production function of the economic sectors. The CGE models are based on social accounting matrix which assume stable demand and supply systems in an economy. It simulates how the demand and supply of goods and services is affected by natural disasters in an economy.

Hence, CGE framework seems more appropriate to analyze the economy-wide impacts of floods. Therefore, this study follows GTAP model (a general equilibrium framework) to account for the effects of flood damages on overall economy of Pakistan. GTAP is main tool for assessing economy-wide effects of international trade and environmental issues. This study uses the GTAP 11 database which will be released soon publically. Dr. Zeshan who is the GTAP data contributor from Pakistan has provided the database along with its sectoral aggregation for this research work[2]. The modeling framework and database used are explained in detail in GTAP database section below. To simulate the model, data of 2014 flood that caused a huge infrastructure loss to Pakistan, has been used in order to analyze its repercussions on macro-economy of the economy.

The empirical results of this research are highly relevant to the policy makers to prepare suitable flood management policies. It will also serve as a good source of information for researchers and policy makers who are engaged in disaster management or impact analysis. It is to be noted that floods can never be fully prevented but they can be managed, and the loss can be reduced through proper management and adaptation policies. But if any social or economic policy is improperly implemented then it may lead to social chaos and economic disaster requiring high readjustment cost and time to adjust. In a nut-shell, flood like disasters hamper the economic growth of a country.

1.2 Problem Statement:

In Pakistan, frequent floods have caused massive devastation to country's economy. Floods of 2014 in Pakistan have not only damaged its agriculture sector rather it has also brought devastating impacts to other sectors aggravating unemployment and inflation. Due to weak implementation of management strategies and policy gaps, floods have caused destruction to physical infrastructure of the country and other businesses resulting in losses

[2] Dr. Muhammad Zeshan is an input-output Economist from Pakistan, he has supervised this research work. He is currently serving as a Postdoc Research Fellow at Norwegian University of Science and Technology - NTNU Trondheim.

to country's GDP. Hence, this study endeavors to analyze the sector-specific impacts of the damages to physical infrastructure due to 2014 flood in Pakistan.

1.3 Objectives of the study

To examine the sector-specific impacts of floods using a general equilibrium framework

To analyze the welfare implications of flood damages

1.4 Research questions:

Following are the research questions based on above mentioned objectives, such as:

i. Which sectors of the economy are more affected by floods when physical infrastructure is damaged?

ii. What are the welfare implications of floods for Pakistan?

1.5 Significance of the study:

The results of this study are useful as a reference material for academia, researchers and policy makers. Though CGE models are widely used for regional studies but applying it to the issue of flood damages particularly in Pakistan is relatively new. Due to the aggravating impacts of climate change on flooding, Pakistan requires a proactive and holistic approach for effective management of floods which requires an economy-wide analysis of flood effects. Thus, this study uses a novel model of GTAP application to Pakistan's economy where the negative shock to physical capital due to floods will have its effects on various sectors of the economy. This study also performs a detailed analysis of the impact of flood damages on macroeconomic indicators and all the important sectors of Pakistan's economy.

1.6 Organization of the Study:

The rest of the study is organized as follows: second chapter of the thesis provides a brief literature review on the economic impacts of floods, situation of floods in Pakistan, flood risk and management and CGE model implications. Third chapter includes research methodology for the simulation of results. The GTAP Database and data aggregation is presented in chapter four. Chapter five presents the analysis of empirical results. Finally, the sixth chapter concludes the results and outcomes of this study and give policy recommendations for flood management.

CHAPTER 2

2 LITERATURE REVIEW

Introduction

This chapter divides the literature review into four themes. The first theme is about the impacts of flooding on economy, community and livelihood etc. Second theme is to show history and the situation of floods in Pakistan. Third is about how mainstream literature discusses various ways of risk and management of floods. While the last and the most relevant theme is about the CGE modeling to show its importance in empirical studies.

2.1 Economic impacts of floods

The economic literature on the aftermath of flood is still in infancy stage. The reason of which may be because the macroeconomic consequences of natural disasters as a whole appear to be vague. The effects of disasters or floods may vary depending upon the nature of disaster and the socio-economic circumstances. Floods can have both direct and indirect effects. The direct effects include the loss of human lives, destruction of buildings, and loss in values of assets as well as the primary losses from the destruction of buildings etc. Whereas, the indirect effects involve the residual effects of the disaster events such as decline in wages, sales, rise in prices, decrease in tax revenues, loss of welfare and GDP etc., as shown in the following review of previous literature on flood damages.

Measuring the macroeconomic impacts of flood for the first time, Albala-Bertrand (1993) considered 28 natural disasters in twenty-six countries using a unique systematic model to assess the disaster incidences and their aftermaths. Collecting datasets for disaster incidences for the period 1960-1979, he found that floods have positive relation with GDP growth due to growth in capital formation and agricultural output. But on the other hand, trade and fiscal deficits were also increased with disasters. He argued that those countries with weaker political and economic bases are highly affected by natural disasters. Thus, political space and economic development both play an important role in disaster risk management.

Previous literature shows that floods can have both positive and negative impact on the GDP depending on the size or intensity of the event. Disasters of larger scale negatively affect the economic growth while those of smaller scale have positive impact on economic growht (Loayza et al., 2012). But on the other hand, Unterberger (2018) found that fiscal budget at subnational level is adversely affected by flood damages to public infrastructure affecting the operating businesses and deteriorating region's financial position.

The effects of floods are also different for countries depending upon the development status. Cunado and Ferreira (2011) used pooled data of 118 countries for the time period of 1985-2008 distinguishing between developed & developing countries to check for the response of output growth of both agriculture and non-agriculture sectors to flood. They found that the effect of flood on overall growth rate was positive and significant in the year after flood, but it peaks two years after flood. This delay in the overall growth response is because of the agricultural sector which is negatively affected in the year of flood. And the beneficial effects are due to improvement in land productivity due to floods. Their results also indicated that floods have positive impact on the GDP for developing countries due to their reliance on agriculture as flood increases the land productivity but negative impact on the GDP of developed countries for they incur great losses in industrial and services sector.

Assessing the short and long-run impacts of floods on the macroeconomic variables and GDP growth in Pakistan, Mujahid et al. (2016) examined the co-integration among the variables so as to find the response of GDP growth to flood dynamics. Their analysis of the determinants of growth affected by flood revealed that both agricultural and non-agricultural (services and manufacturing) sectors have positive and significant long-run impact on GDP growth. However, floods on the other side also have positive impact on GDP growth. Which according to their study is due to the fact that Pakistan is highly dependent on agricultural sector and floods increase soil fertility, moisture, water availability in the reservoirs. But the results for exports and investment were found inconclusive due the macroeconomic instability in the country.

Investigating the determinants of flood related hazards, Sardar et al. (2016) also investigated for its impact on growth of per capita GDP using time series data for the period 1972-2013. They analyzed the effect of flood related hazards: property damage, mortality, and non-fatal effects on population, on per capita GDP growth. They employed 2SLS technique due to the endogeneity of the damages or hazards of flood. The evidence from their study suggested that the scale of flood related hazards can be reduced through flood management and GDP growth. But due to low learnings from the past experiences and poor disaster management, there has been larger frequency of floods in Pakistan. Strong negative impact of property damage on per capita GDP growth was found while on the other hand GDP growth and infrastructure showed significant negative impact in their analysis.

Floods in Thailand caused a GDP loss of 13% in 2011. But the impacts of floods at household or micro level were not the same rather heterogeneous. As found by Noy et al. (2019), the direct impacts of floods caused great loss to those rural-urban households who were dependent on business income while those relying on agricultural income were less affected. The difference was referred to the different resilience strategies by both types of households. Further, floods also affected households indirectly as their expenditures were increased due to higher prices of commodities as a consequence of floods.

Effects of floods also vary across sectors just as it varies across regions and countries. The effects are mainly felt in agriculture sector followed mostly by forestry, built infrastructure and fisheries. As it causes the disruption of communication and transportation as well as reduces production, the manufacturing sector is affected as well. Identifying the long-run relationship between GDP and other flood variables, Shaari et al. (2017) explored that total cost from flood damages was positively related with GDP. Their results also showed that growth in manufacturing sector was increasing GDP growth by 0.6 percent while it was negative in case of Agriculture sector, decreasing GDP growth by 0.22 percent. However, the total damage costs were found to decrease GDP growth by 0.17%.

Physical infrastructure is an essential part of the critical infrastructure, the interdependency of which plays important role in country's welfare. Critical infrastructure on the whole refers to the country's assets or system which if destroyed or disabled can lead to a catastrophic damage. Through the damages of flood to such interdependent critical infrastructure, the total economic loss estimated by Neal (2014) for Hamilton County for the 100 years return period was about US$ 611.77 million which accounted for 12.6% of the total value of the buildings considered in the study.

As discussed earlier, floods do not only have direct effects in the hazard area but also cause disruption of critical infrastructure such as telecommunication, electricity network, gas, etc. Loss of critical infrastructure will have cascading effects on businesses dependent on that infrastructure thus affecting the whole economy. Koks et al. (2019) employed geospatial information on the infrastructure, geospatial modeling for the business that rely on those infrastructure and multiregional economic supply-use modeling to analyze its wider impacts on the economy. Their results showed that economic losses were increased by 300% when outages of power were included in the risk assessments compared to the losses which only considered disruptions due to flooded enterprises' premises. Applying their models to a case study of UK, their study suggested that a small loss in local economy can cause a greater macroeconomic impact that showed the relationship of direct and indirect losses.

Besides other factors, residing in the area prone to floods, absence of proper irrigation canal system and poor drainage due to dense settlements were also identified as some of the reasons for the vulnerability to floods. Rahman (2014) through his narrative cross-sectional study demonstrated that floods have negatively affected livelihoods of the community. The study also revealed that the negative impacts of floods in one sector also affect other sectors of the country/region. Hence, encouraging communities to use durable material when building houses and the cooperation of authorities to minimize risk and reduce post flood effects were considered necessary in their study.

Frequent studies have been undertaken to study the socio-economic impacts of the floods. The underlying causes that made Skiwanze community in Zambia, vulnerable to floods were increased exposure to floods, lack of resilience, limited livelihood options. However, the socio-economic impacts of floods in the community included damages to crops, health loss or disruption in health services, increase in outbreak of diseases, effects on education when school infrastructure was damaged, and the collapse of houses and other productive assets. Around 36% percent of the total respondents in the study area had their houses collapsed due to floods (Mwape, 2009).

Similarly assessing the coping strategies and the socio economic impacts of 2014 flood in the most vulnerable districts of Punjab, Pakistan, Hyder and Iqbal (2016) discovered that the loss to agriculture sector was about 89% of the crop area being lost, whereas many had their dwellings destructed due to floods. The coping strategies adopted by the flood-stricken households involved the disposal of assets such as disposing their livestock, cash grants by government or borrowings from informal sector.

As stipulated by Masese et al. (2016) exposure and vulnerability were also found to be major drivers of loss and damages due to floods through increasing capital assets and population. Conducting a research study in the Kisumu County of Kenya, the authors explained that flood have seriously affected the physical, economic, social and environmental wellbeing of people in the study area.

The greater losses and damages were found to have incurred to traders and household for losing their sources of income. Health related damages were also observed due to the disruption of environment, loss of affordability and the damages to transport and health services. Thus, concluded that flood has a negative impact on the built environment and infrastructure or physical capital in the form of destruction of power supply, road damages, communication services as well as the disruption of clean water supply, education, and health services.

2.2 Floods situation in Pakistan:

The floods triggered by monsoon rain in September 2014 in Pakistan and India were the costliest disasters of the year. These floods took more than 500 lives in the region, the threat of which extended well beyond the Southeast Asia. Among all other natural disasters, floods are considered to be more fatal affecting approximately 21 million people each year on average around the globe. In terms of GDP exposure to floods by 2030, developing countries are more vulnerable to flood risk (Riluo et al., 2015).

Paulikas and Rahman (2015) mentioned that increase in the consequences and threat of climate change floods have caused great damage to the country including both physical and financial damage. During the period of 1950-2016 approximately 15,000 fatalities have been reported only from floods in Pakistan. Hence, the loss from the Mega flood of 2010 in Pakistan was about 6% of that year's GDP (LEAD, 2015). In the last seventy years, Pakistan has experienced about 22 catastrophic flood events.

Since 1947-2015, major flood events have caused the financial loss of US$ 38.165 billion to Pakistan (Aslam, 2018). According to annual flood report (2014), the flood of 2010 was declared as the worst one in the region for the past 80 years. The physical capital ruined by 2010 flood was worth US$16 billion while the total estimated flood damages due to 2014 floods were US$0.44 billion. The major loss revealed was to infrastructure sector followed by housing and crops (Mujahid et al., 2016).

2.3 Flood risk and management:

During the past decades, the management of flood risk has gained a lot of attention and hence shifted from a hazard-based perspective to broad risk-based approach covering both societal and physical processes (Van Ree et al., 2012). Moreover, considerable amount of work in natural and social sciences has been devoted to improving the ability to forecast disasters and to look at the preventive side of it. Though in early 2000, the topic was discussed in the domain of technical and social sciences (Cavallo and Noy, 2010). Along with countries' economic activities their fiscal position is also vulnerable to extreme weather events which necessitates flood management and adaptation strategies. Adaptation strategies requires information of extreme weather impacts and regional vulnerability. According to Zeshan and Ko (2017) the most important adaptation strategies require agrarian countries to make efficient use of water resources. To model a regional adaptation policy to climate change in a research framework, Zeshan and Ko (2019) used Dynamic GTAP-Water (Gdyn-W) model.

The effects of floods are further categorized into environmental, economic and social impacts. But not all the values attached to each type of impacts can be quantified, thus identified separately by non-monetary and monetary terms.

Floods particularly have impacts on the community or public Infrastructure which further causes fiscal implications to the country or region by affecting their budget indicators. Conducting study on the regional flood damages to public infrastructure in Austria region of Austria, Unterberger (2017) suggested that municipalities should implement stricter regulations for land use and adopt precautionary measures for better flood management and to reduce flood damages and its implications.

The death tolls in developing countries due to disasters are higher than in developed countries. The difference is possible due to the higher expenditures on preventive and averting measures or higher bounce back capacity (Powell and Becerra, 2010). Examining the various measure of economic development, Skidmore and Toya (2007) suggested that countries with higher economic development including better infrastructure, financial and trade openness, higher educational attainment and higher income are less likely to encounter risks or damages from natural disasters than countries with lower economic development.

However, it is also suggested that government expenditures and insurance sectors can play their role in mitigating the flood related hazards and reducing the vulnerability and exposure (Masese et al., 2016). While the most important mitigation strategy proposed by Zeshan and Ko (2017) to combat climate change is to reduce carbon emissions.

Alfieri et al. (2016) simulated four types of adaptation strategies or measures in their European flood risk modeling framework considering the 4^0C global warming by the end of 21^{st} century increasing the frequency and intensity of river floods in Europe. Their framework for risk assessment includes hydrological modeling, mapping of 2D flood hazard, threshold-based evaluation of magnitude of extreme events, depth-damage functions which are country specific, exposure maps and information on vulnerability to estimate present and future flood risk. Comparing the post-event adaptation and no adaptation scenario for 28 countries in their model, they found an increase in flood protection in case of adaptation scenario and the benefits of adaptation were more in the second half of the century. They also found that impact estimates for both scenarios in early 2000s were overlapping. However, average risk reduction rate at country level was found between 30-73%. Their study recommended that traditional measures against flooding do not lead to sustainability rather strategies for adaptation should be based on various modern measures.

A research study held at Bangladesh by Rahman (2014) explored that signs like movements of ants, abnormal bite of fly, clouds' position in the sky, abnormal voices of animals, increased rainfall in catchment area, muddy smell of water, strange sounds from torrents, high intensity of the rainfall etc. were perceived as indicators of floods in the study area. The study recommends that community-based management, forecasting of flood and early warnings are highly effective methods for local flood management.

The mitigation strategies proposed in the work of Neal (2014) involved assessment of risk as the first step of response to flooding, so that the potential emergency scenarios can be identified which includes ensuring the safety and event stabilization and this is known as disaster plan implementation. Further, it included the warning systems, evacuation, or rescue response, etc.

Various measures for flood management are executed in Pakistan. Structural measures include the construction of embankments, spurs, studs, dykes and bunds, etc. There is a great variation in the nature of floods across regions due to different hydrologic, climatic, socioeconomic and physiographic factors. Indus water treaty, formulation of national flood protection plans since 1974 and advanced flood protection methods have attracted settlements and economic activities in the flood Plains. But with the rising threat of climate change, the country needs to take more actions and to expand both structural and non-structural measures. Further, for sustainable management flood a pro-active, and a risk-based approach is needed (Tariq and Giesen, 2011).

In order to identify prospective for improved management of floods in Pakistan and to highlight the key challenges, a review by Aslam (2018) of the current state of flood management in the said region stated that though Pakistan has taken several measures to manage floods but it still face the challenges like lack of comprehensive flood policies, institutional and planning issues, improper flood infrastructure, lack of proper pre and post flood preparedness, improper flood fighting operations and also lack of education and awareness and training for such disaster's preparedness and mitigation strategies.

Many times, the focus of disaster plan for prevention is on some particular area however it is important to consider its impacts on other areas and economies as well. But again, such an effective disaster plan or designing a mitigation strategy is not possible without having a detailed study of the flood damages and its impacts on various sector. Thus, our study is focused on analyzing such far-reaching impacts of the flood damages to physical infrastructure.

2.4 Research gap

All the studies, cited in above three themes of literature review, present a diverse literature on effects of floods. Authors have covered various research areas but to the best of our knowledge a system-wide analysis of indirect flood damages using CGE framework has not been conducted yet in Pakistan's context. Research on climate change impacts is also limited to crops and agriculture or to other few sectors which can be directly affected by extreme weather events. But climate change is a broader and macro-level phenomenon affecting the whole economy of the country in different ways. Hence, this study takes into account the impacts of flood damages on the whole economy of Pakistan using a CGE framework. It will help in identifying sectors that require more attention for better management plans to be undertaken against floods.

2.5 CGE modeling framework:

This section shows why CGE models are more suitable for this research work. These models are extensively used in a variety of studies for both developing and developed countries based on various purposes particularly to examine the effect of an external shock on the whole economy.

Using a spatial CGE model based on Ramsay's growth model, Nakajima et al. (2014) studied the damages caused by flood and their spillover effect on the economy. They found an increase in flood damage cost from $0.4billion to $5.6billion in the simulation period 2000-2050. Further their simulation results for comparing a baseline scenario with flood scenario showed that investment return will decrease leading to decrease in consumption and savings thus the dynamic multiplier of cost was estimated to be from 1.2 to 1.7 times.

Gertz et al. (2019) used a dynamic CGE model in which government, firms and households all make their economic decisions based on their informed future expectations. They applied their framework to Vancouver city of Canada with GDP of $110 billion which counts for 59% of the GDP of the British Columbia Province. Modeling the initial damage due to flood as a shock to capital stock in which 25% of the capital located in the city was destroyed, they found out that the direct cost of this destruction of physical capital will be $14.6 billion. The GDP loss due to this damage as compare to the scenario of no flood was found to be 2.0%, 1.7% and 1.2% in the first year, second year and in the fifth year respectively after the flood. The sectors they found most affected in their study were those of transportation, warehousing, manufacturing and wholesale trade.

Zeshan and Ko (2019) have also recently developed a dynamic CGE-Water model to examine the usefulness of adaptation policies to climate. With focus on south Asian countries, the study employed GTAP database version 9. Empirical results revealed that under the scenario of 1^0C rise in temperature until 2040, all the countries under analysis face loss in domestic production. The main adaptation policy suggested in their work is efficient use of water resources as it serve as primary factor of agricultural production when used in irrigation.

Dwyer (2015) applied CGE modeling framework to show its advantages over I-O approach and its implications for tourism industry. Applying this model, the study identified several areas where the analysis of tourism and policy for this industry can be suitably informed. Important contributions of CGE modeling have been reviewed in his paper in the context of tourism, providing insights to forecasting, planning and policy analysis. The author concluded that policy makers, while proposing policy for tourism in destination also need to consider the impact of strategic aviation alliances on tourism and such impacts can be better analyzed via CGE modeling.

Pauw et al. (2010) examined the economy-wide impact of floods and droughts on the economy of Malawi which is highly dependent on its agriculture. They used CGE modeling framework for this purpose and found that Malawi bears the loss of 1.7% of its GDP on average due to the combined effect of floods and drought that hits it almost every year. This loss equals to about US $22 million in 2005 prices. The study further revealed that, due to the impact of extreme climate events on the overall economic system with its major impact on crops, prices were increased due to the destruction or shortage of food resulting in reduction of household income.

Carrera (2014) made risk analysis, and assessment of social vulnerability to floods in Po river Basin in Italy. The analysis included major economic losses and wider economic damages due to Po river floods in 2000. This study incorporated the sub-national CGE model for Italy in order to study the macro economic impacts of floods in Italy in the context of research objectives. Using GTAP 7 database, the author found out that flood damages caused significant losses to capital assets and productive sectors. The total damages in this study accounted for about 4 billion euro in 2006 prices. The total direct loss exceeded 103 billion euro with highest damage factor. The total effect in Italy was found negative and alike to a rigid version of the model but there is more unequal distribution of effects geographically.

Assessing the macro-economic effects of flooding that occurred due to rise in sea-level as well as to assess the economy-wide impacts and adaptation measures for GHG emissions, Schinko et al. (2020) did a multi-model global analysis with main focus on G20 countries. Their results indicated that India, China and Canada will face the highest impacts of climate events such as floods and GHG emissions at macro level. They also employed CGE models along with growth models to study the macro-economic impacts of both coastal flooding and GHG emissions mitigation and adaptation strategies.

Extreme weather events such as floods can also be increased in frequency and intensity due to inappropriate use of land and the growing population. Thus, analyzing both direct and indirect impacts of flood damages and inquiring into the financing of adaptation strategies in federalist economy, Christian and Hoffman (2017) used a dynamic Ramsay type spatially differentiated general equilibrium framework. They found out that flood damages have their impacts extended to less vulnerable regions as well, when it hits the vulnerable ones. Their analysis also proved that adaptation strategies financed through output tax levied by national economy than by land tax levied by regional economy will result in lower tax rate.

Based on the SAM data framework of Zimbabwe, Benitez et al. (2018) incorporated a CGE model to check for economy-wide impact of possible scenarios (dry or wet) of climate variability and shocks. Their analysis was based on the time series projected for 2017-2030 crop prices. The impact on GDP was found significant and that a dry future with no adaptation can decrease the GDP of Zimbabwe by 2.3% that approximately equals to $370 million annual based on GDP level of 2016.

Perez Blanco and Standardi (2019) assessed the impacts of agriculture water buy-back on whole economy of Murcia region in Spain. They established a modeling framework of combining a macro-economic CGE model with a micro-economic model known as PMAUP model.[3] The simulation output from the PMAUP model were used in a CGE framework to check for the intensity and spread of the policy shock throughout the economic agents, macroeconomic sectors and other spatial units. The results revealed that losses in income from Murcia's agriculture was about 33% in the combined PMAUP-CGE model whereas the GDP losses were up to 2.1% due to decrease in the agricultural and other sector's supply in most scenarios of the model.

Computable general equilibrium model has also been used by Dudu and Cakmak (2018) to compute the economic impacts of climate variability on economy of Turkey. They simulated the scenarios of climate change shocking the water requirements and the average agricultural yield. Their simulation results for the whole economy indicated a significant

[3] Microeconomic Positive multi-attribute utility programming model.

impact of climate change on major macroeconomic indicators such as welfare and agriculture production and GDP. Although they will not be changed significantly in the 1st period (2010-2035), but negatively affected in 2nd (2035-2060) and 3rd (2060-2099) period. Agricultural production was found to decrease by 5.1% whereas, agricultural imports will increase by 15% due to climate change by 2060-2099.

Hence, the above analysis indicates that CGE models provide a reasonable framework to study economy-wide impacts of any event, shock, policy or technological change. This framework has been used thoroughly in the literature to study the impact of policies related to climate-change. These models are also used to analyze sector-specific impacts of disaster shocks and policies of welfare in the economy. Moreover, the theoretical basis of CGE models help one to interpret the simulations in the form of firms and consumers in the economy. Due to these reasons, this study incorporates the GTAP based CGE framework to examine the impact of flood damages to physical infrastructure on the economy of Pakistan.

CHAPTER 3

3 METHODOLOGY

3.1 Introduction

The numerical analysis in this document uses the theoretical model for the better understanding of the economic impacts of flood damages on physical infrastructure in Pakistan. For this reason, this chapter explains the CGE modeling framework, how the standard GTAP model works and the numerical data to be used in this model for analysis.

3.2 CGE model

CGE models are numerical models that combine real economic data with economic theory to explain how an economy responds to a change in policy, technology or any other external shock. These models are also called as applied general equilibrium models. The CGE models are theoretically consistent with economic theory and capture both direct and in-direct inter-regional, inter-temporal and inter-sectoral effects that occur due to policy changes. CGE models consist of model variables, database, set of economic agents and equations which capture the behavioral response of those agents and the structure of economy.

The main steps of a CGE model include; defining a case to be studied, construction of a consistent model, collection of data, construction of a benchmark to be used in calibration, coding the model, conducting an experiment and finally the analysis of results (Reihan, 2017). These models differ from other econometric or macroeconomic approaches as the later focus on only one sector while CGE framework takes the whole economy into account and capture the effects and interactions between its different sectors.

3.3 Graphical representation of standard GTAP model:

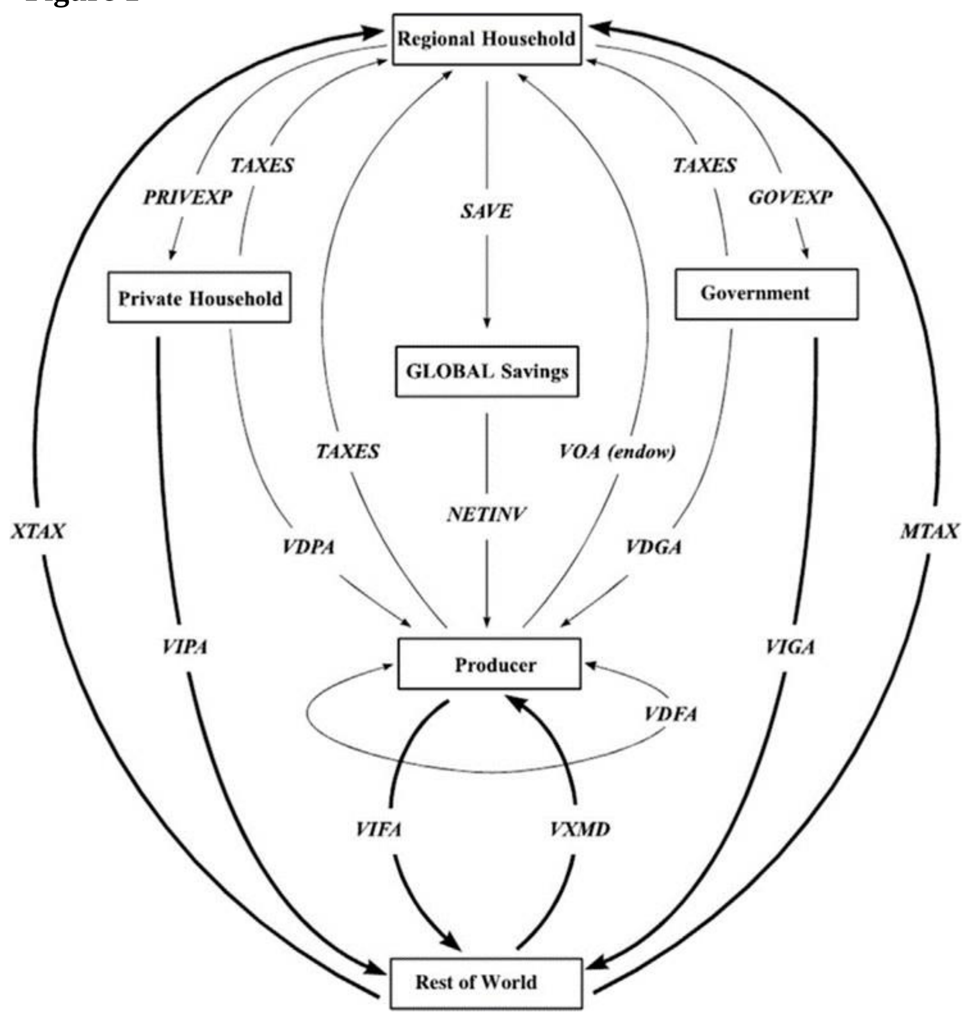
In economics, the two main aspects of costs that occur due to floods include direct cost and indirect cost. The most essential direct cost is the cost to physical capital while the important indirect cost is the loss to GDP. Though, it is easy to estimate flood damages through information on assistance payouts for disasters and insurance claims and the future damages from the information based on engineering analysis and previous floods (Gertz et al., 2019) but predicting indirect costs of disasters through economic modeling is a complex matter. The indirect effects of disasters on the economy are generally measured through model-based approach or econometric approach. Based on the series of past events of the disasters, econometric models evaluate the average effect of the event on the economy. Whereas model-based approach analyzes the cost and impact of the disasters on the whole economy using input-output or CGE models (Unterberger, 2018).

Whenever a good is produced in a firm, or prices are changed, it has its consequences on income, employment, government consumption, and output of other firms and industries, thus underscoring the importance of essential connections amongst the markets and products. Because of the above reasons, CGE models suit more for economy-wide analysis. Importantly, CGE models can incorporate welfare measure. They are based on Walras theory of general equilibrium (Dwyer, 2015). CGE models generally concentrate on the linkages between factor and products market, output production and prices via input-output linkages and equations. These models also link macroeconomic variables i.e. savings and investment (Murevarwi and Minor, 2013).

This research work employs a global CGE model called GTAP to investigate the effects on the whole economy due to damages to physical capital in Pakistan by floods in 2014. This is a relative stationary and linear model that uses global database for economy-wide analysis of the world. It relies on the assumption of perfect competition in all markets, all trade and manufacturing activities show constant return to scale, all households and industries show utility maximization and profit maximization behavior respectively. The GTAP model to be used in this study will be simulated using GEMPACK software (Harrison and Pearson, 1996).

Before we explain the model closure or simulations design, it is important to discuss and graphically illustrate the GTAP model, please see Figure 1. In the standard GTAP model, there is a representative regional household for each country as shown in the upper part of the illustration. This regional household receives all income and exhaust it into three categories including expenditures by private household (PRIVEXP), savings (SAVE) and expenditures by domestic government (GOVEXP). All the three components of final demand possess a constant share in regional income according to cobb-Douglas per capita utility function (Hertel and Tsigas, 2000).

3.3.1 Figure 1



Source: Brockmeier (2001)

While allocating the income no component can spend more than it receives from the regional household. In the lower half when producers are included in the model, the firms build closed economy with regional household along with its three components. This provides a deeper look at the accounting relationships in the GTAP model. Starting with the regional household the upper half of the diagram shows that the available regional income actually consists of the VOA (value of output at agent's prices) paid by producers in return of the endowment commodities to the regional household. These endowment commodities or primary inputs are then combined with the intermediate goods by firm (VDFA= value of domestic purchases by firms at agent's prices) to produce final goods. These final goods are then sold to private household and government resulting in (VDPA=value of domestic private household purchases at agent's price) and (VDGA=value of domestic government purchases at agent's price). While the investment goods are sold to the regional household by producers in order to meet their demand for saving (NETINV). Thus, by this process a circular flow of expenditures, income and production is completed without taxes in a closed economy.

The model is then extended by adding another region, ROW (rest of the world). The structure of this region is same as domestic economy in the model and its inclusion depicts the destination of exports from the domestic economy to other regions and the imports into the regional economy. The exports are shown by (VXMD = value of exports at market price by destination) whereas, the imports are made by three different economic agents in the local economy. Thus, all the three makes different payments for imports to the rest of the world region (ROW). Payments made by firms, private households and government are presented in the standard model by (VIPA), (VIFA) and (VIGA) respectively.

In the multi-region open economy without taxes the third component of savings is denoted by global savings as the savings and investments in the open economy are computed at global level (Brockmeier, 2001). But open economy involves two global sectors including global bank and the second global sector which deals with all the international transport activities and international trade. Intermediation between regional investment and global savings take place through Global bank as illustrated in the middle of Figure 1. It also works as assembling the portfolio of regional investment goods and also satisfy regional household's demand for saving by selling the shares in this portfolio. Similarly, regional trade exports, insurance services, transport are assembled by the second global sector as mentioned above and a composite good is produced to move merchandise trade among the regions. The differences between global imports are valued on *cif* basis and global *fob* exports (Hertal and Tsigas, 1997).

Now adding taxes to both closed and open economy we get the values as follow. In a closed economy taxes flow from government, firms, and private households to the regional household. When taxes accrue to the regional household then the regional income consists of *VOA* paid against the use of endowment as well as the sum of the taxes net of subsidies. If tax is levied on the demand that is tax on the consumption of private household then the tax revenue can be computed as the difference between the value of domestic purchases of commodity i in region r, at agent's price and value of domestic purchases at market price.

$$DPTAX(i,r) = VDPA(i,r) - VDPM(i,r)$$

If tax is levied on the demand side than the agent's price is higher than the market price while it is lower if tax is levied on supply side. The taxes paid by private households to the regional household is actually the net tax revenue. If tax is imposed on the producer of the commodity i in region r, then the producer tax revenue is calculated as the difference between value of output at market price and value of output at agent's price:

$$PTAX\ (i,r) = VOM(i,r) - VOA(i,r)$$

Now in the open economy where exports and imports are involved taxes will be imposed on exports and imports, the trade generated tax revenue is computed in a manner analogous to taxes in closed economy. To check for the accounting relationships for the rest of the world, the figure 1 shows that the rest of the world receives payments against selling goods to firms, governments and to private households for private consumption. These revenues from selling goods will be exhausted on goods exported from single region in question to the ROW denoted as *VXMD*, and on export taxes, *XTAX*, that flows from rest of the world to the regional household, on import taxes, *MTAX* which flows to regional household from private household, producers and government.

When export Tax is implemented, the domestic price of commodity i, in region s is decreased whereas, FOB price is increased according to the price linkage relationship *PM= PFOB/TXS* and the export tax revenues are calculated as the difference between *VXWD(i,r,s)* and *VXMD(i,r,s)*. On the other hand, if tax is imposed on commodity i imported by country r from region s, it drives a wedge between the domestic price and the *CIF price*. In the presence of import tax, the domestic price of the importer exceeds the *CIF* price of the commodity i, supplied to region r from region s. The import tax can be computed as follows:

$$MTAX = VIMS(i,s,r) - VIWS(i,s,r)$$

The savings in figure 1 are represented by Global savings as mentioned earlier, which means that investment and savings are computed on global basis in the multi-region version of GTAP model so that a common price is faced by all the savers against the saving commodity. All this clearly means that all the households are on their budget constraint, all the firms earn zero profits if all the markets are stable or in equilibrium. Then the global investment must be equal to global saving to satisfy Walras' Law.

Thus, all the accounting relationships when exhausted create a general equilibrium situation in a GTAP model. If all the conditions are met, then Walras' law will be satisfied. For supplies of tradable commodities, market clearing conditions are as follows:

$$\mathrm{VOM(i,r)} = \mathrm{VDM(i,r)} + \mathrm{VST(i,r)} \sum_{s\varepsilon REG} \mathrm{VXMD(i,r,s)} \qquad \text{(i)}$$

It can be rewritten in terms of quantities and a common domestic market price:

$$\mathrm{PM(i,r)} * \mathrm{QO(i,r)} = \mathrm{PM(i,r)} * [\mathrm{QDS(i,r)} + \mathrm{QST(i,r)} + \sum_{s\varepsilon REG} \mathrm{QXS(i,r,s)}]$$

(ii)

Dividing by PM(i,r), it results in the usual form of the tradeable commodity market clearing condition:

$$\mathrm{QO(i,r)} = \mathrm{QDS(i,r)} + \mathrm{QST(i,r)} + \sum_{s\varepsilon REG} \mathrm{QXS(i,r,s)}] \qquad \text{(iii)}$$

Similarly, market clearing conditions can be produced for nontradeable commodities in the same way. Value terms of any market clearing condition can be obtained if it is multiplied by a common price. Hence, all the required equilibrium conditions in standard GTAP model are embodied in its accounting relationships. Following Hertel and Tsigas (1997), the market clearing conditions in the standard GTAP model are as follows:

(1) $\mathrm{VOM(i,r)} * \mathrm{qo(i,r)} = \mathrm{VDM(i,r)} * \mathrm{qds(i,r)} + \mathrm{VST(i,r)} * \mathrm{qst(i,r)} + \sum_{seREG} \mathrm{VXMD(i,r,s)} * \mathrm{qxs(i,r,s)} + \mathrm{VOM(i,r)} + \mathrm{tradslack(i,r)}$ (iε TRAD_COMM, rεREG)

(2) $\mathrm{VIM(i,r)} * \mathrm{qim(i,r)} = \sum_{J\varepsilon PROD} \mathrm{VIFM(i,j,r)} * \mathrm{qfm(i,j,r)} + \mathrm{VIPM(i,r)} * \mathrm{qpm(i,r)} + \mathrm{VIGM(i,j,r)} * \mathrm{qgm(i,r)}$ (iε TRAD_COMM, rεREG)

(3) $\mathrm{VDM(i,r)} * \mathrm{qds(i,r)} = \sum_{j\varepsilon PROD} \mathrm{VDFM(i,j,r)} * \mathrm{qfd(i,j,r)} + \mathrm{VDPM(i,r)} * \mathrm{qpd(i,r)} + \mathrm{VDGM(i,r)} * \mathrm{qgd(i,r)}$ (iε TRAD_COMM, rεREG)

(4) $VOM(I, r) * qo(i, r) = \sum_{j\varepsilon PROD} VFM(i, j, r) * qfe(i, j,r) + VOM(i, r) * endwslack(i, r)$

(iεENDW, rεREG)

(5) $qoes(i, j, r) = qfe(i, j, r)$ (iεENDW, j,PROD_COMM, rεREG)

(6) $VOA(j, r) * ps(j, r) = \sum_{i\varepsilon ENDW} VFA(i, j, r) * pfe(i, j, r) + \sum_{j\varepsilon TRAD} VFA(i, j, r) * pf(i, j, r) + VOA(j, r) * profitslack(j, r)$ (jεPROD_COMM, rεREG)

(7) $VT * pt \sum_{i\varepsilon TRAD} \sum_{r\varepsilon REG} VST(i, r) * pm(i, r)$

(8) $PRIVEXP(r) * yp(r) = INCOME(r) * y(r) - SAVE(r) * [psave + qsave(r)] - \sum_{i=TRAD} VGA(i, r) * [pg(i, r) + qg(i, r)]$

(rεREG)

(9) INCOME(r)*y(r)

= sum(i,ENDW_COMM,VOA(i,r)*[ps(i,r)+qo(i,r)]- VDEP(r)*[pcgds(r)+kb(r)]

$+sum(j, PROD_{COMM}, sum(i, TRAD_{COMM}, \{VIFA(i, j, r) * [pfm(i, j, r) + qfm(i, j, r)]\} - VIFM(i, j, r) * [pim(i, r) + qfm(i, j, r)]\}))$

$+sum(j, PROD\_COMM, sum(TRAD\_COMM, \{VDFA(i, j, r) * [pfd(i, j, r) + qfd(i, j, r)]\} - \{VDFM(i, j, r) * [pm(i, r) + qfd(i, j, r)]\}))$

$$+sum(i,TRAD\_COMM,\{VIPA(i,r)*[ppm(i,r)+qpm(i,r)]\}-\{VIPM(i,r)*pim(i,r)+qpm(i,r)]\})$$

$$+sum(i,TRAD\_COMM, \{VDPA(i,r)*[ppd(i,r)+qpd(i,r)]\}-\{VDPM(i,r)*pm(i,r)+qpd(i,r)]\})$$

$$+sum(i,TRAD\_COMM,\{VIGA(i,r)*[pgm(i,r)+qgm(i,r)]\}-\{VIGM(i,r)*pim(i,r)+qgm(i,r)]\})$$

$$+sum(i,TRAD\_COMM, \{VDGA(i,r)*[pgd(i,r)qgd(i,r)]\}-\{VDGM(i,r)*pm(i,r)+qgd(i,r)]\})$$

$$+sum(i, TRAD\_COMM, sum(s, REG, \{VXWD(i, r, s) * [pfob((i, r, s) + qxs(i, s, r)]\} - \{VXMD(i, r, s) * [pm(i, r) + qxs(i, r, s)]\}))$$

$$+sum(i, "TRAD\_COMM, sum(s, REG, \{VIMS(i, s, r) * [pms(i, s, r) + qxs(i, sr)]\} - VIWS(i, s, r) * [pcif(i, s, r) + qxs(i, s, r)]\}))$$

$$+INCOME(r) * incomeslack(r)$$

(10) $$INCOME(r) * y(r) = sum(i, ENDW\_COMM, VOM(i, r) * [pm(i, r) + qo(i, r)]) - VDEP(r) * [pcgds(r) + kb(r)] +100.0 * INCOME(r) * [TPCR(r) + TGCR(r) + TTUR + TFUR(r) + TOUTR(r) + TEXPR(r) + TIMPR(r) + TINCR(r) + y(r) * [TPC(r) + TGC(r) + TIU(r) + TFU(r) + TOUT(r) + TEX(r) + TIM(r) + TINC(r) * y(r)] + INCOME(r) * incomeslack(r)$$

(rεREG)

Where:

VOM(i,r) = Value of commodity i output in region r at market prices

qo(i,r) = Industry output of commodity i in region r

VDM(i,r) = Domestic sales of commodity i in region r at market prices (tradeables only) qds(i,r) = Domestic sales of commodity i in region r

VST(i,r) = Exports of commodity i from region r for international transport valued at market prices (tradeables only)

qst(i,r) = Sales of commodity i from region r to international transport

VXMD(i,r,s) = Exports of commodity i from region r to region s valued at market prices (tradeables only)

qxs(i,r,s) = Export sales of commodity i from region r to region s

VIM(i,r) = Value of imports of commodity i in region r at domestic market prices

qim(i,s) = Aggregate imports of commodity i in region s, market price weights

VIFM(i,j,r) = Purchases of imports of commodity i for use by industry j in region r

qfm(i,j,s) = Demand for commodity i by industry j in region s

VIPM(i,r) = Private consumption expenditure on i in r

qpm(i,r) = Private household demand for imports of i in region r

VIGM(i,r) = Government consumption expenditure on commodity i in region r

qgm(i,s) = Government household demand for imports of commodity i in region s

VDM(i,r) = Domestic sales of commodity i in region r at market prices (tradeables only)

qds(i,r) = Domestic sales of commodity i in region r

VDFM(i,j,r) = Purchases of domestic good i for use by industry j in region r

qfd(i,j,r) = Domestic good i demanded by industry j in region s

VDPM(i,r) = Private consumption expenditure on domestic good i in region r

qpd(i,r) = Private household demand for domestic good i in region r

VDGM(i,r) = Government consumption expenditure on domestic commodity i in region r

qgd(i,r) = Government household demand for domestic good i in region r

VFM(i,j,r) = Producer expenditure on commodity i by industry j in r valued at market prices

qfe(i,j,r) = Demand for endowment i for use in industry j in region r

endwslack(i,r) = Slack variable in endowment market clearing condition

qoes(i,j,r) = Supply of sluggish endowment i used by industry j in r

qfe(i,j,r) = Demand for endowment i for use in industry j in region r

ps(j,r) = Household's supply price for endowment j in reg r

pfe(i,j,r) = Firm's prices for endowment commodities i in firm j in region r

pf(i,j,r) = Firm's prices for composite intermediate inputs i in firm j in region r

yp = Private household demand

pm = Market price

profitslack = It permits to fix output and eliminate the zero-profit condition for any sector j in any region r

This study inquire the impact of flood damages to physical capital on the overall economy of the country. The CGE model in this study uses GTAP 11 database with reference year 2011, 2014 and 2017 to look at the macroeconomic impacts of this negative shock to physical capital on Pakistan's economy. The macroeconomic variables to be evaluated in this thesis will include real GDP, terms of trade, imports, exports, change in market prices and total welfare change.

3.4 Model closure:

The standard GTAP model to be used in this study will assume full employment of endowment commodities (labor, land, and capital), perfect competition (zero economic profits), factors mobility (except land which seldom moves between uses), capital mobility between regions and elastic trade balance.

3.5 Simulation steps

In order to obtain simulation results in runGTAP software, following steps can be followed:

1: First of all, aggregated datasets are developed in the form of SAM using GTAPAgg software. This software also helpfull in overall database aggregation.

2: Upload the aggregated datasets in RunGTAP software that uses GEMPACK programs and save the data for simulations. It can be performed by clicking on File →version archive → Load archive →then select aggregations (in the zip file), that are already prepared with GTAPAgg software.

3: To check or run a new simulation, simply click on the shock.

4: Shock the variable in question, in our case we have produced a negative shock to "qo" by reducing the physical capital by 39% to analyze the impact on macro-economic indicators of Pakistan Economy.

5: Click on solve the Shock, and save the experiment for future analysis, otherwise directly examine the results without saving the experiment.

7: Do not forget to name your experiment in the description bar that pop up while solving an experiment.

8: On the results page click on variables you want to analyze or interpret. And its values will occur in table form.

9: Copy your results by clicking on the “copy” option available in the upper bar.

10: Save your results and it is now ready for analysis.

Chapter 4

4 GTAP Database and Simulation Design

4.1 GTAP database version 11 (pre-release 1)

GTAP (Global Trade Analysis Project) was initially focused only on trade policy analysis but its extended version analyze environmental and climate change issues as well. At first, the GTAP database was created by Thomas Hertel.[4] The GTAP database version 10 is an updated form of the standard database, which is available publically. The database represents the world economy for the pre-determined reference years of 2004, 2007, 2011 and 2014. But, the GTAP database version 11 used in this study (will be released soon) is updated with additional reference year of 2017. This database is produced with efforts and contributions of many organizations and experts around the world providing country-specific input-output tables. The data from the experts is then combined at the GTAP Centre (Purdue University of Indiana State, USA) to make it a global I-O table.

The data sources used in this database include social accounting matrix (SAM), national accounts, I-O tables, protection, macroeconomic, trade and energy data. Ensuring the user with consistency of the economic dataset, the simulation of economic models is made easy to operate with GTAP database. It comprehensively provides values for the flow of goods and services at both regional and international level. This database is designed in

[4] Thomas Hertel is Distinguished Professor of Agricultural Economics at Purdue University, where his research and teaching focus on international trade, food and environmental security. Dr. Hertel is a Fellow, and a Past-President, of the Agricultural and Applied Economics Association (AAEA).

such a manner that it can only be used with the GTAP model and run through "runGTAP software" based on GEMPACK.[5]

The GTAP database version 10 geographically covers 141 countries/regions, accounting for about 92% of the world population and 98% of global GDP. This version cover 65 sectors and also provide the satellite accounts for energy and GHG emissions (Aguiar 2019). Although GTAP database version 10 is the latest version released till now, but the new version 11 is extended to 142 regions and 65 sectors with and additional reference year 2017 as mentioned earlier. This database is not publicly available for free, so Dr. Zeshan[6] who is GTAP data contributor from Pakistan has provided the data for this study. He has also made the data aggregation used in this research work.

4.2 Research simulation:

Incorporating GTAP model to check the economy-wide impacts (sectoral impacts) of the damages to physical capital due to floods on the economy of Pakistan, this study have assumed the loss of physical infrastructure due to floods in all provinces of the country. Empirically, we have applied shock by decreasing in percentage the element "capital" of variable "q_o" (capital, land, labor) that represent primary factors and are exogenous factors of the CGE model. We have followed the simulation steps mentioned in methodology chapter. The shock value used as initial damage to physical infrastructure is 39% taken from 2014's flood data.

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[5] https://www.gtap.agecon.purdue.edu/databases/v10/index.aspx
GEM Pack stands for general equilibrium modeling package.
[6] Dr. Muhammad Zeshan is an input-output Economist from Pakistan, he has supervised this research study.

4.3 Sectoral Aggregation used in this Study:

Most commonly *GTAPAgg* window program is used to prepare aggregation scheme for GTAP data and then that scheme is used to make aggregated database for the GTAP model. There are different versions of this window program (Horridge, 2015). In our study, regional aggregation includes Pakistan as a region while sectoral aggregation is as follows.

4.3.1 Table: 2 Sectoral aggregation of data used in this study with respective codes

Code	Comprising GTAP Sectors (Code)
GrainsCrops	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, pcr
MeatLstk	ctl, oap, rmk, wol, cmt, omt,
Extraction	frs, fsh, coa, oil, gas, oxt,
ProcFood	vol, mil, sgr, ofd, b_t,
TextWapp	tex, wap,
LightMnfc	lea, lum, ppp, fmp, mvh, otn, omf,
HeavyMnfc	p_c, chm, bph, rpp, nmm, i_s, nfm, ele, eeq, ome,
Util_Cons	ely, gdt, wtr, cns,
TransComm	trd, afs, otp, wtp, atp, whs, cmn
OthServices	ofi, ins, rsa, obs, ros, osg, edu, hht, dwe

4.3.2 Table: 3 Sectoral aggregation of data used in this study with sectors' description

Sector (code)	Description	Comprising GTAP sectors' description
GrainsCrops	Grains and Crop	Paddy rice, Wheat, Cereal grains nec, Vegetables, fruit, nuts, Oil seeds, Sugar cane, sugar, beet,Plant-based fibers, Crops nec, Processed rice
MeatLstk	Livestock and Meat Products	Bovine cattle, sheep and goats, Animal products nec, Raw milk, Wool, silk-worm cocoons, Bovine meat products, Meat products nec,
Extraction	Mining and Extraction	Forestry, Fishing, Coal, Oil, Gas, Minerals nec
ProcFood	Processed Food	Vegetable oils and fats, Dairy products, Sugar, Food products nec,
TextWapp	Textiles and Clothing	Textiles, Wearing apparel
LightMnfc	Light Manufacturing	Leather products, Wood products, Paper products, publishing, Metal products, Motor vehicles and parts, Transport equipment nec, Manufactures nec
HeavyMnfc	Heavy Manufacturing	Petroleum, coal products, Chemical products,Basic pharmaceutical products, Rubber and plastic products, Mineral products nec, Ferrous metals, Metals nec, Computer, electronic and optic, Electrical equipment,
Util_Cons	Utilities and Construction	Electricity, Gas manufacture, distribution, Water,Construction,
TransComm	Transport and Communication	Trade, Accommodation, Food and servic, Transport nec, Water transport, Air transport, Warehousing and support activi, Communication
OthServices	Other Services	Financial services nec, Insurance, Real estate activities, Recreational and other service, Public Administration and defe, Education, Human health and social work, Dwellings

CHAPTER 5

5 ANALYSIS OF RESULTS

This chapter include detail analysis and discussion of empirical results which are obtained by using the previously mentioned methodology.

5.1 Data for our research objectives:

To achieve the objectives of our study, we have used the GTAP database version 11 with reference year 2017 to check the impact of flood as unexpected negative shock to physical capital on the macroeconomic indicators of Pakistan economy. Our results are based on the standard GTAP model where a flood scenario is assumed in which 39% of physical capital is lost in all provinces of Pakistan due to floods just like it was damaged in 2014 floods. The direct cost of this damage is around USD7.6 billion.

Hence, we present our results in tables and graphs to illustrate the impact on macroeconomic variables of Pakistan's economy.

5.2 Impact on GDP and Trade

The table below present effects of flood damages to physical infrastructure on GDP, exports and imports of Pakistan.

5.2.1 Table: 4 Effect of disaster shock to physical infrastructure on GDP, exports and imports of Pakistan

Variable	**Pre-sim USD million**	**sim**	**Post-sim USD million**	**NET EFFECTS (USD)**
GDP	304,562.72	-22.27	236,746.28	-67,816.44
real exports	29,676.68	-55.82	13,111.05	-16,565
real imports	70,003.47	1.2	70,840.30	836.83

Source: Author's simulation

The simulation results show a negative change in real GDP of Pakistan which means that if 39% of physical capital is lost due to floods or other such disaster it will reduce real GDP by 22.27% from the base value, which is quite a significant loss to the country. Physical infrastructure is the backbone of the economy and its damage will slow down the growth of the economy. Our results project that the real GDP may fall by USD 67,816.44 million as a consequence of destruction of physical capital in the country.

Thus our results, conform to the fact that floods affect GDP negatively either directly by destroying physical and economic assets, or indirectly through its negative impacts on various economic sectors and economic flows, income losses, production delay and loss, damages to power supply lines, destruction to political infrastructure and decline in revenues etc. Pakistan being highly vulnerable to climate related calamities, it needs to make its financial position strong in order to spend more in economic development and adapting strategies to climate change and reduce territorial inequities (Hasan and Zaidi, 2012).

Our simulation results also show that the exports of Pakistan are likely to fall by 55% while imports will rise by 1.2 %. The net effect for both give an enormous value of US$16,565 million and US$ 836.83 million, respectively. Pakistan being an energy scarce country with relatively poor infrastructure if further hit by flood will lower the industrial efficiency, performance and output, hence declining the exports of a country. The exports will also fall in order to satisfy the local demand of the country. Industries like heavy manufacturing, light manufacturing, transport and communication and textile industries are highly dependent on physical and power infrastructure. However, imports that include the raw material of our exports i.e. machinery, metals oil etc. as well as refined goods will also rise to meet the domestic need. This increase in imports and decline in exports will widen Pakistan's trade deficit.

5.3 Impact on welfare:

The table below shows change in the overall welfare level after the 2014 flood damages to physical infrastructure. According to our GTAP model, it shows how worse-off or better-off a region become after any policy or other exogenous shock. It depends upon what the shock does to the national income.

5.3.1 Table: 5 Effect of loss of Physical Infrastructure on welfare of the region (Pakistan)

EV (Equivalent Variation)	**(Sim) Million USD**
Pak	-50,275.80

Source: Author's simulation

The simulation results present that flood damages will reduce the overall welfare level by US$ 50,275.8 million and this is again a big loss to Pakistan's economy. Whenever flood or other such disasters hit an economy it leaves its people worse off than before affecting their welfare both directly and indirectly in numerous ways such as through income losses and socioeconomic damages to communities and their assets.

A study from Vietnam by (Thomas et al 2010) shows that about 23% of the welfare loss can occur to the Vietnamese community by riverine floods. Our results also indicate that Pakistan will incur huge welfare losses if no proper flood management policies are undertaken.

5.4 Impact on trade balance

The Table 6 below presents results for changes in sectoral trade balance (million US$) when physical infrastructure is lost by 39% due to floods.

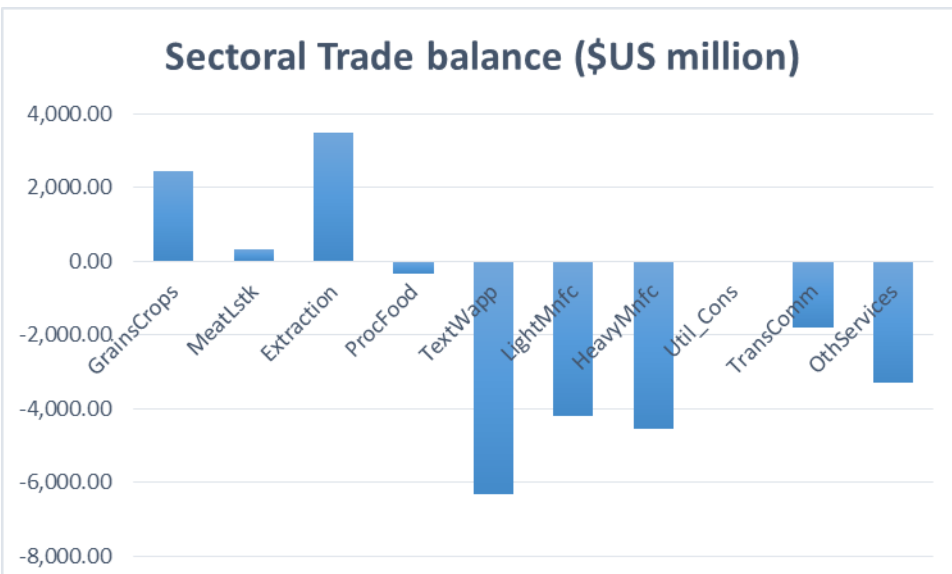
5.4.1 Table: 6 Changes in sector-wise trade balance of Pakistan ($US million)

Variables	**Sectoral Trade balance ($US million)**
GrainsCrops	2,445.18
MeatLstk	310.17
Extraction	3,482.19
ProcFood	-346.47
TextWapp	-6,333
LightMnfc	-4,213.11
HeavyMnfc	-4,557.44
Util_Cons	-25.99
TransComm	-1,816.56
OthServices	-3,285.84

Source: Author’s simulation

Our simulation results depict that flood damages to physical infrastructure negatively affect the trade balance of industries. As infrastructure supports trade and promotes market connectivity but lack of it will disrupt trade activities, same is the case in Pakistan. Our results show that if there is lack of infrastructure provision to industries, it will not only increase their transportation cost and lower their output and access to markets but will also widen trade deficit of the country. The deficit mentioned for various sectors in the table is enormous. The highest deficit accrues to Textile industry i.e., US$6,333 million, Followed by US$ 4,557.44, US$ 4,213.11, US$3,285.84, US$1,816.56 million for heavy manufacturing and light manufacturing industries, transport and communication and other services respectively.

Floods specially Infrastructure improves trade and reduces trade deficit, (Rehman et al., 2020) but poor infrastructure will limit access to local and international markets discouraging foreign direct investment, trade and production (Mlambo, 2005). Floods have affected infrastructure of Pakistan in 2010 and 2014 at such a wide range that it will take years to rebuild (New York Times 2010).



5.4.2 Fig: 2 Sectoral Trade balance ($US million)

5.5 Impact on prices of commodities in various sectors of Pakistan's economy:

The following Table 7 provide an insight about changes in prices of commodities when industries are hit by the flood.

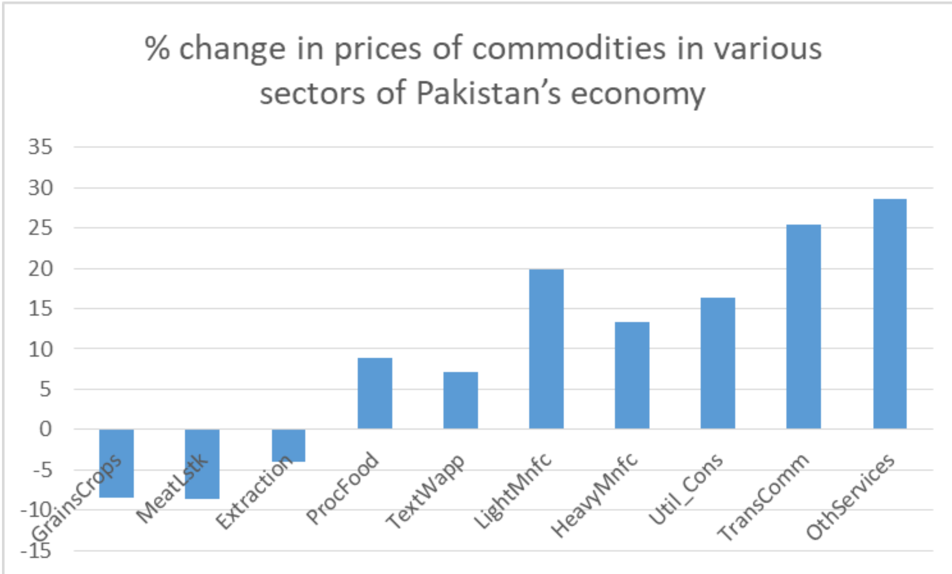
5.5.1 Table 7: % change in prices of commodities in various sectors of Pakistan's economy

Variables (sectors)	% **change in prices of commodities in various sectors of Pakistan's economy**
GrainsCrops	-8.53
MeatLstk	-8.59
Extraction	-4.07
ProcFood	8.87
TextWapp	7.21
LightMnfc	19.88
HeavyMnfc	13.41
Util_Cons	16.37
TransComm	25.46
OthServices	28.57

Source: Author's simulation

Our simulation results demonstrate an overall increase in prices, because infrastructure loss negatively affects industrial production hence lessening their supply and increasing their cost. When floods occur, they disrupt the whole economy of the country with its devastating effects on various sectors. The sectors like transport and communication, heavy manufacturing, and light manufacturing are most affected. Table 7 presents higher changes (increase in price) as they all rely on infrastructure. Although the prices of agriculture sectors such as grain crops and livestock do not rise, it may be firstly, because of the reason that these sectors do not highly depend upon physical infrastructure. Secondly, our study is aimed at analyzing the indirect effects of flood damages to physical infrastructure on various sectors of economy while previous literature in Pakistan has focused on direct effects of floods only. Measuring the direct impacts of floods, previous studies discovered that major losses were occurred to agriculture sector, resulting in rising prices of agricultural commodities.

Hence, our results contradict previous literature as previously many researchers have found that when floods directly hit agriculture, such as crops and livestock then it result in shortening the supply and increasing the prices of agricultural commodities (Mediodia et al., 2013) while our results show the indirect effect. The particular reasons for why our results differ include difference in methodology, objectives of the research and the use of shock in CGE models (A Rehman et al., 2016; Neal 2014; Unterberger 2017 etc). The effects of natural disasters can have both long run and short run effects on the economy. Many theories of economic growth explain the important role of physical capital which if destroyed will have repercussions on economy (see for example Bond et al., 1996).



5.5.2 Fig: 3 % change in prices of commodities in various sectors of Pakistan’s economy

5.6 Impact on industrial output

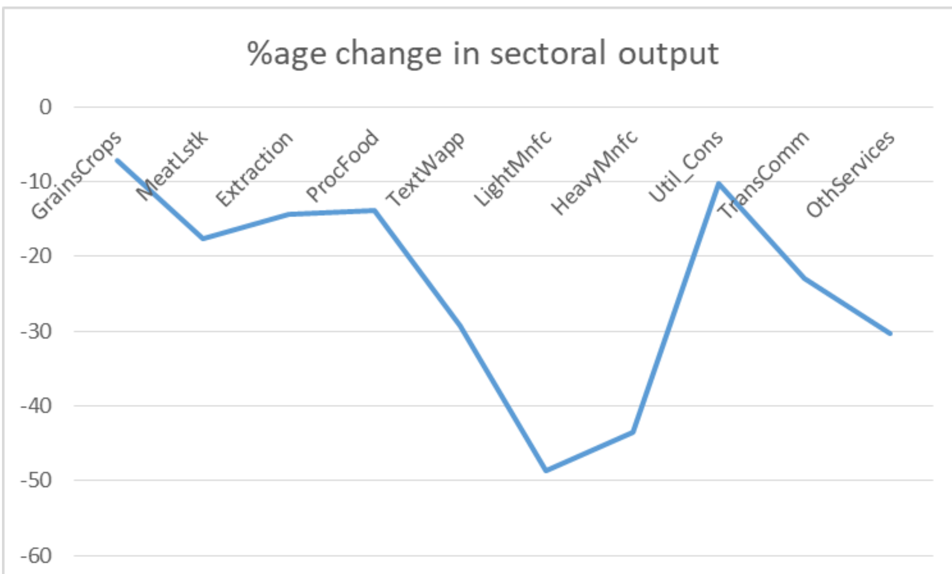
The following table 8 provide changes in the sectoral output after the negative shock is countered by the physical infrastructure of the country causing destruction to various businesses.

5.6.1 Table: 8 %age change in sectoral output

Variable	**%age change in sectoral output**
GrainsCrops	-7.18
MeatLstk	-17.57
Extraction	-14.32
ProcFood	-13.79
TextWapp	-29.2
LightMnfc	-48.67
HeavyMnfc	-43.51
Util_Cons	-10.31
TransComm	-22.97
OthServices	-30.24

Source: Author's simulation

The simulation results show an overall decrease in industrial output with the highest decrease of 48% and 43% in light and heavy manufacturing industries respectively, followed by other services sector, transport and communication, and textile and wearing apparel industries. As having said earlier, all these industries require infrastructure for production, market access and other operations. As visualized in Fig 4, our results indicate that if infrastructure is damaged it will lower the industrial output causing the price hike and supply shortages and the effects will spill over to economic growth and trade as well. Pakistan needs to build and improve the resilience of its critical sectors and bounce back capacity of its infrastructure including communication, transport and energy infrastructure (Khalid and Ali, 2018).



5.6.2 Fig: 4 %age change in sectoral output

CHAPTER 6

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study has evaluated the impact of flood damages to physical infrastructure on the economy of Pakistan applying a static GTAP model. The database incorporated is, GTAP database version 11 which is an advanced version with most recent base year i.e. 2017, and increased number of sectors and regions than all previous versions. In Pakistan, a vast literature on flood damages has either considered direct losses or other socio-economic losses neglecting the indirect losses to economy. In fact, losses from floods are not only limited to one sector or one area of research, rather its effects spill over to other sectors affecting macroeconomic indicators. In Pakistan, to the best of our knowledge, no proper attention has been made to evaluate the indirect losses from floods to economy as a whole. It is thus the major contribution of this study to analyze economy-wide impacts of floods when it damages physical infrastructure of the country.

In the current study a model has been simulated assuming a flood scenario where 39% of physical infrastructure in all provinces of the country is lost due to 2014 floods. Simulation results reveal decrease in real GDP by 22% if infrastructure of the country is severely damaged or lost. Welfare level has shown decrease by US$ 50,275.8 million, real exports of the country fall by approximately 56%. Examining sector-specific impacts, simulation results have also demonstrated that the most affected sectors are, light manufacturing, heavy manufacturing, other services, textile and transport and communication, as all of them have shown decrease in output and deficit in trade balance. This show their dependency on infrastructure.

From the outcomes of our investigation it is possible to conclude that physical infrastructure is crucial for development and growth of economic activities in the country. If physical infrastructure of the country is lost, it will disrupt business activities in the country resulting in GDP loss as well as negatively affecting other economic indicators. It will also leave the people of the country worse off.

6.2 Policy Recommendations

Based on results, this study suggests the following.

- Based on the results it is recommended to ministry of water resources to ensure the implementation of 4th flood protection plan in order to avoid such huge losses. The implementation includes regular evaluation and monitoring of the progress of implementation.
- As we have found that physical infrastructure (roads, bridges and buildings etc) is crucial for economic development and all of our industries rely on it for many purposes. Hence, the ministry of water also needs to do a thorough review of all damages due to floods and damages occurred to restoration works, thus new dams need to be build.
- In all the key sectors identified in this thesis such as heavy manufacturing, light manufacturing, transport and communication, textile industries etc. The national disasters management Authority is responsible to provide pre

and post-disaster emergency trainings to the staff in these industries so they can cope up with the disaster. Thus capacity building and disaster preparedness in all institutions is necessary.

- More innovative research and field surveys are required to specify the places where the renewal or reconstruction, and standardization of designs of physical infrastructure is required.
- Developments in floods forecasting methods, and warning systems are required to be more advanced and efficiently undertaken by meteorology Department of the country.
- Poor infrastructure being a hurdle for Asian countries, it also deprives them from competing at economic fronts, thus Pakistan needs to invest more in critical infrastructure to lower trade deficit and increase industrial output.

6.3 Study Limitations and future directions

In this study, standard GTAP model is used which is a static model and operates on assumptions of perfect competition in all markets. Hence future research can be done using advanced models with features of imperfect competition for the same research area to obtain more realistic results in the context of Pakistan. This study is also limited to analyze the flood damages scenario for Pakistan only, it can be extended to a comparative study at global level. Further, the proposed methodology can be used to investigate economy wide impacts of other environmental issues.

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