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- Essay 1. Imran Qaiser and Theocharis Grigoriadis

"History, Diversity and Development: Evidence from Afghan Provinces."

- Essay 2. Imran Qaiser and Theocharis Grigoriadis

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- Essay 3. Imran Qaiser

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Table of Contents

English Summary

This thesis proposes the application of various economic theories and analytical techniques from the fields of energy economics, environmental economics, comparative economic systems and, development economics in the regional context of South and Central Asia. Applying IV estimation in essay one leads to the conclusion that ethnolinguistic diversity instrumented by diversity of ancient civilizations/empires is strongly linked with contemporary development in Afghanistan. Ethnolinguistic diversity induces higher levels of trust and lower levels of individualism. Moreover, it is associated with higher levels of income and lower levels of violence or crime. A robust regression discontinuity design has been used to estimate the impact of historical ethnolinguistic borders on the contemporary economic development of Afghanistan. Pashtuns have the clear advantage over the other ethnolinguistic groups in Afghanistan in terms of level of income and provision of public goods such as safe drinking water and electricity. The Pashtun belt has suffered more violence and crime due to foreign interference in the Pashtun areas. The ethnolinguistic division in Afghanistan in terms of political preferences is obvious by the fact that support for Ashraf Ghani declines significantly when crossing the ethnic and linguistic border into the non-Pashtun areas. Structural equation modeling results reveal that the empires of Achaemenids, Parthians, and, most prominently, Sasanians, categorized as Old Persian, and the empires of Turkic origin left a positive and persistent impact on the contemporary economic development of Afghanistan.

Essay 2 and essay 3 of the dissertation deal with the economics of electricity and sustainable energy. Electricity generation from the use of fossil fuels is one of the largest sources of man-made carbon dioxide emissions in the world. Switching the power industry to the use of renewables such as hydro, solar, and wind energy is an option to deal with the issue of climate change. There are various challenges confronting the world and particularly South Asia in this energy transition towards renewable energy resources. Therefore, there is a necessity to take policy measures that enable electric utilities operating on fossil fuels to reach a technically efficient point where considerable savings in terms of costs and carbon emissions can be made. This has been estimated in the case of Pakistan in essay 2, with a possible reduction of about 34% of carbon emissions and 26% of the cost of power generation from fossil fuels with the use of technically efficient inputs. In essay 3, this thesis explores factors that are impediments to growth of the renewable energy sector by using pooled mean group autoregressive distributed lag (PMG ARDL) and the time series autoregressive distributed lag model, as well as by using the analytical tool of SWOT methodology to identify the strengths, weaknesses, opportunities, and threats in relation to the internal and external environment of development of the renewable energy sector in South Asia. Empirical results suggest that poor economic growth and the depreciating exchange rate are the major barriers to the development of the renewable energy sector of South Asia. SWOT analysis suggests that credit institutions' lack of interest in financing for renewable energy projects, the poor financial situation of the distribution companies, and inadequate research in the sustainable energy sector are the main obstacles to this development.

German Summary

Diese Arbeit schlägt die Anwendung verschiedener ökonomischer Theorien und Analysetechniken aus den Bereichen Energiewirtschaft, Umweltökonomik, vergleichende Wirtschaftssysteme und Entwicklungsökonomie vor, im regionalen Kontext Süd- und Zentralasiens. Durch die Anwendung der IV-Schätzung in Aufsatz 1 lässt sich eine Schlussfolgerung ziehen, dass ethnolinguistische Vielfalt – instrumentiert durch die Vielfalt der alten Zivilisationen / Reiche – ist eng mit der gegenwärtigen Entwicklung in Afghanistan verbunden. Ethnolinguistische Vielfalt führt zu einem höheren Vertrauensniveau und einem verminderte Individualität. Darüber hinaus ist es mit höheren Einkommen und niedrigeren Niveaus von Gewalt oder Verbrechen verbunden. Eine robuste Regressions-Diskontinuitäts-Analyse wurde verwendet, um die Einfluss historischer ethnolinguistischer Grenzen auf die zeitgenössische wirtschaftliche Entwicklung von Afghanistan zu schätzen. Paschtunen haben den klaren Vorteil gegenüber den anderen ethnolinguistischen Gruppen in Afghanistan in Bezug auf das Einkommensniveau und die Bereitstellung öffentlicher Güter wie sicheres Trinkwasser und Strom. Der Paschtunen-Gürtel hat aufgrund ausländischer Einmischung mehr Gewalt und Kriminalität erlitten. Die ethnolinguistische Spaltung in Afghanistan in politischer Hinsicht wird durch die Tatsache offensichtlich, dass die Unterstützung für Ashraf Ghani deutlich abnimmt, durch die Überquerung der ethnischen und linguistischen Grenze in den nicht-paschtunische Gebieten. Die Ergebnisse dem Strukturgleichungsmodell zeigen, dass sowohl die Reiche von Achämeniden, Parther und vor allem Sassaniden (als altpersisch eingestuft), als auch die Reiche türkischen Ursprungs ein positives und anhaltende Auswirkungen auf die aktuelle wirtschaftliche Entwicklung Afghanistans hinterlassen haben.

Aufsatz 2 und Aufsatz 3 der Dissertation befassen sich mit der Wirtschaftlichkeit von Elektrizität und nachhaltige Energie. Die Stromerzeugung aus fossilen Brennstoffen ist eine der größten Quellen für, vom Menschen verursachte, Kohlendioxidemissionen in der Welt. Umstellung der Energiewirtschaft auf die Nutzung erneuerbarer Energien wie Wasser-, Solar- und Windenergie ist eine Option, um das Problem des Klimawandels zu lösen.

Die Welt und insbesondere Südasien stehen vor verschiedenen Herausforderungen bei dieser Energiewende hin zu erneuerbaren Energiequellen. Daher gibt es eine Notwendigkeit, politische Maßnahmen zu ergreifen, die den mit fossilen Brennstoffen arbeitenden Elektrizitätsversorgungsunternehmen anvisieren. Dadurch können diese Unternehmen einen technischen Effizienzpunkt erreichen, an dem beträchtliche Einsparungen in Bezug auf Kosten und Kohlenstoffemissionen gemacht werden können. Unter Verwendung technisch effizienter Inputs wurde dies im Fall von Pakistan in Aufsatz 2 mit einem möglichen geschätzt Reduzierung von rund 34 % der CO2-Emissionen und 26 % der Kosten für die Stromerzeugung aus fossilen Brennstoffe. In Aufsatz drei untersucht diese Dissertation die Hindernisse für das Wachstum des Sektors der erneuerbaren Energien, durch die Anwendung der ökonometrischen Methoden der Pooled Mean Group Autoregressive Distributed Lag (PMG ARDL), Time Series Autoregressive Distributed Lag Model, und der SWOT-Analyse. Dadurch werden die Stärken, Schwächen, Chancen und Risiken in Bezug auf internen und externen Umfeld der Entwicklung des Sektors für erneuerbare Energien in Südasien identifiziert. Empirische Ergebnisse deuten darauf, dass ein schlechtes Wirtschaftswachstum und den abwertenden Wechselkurs die Haupthindernisse für die Entwicklung des Sektors für erneuerbare Energien in Südasien darstellen. Des Weiteren schlägt die SWOT-Analyse vor, dass das mangelnde Interesse der Kreditinstitute an einer Finanzierung für erneuerbare Energieprojekte, die schlechte finanzielle Situation der Vertriebsgesellschaften und die unzureichende Forschung im Bereich der nachhaltigen Energie die Haupthindernisse für diese Entwicklung repräsentieren.

List of Tables

List of Figures

Introduction

Applied economics is the science of how to apply economic theory and econometrics to deal with practical and real issues related to various fields of economics. It uses empirical methods such as simulations, input-output analysis, and econometrics as well as historical analogy, case studies, or common sense to acquire the facts (Swann, 2006). This study discusses a wide range of practical issues pertaining to energy economics, environmental economics, economic history, and political economy in the context of Central and South Asia with the help of various econometric, statistical, and analytical tools. The second and the third essays deal with the economics of climate change and the environment and discuss how the process of carbon emissions and environmental degradation can be slowed down with the resources available. The second essay of the dissertation is specifically concerned with the ecological efficiency of thermal power plants in Pakistan, while the third essay is dedicated to the determinants of a sustainable energy transition in South Asia. The first essay, on the other hand, is focused on the economic history and the political and economic development of Afghanistan. It investigates how the historical empires, diversity, and ethnolinguistic borders have a persistent impact on the contemporary development of Afghanistan.

Various researchers, such as Dimitrova et al. (2007), Grosfeld and Zhuravskaya (2015), and Tabellini (2010), have used applied models to explore how history relates to contemporary socio-economic development and to reveal how imperial legacies have a long-lasting effect on the different regions. The first essay of this dissertation is a first attempt to empirically analyze how history matters in the context of the contemporary development of Afghanistan. Afghanistan has been ruled exclusively by Pashtuns since its formation in 1747. It was a buffer state between Great Britain and Russia during the Great Game in the nineteenth century. Although Afghanistan has never been a colony of any Western country, many of the Western powers have exercised their influence in Afghanistan over the years. This research tests the hypothesis whether the rulers of Afghanistan had a tendency towards the betterment of their co-ethnic group. Therefore, a robust geographic regression discontinuity design has been applied in essay one of the dissertations to examine the impact of historical ethnolinguistic borders on the contemporary development of Afghanistan. This research uses the robust regression discontinuity design proposed by Calonico et al. (2014a), Calonico et al. (2014b), Calonico et al. (2017), and Calonico et al. (2019) to estimate the impact of historical ethnolinguistic borders on the contemporary level of income, violence or crime, general trust, individualism, political preferences, access to safe drinking water, and access to electricity provision. A sharp geographic regression discontinuity design that considers the geographical ethnolinguistic borders as the cut-off points has been applied. The distance of each provincial capital from the ethnic and linguistic borders was taken by using the ethnic map presented in the Historical and Political Gazetteer of Afghanistan (1972) and the linguistic map published in the National Atlas of the Democratic Republic of Afghanistan (1985). Ethnolinguistic diversity is a factor that is linked with various socio-economic factors, as discussed in the introduction of essay one. Afghanistan's present ethnolinguistic diversity is linked with its ancient past and can be measured using the assortment of ancient archaeological sites from the various empires. Instrumental variable estimation has been used in this research to reveal the impact of ethnolinguistic diversity instrumented by ancient civilization diversity on the contemporary development of Afghanistan. Furthermore, different methods of IV estimation have been used to overcome the problem of endogeneity. The endogeneity problem can arise if any endogenous variable works as the explanatory variable, and it can lead to biased estimators. Ethnolinguistic diversity is an endogenous variable that works as the regressor in our model since diversity itself can be an outcome of many of the socio-economic and political factors. As mentioned, this diversity has been instrumented by ancient civilization diversity and the share of archaeological monuments/sites belonging to various empires, classified into five categories. The empires of Achaemenid, Parthian, and Sasanian are categorized as Old Persian, while the Hellenistic era is labeled as the Greek period. Since the official language of the Kushan Empire for the greater part of its rule was Bactrian, which belongs to the East Iranian group of languages, the Kushan Empire is regarded as part of the East Iranian empire. Due to the emergence of Islam, the empires of Samanid, Seljuk, Ghaznavid, and Ghurid are characterized as Islamic Persian. The empires of Timurid and Chagatai are of Turkic origin and are described as Turkic in this research. Different measures of ethnic and linguistic diversity have been calculated by using both historical data from Historical and Political Gazetteer of Afghanistan and contemporary data taken from the Asia Foundation Survey. The measures of diversity considered for this research are ethnic and linguistic fractionalization proposed by Montalvo and Reynal-Querol (2005), ethnic and linguistic polarization proposed by Montalvo and Reynal-Querol (2005), linguistic fractionalization with linguistic distance proposed by Greenberg (1956), the linguistic polarization index in the form of linguistic distance proposed by Esteban and Ray (1994), and the peripheral heterogeneity index proposed by Desmet et al. (2005). The impact of different measures of diversity on the outcome of level of income, violence or crime, general trust, individualism, and political preferences has been examined with the application of the IV estimation methods of random effect two-stage least squares, between-effect two-stage least squares, and the pooled generalized method of moments.

Structural equation modeling has been used to investigate how the ancient history of Afghanistan links to its contemporary economic development, with mediation analysis being performed with the implementation of this structural equation modeling to estimate the impact of historical empires on the contemporary economic development of Afghanistan with the mediation of ethnic fractionalization. Structural equation modeling (SEM) is preferred over other techniques due to its efficacy in the presence of endogeneity and simultaneity (Gunzler et al., 2013).

The second and third essays of this dissertation deal with the issue of the environment and energy. Global greenhouse gas (GHG) emissions and non-GHG emissions, such as SO_x, NO_x, and particulate matter, resulting from the massive use of fossil fuels over the last two centuries have led to climate change and environmental degradation, both of which have serious implications worldwide in the form of natural disasters, declines in agricultural production, and health deterioration. The power industry is one of the main producers of GHG and non-GHG emissions in the world, and various steps are being taken to switch the power industry from coal or oil to more environmentally friendly fossil fuels, such as natural gas. Furthermore, the world is gradually making efforts to move to sustainable energy resources. There has been rapid growth in the renewable energy sector all over the world in recent years. However, the renewable energy sector is facing various challenges particularly in South Asia. One of the objectives of essay three is to analyze the renewable energy sector of the selected South Asian countries using SWOT methodology to highlight the strengths, weaknesses, opportunities, and threats to this sector. Since the complete energy transition to renewables can take many years and requires considerable effort, resources, and research in this sector, there is a need to conduct applied research on reducing GHG and pollutant emissions from the use of existing fossil fuel resources. The second essay of this dissertation is therefore dedicated to this objective. Various researchers, such as Siefert et al. (2014) and Welch and Barnum (2009) have used different approaches based on data envelopment analysis to estimate the environmental efficiency of decision-making units (DMUs). Essay two measures the ecological efficiency of the thermal power plants operating on fossil fuels in Pakistan using the various approaches based on data envelopment analysis. Essay two also uses the material balance condition to estimate the cost and environment efficiency of the thermal power plants in Pakistan combined with the meta-technology ratio to find which production method has a major part in forming the metafrontier. Furthermore, the total factor productivity change has been measured with the application of the Malmquist DEA index.

This approach splits the total factor productivity change into the technical efficiency change and the technological change. The technical efficiency change is the product of the pure efficiency change and the scale efficiency change.

Coelli et al. (2007) introduced the material balance principle into the data envelopment analysis. In this method, carbon efficiency is estimated like cost efficiency by treating the carbon emission factor like the price. This method locates the points on the production frontier that can improve both cost and carbon efficiency simultaneously. Moreover, this method estimates how much the cost and carbon emissions can be cut simultaneously by simply reaching the technically efficient point on the isoquant/production frontier. The meta-technology ratio or the technology gap ratio proposed by Battese et al. (2004) is also the part of this research and is measured by taking the ratio of efficiency scores obtained by the group frontier analysis and the efficiency scores obtained by the metafrontier analysis. Group frontier efficiency scores are computed by using the set of firms using the same technology. Metafrontier efficiency scores are calculated by combining the entire data set. Efficiency scores are upward biased. Therefore, bootstrap data envelopment analysis proposed by Kneip et al. (2008) has been performed to obtain bias-corrected efficiency scores by performing 2000 replications (Qaiser and Grigoriadis, 2020).

Another objective of essay three is to find the determinants of growth of the renewable energy sector in South Asia with the help of time series and panel data methodologies of the panel data technique of the pooled mean group autoregressive distributed lag (PMG ARDL) approach proposed by Pesaran et al. (1999), and the time series methodology of ARDL proposed by Pesaran et al. (2001).

Essay 1

History, Diversity & Development: Evidence from Afghan Provinces[1]

Abstract: In this paper, we explore the effects of historical and contemporary ethnolinguistic diversity on socio-economic development in Afghan provinces. We find that higher levels of contemporary diversity are likely to induce lower levels of conflict, higher levels of income and trust, and lower levels of individualism. Historical ethnolinguistic borders are strongly associated with income, provision of public goods and political preferences in Afghanistan, particularly when it comes to Pashtuns and Dari-speakers. The Old Persian empires of the Achaemenids, Parthians, and most importantly Sasanians, as well as the Turkic empires of Timurids and Chughtai have had a positive long-run impact on Afghan socio-economic development, while the opposite holds for Islamic Persian empires.

Keywords: civilization, diversity, development, Afghanistan
JEL Codes: P16, P26, P48

1.1. Introduction

Colonial rule and persistent internal borders of language and ethnicity have hallmarked the history of Afghanistan. It has been clearly shown in the comparative development literature that colonial powers and empires leave long-lasting impacts on the countries that remained under their rule for centuries. This is borne out by the role of the Habsburg and Ottoman Empires on the performance of contemporary institutions in their respective successor states. Institutions in the former Habsburg successor states were significantly more efficient than institutions in the former Ottoman Empire successor states (Dimitrova, 2007). Contemporary levels of democracy in colonized countries is also determined by the duration of colonization: countries colonized during the imperialist era after 1850 have a weaker democracy than the countries that were colonized much earlier during the mercantilist era (Olsson, 2009).

[1] This chapter is a result of joint work with Theocharis Grigoriadis (Freie Universität Berlin). To honor his contribution, “we” will be used throughout this chapter.

The level of financial development in the successor states of the former Ottoman Empire is presently low due to prohibition of interest lending in the Muslim Ottoman Empire (Grosjean, 2011). This observation also holds for Africa, whose contemporary underdevelopment is associated with its history of slave trade and colonialism. The high degree of external extraction made the economy move from a high production equilibrium with secure property rights to a low production equilibrium with insecure property rights. As the latter remained stable, that society remained trapped in suboptimal equilibrium even with the end of the slave trade (Nunn, 2007). An experimental study by Kim (2017) reveals that the homogenous population of Korea, which has remained divided in communist North Korea and capitalist South Korea for the last several decades, shows very different characteristics. North Koreans were found to possess a less self-centered approach, whereas Rawlsian, altruistic and utilitarian types were less common among South Koreans. These social preferences and attitudes towards political and economic institutions remained persistent even two years after migration of the North Koreans, as revealed by a follow-up study. This was the case because the cultural and social norms changed slowly (Kim et al., 2017). Present-day governments, through their policy interventions, can eradicate several historical differences between regions, such as those of income, education, institutions and trust in government. Such was the case in Poland despite remaining divided among three empires for almost a century. However, these empires left their legacies in relation to religious practices and political beliefs apparently via intergenerational transmission (Grosfeld and Zhuravskaya, 2015).

Past political institutions and the rate of literacy of past generations determine the level of economic performance only through culture, mainly because culture is composed of broad aggregates (Tabellini, 2010). Colonial history may also be a determinant of conflict in colonized countries through its impact on ethnolinguistic divisions. The scale of ethnolinguistic polarization based on the experience of English language acquisition across Sri Lankan districts during colonial rule was found to be the most significant determinant of conflict. This suggests that history matters the most in understanding segmentations within society (Dower et al., 2016). Historical events may also have long-lasting impacts, such as in the regions in Russia affected by the Holocaust during the Second World War. These regions are presently less developed than the rest of the country as the size of the Jewish middle class shrank after this event (Acemoglu et al., 2011). Nevertheless, historical legacies may diminish with time, as was the case in Romania, where it was found that support for NGOs and volunteer activities were negatively associated with age (Badescu and Sum, 2005).

High ethnolinguistic diversity is linked to the determinants of poor economic growth, such as low financial development, underdeveloped infrastructure, malfunctioning foreign exchange markets and low levels of schooling (Easterly and Levine, 1997). Countries that are ethnolinguistically heterogeneous also display low quality of government (La Porta et al., 1999). Border changes in Europe after the First World War had no impact on international trade. The most significant reason for low trade was in fact ethnolinguistic differences among European countries (Heinemeyer et al., 2008). Societies that are more diverse in values vis-à-vis income redistribution and government interference in markets have lower levels of trust. Moreover, this association holds even when the value diversity of a country is instrumented by the value diversity of the neighboring country. This association is conditional on the level of social diversity in other aspects. Diversity in values, particularly values linked with economic policy, is a key element of societal diversity. This factor is important not only in determining the level of trust in society, but also in influencing different socio-economic outcomes (Beugelsdijk and Klasing, 2016). Nevertheless, growing ethnic diversity in European and most of the neighboring ENPI (European Neighborhood and Partnership Instrument) countries has had no connection with social cohesion, human development, general trust and institutional performance. This is particularly the case in long-established democracies and the countries with high institutional quality and good governance (Hlepas, 2013).

Diversity challenges social values, which usually makes people come back to their traditional values to protect their in-group separate identity. Religious diversity plays a key role in determining human attitudes to gender roles and marriage. Ethnic diversity has an association with lower support for marriage. However, it has no significance in determining gender roles, while linguistic diversity has no association with family values (Viocu, 2016). Ethnic polarization increases the probability of occurrence of civil conflict (Montalvo and Reynal-Querol, 2005). Three indicators of ethnic distribution – fractionalization, polarization, and the Gini-Greenberg index – are significant determining factors of conflict (Esteban et al., 2012).

High levels of ethnic polarization are strongly associated with the duration of civil war (Montalvo and Reynal-Querol, 2005). Language is a key factor triggering civil conflict, whereas the economic cost of rebellion determines the level of resistance, as was shown in the study on Ukraine by Zhukov (2016). Countries that are linguistically and ethnically more diverse and oil-wealthy have an added probability of suffering civil unrest. Furthermore, countries that are more democratic and wealthier are at lower risk of violence (Anyanwu, 2014). However, according to Elbadawi and Sambanis, (2000), the level of occurrence of civil conflict in Africa is not explained by ethnic divisions. Instead, civil conflict is an outcome of poor political institutions, poverty and economic dependence on natural resources. In the case of the Basque country study by Gardeazabal (2011), linguistic polarization and education were found to reduce conflict, whereas political polarization had a dual impact on conflict. Political polarization with respect to left-right politics had a positive impact, whereas nationalist polarization had a negative impact, on conflict (Gardeazabal, 2011). Data from post-communist countries reveal a negative association between conflict and democracy although this study found no evidence of any impact of social fractionalization on democracy or civil conflict. Instead, in the case of Bulgaria, diversity may promote institutions and practices for open politics (Fish and Kroenig, 2006). Between-group inequality is negatively correlated to the level of provision of public goods predominantly in less-established democracies (Baldwin and Huber, 2010).

According to Jackson (2013), the relationship between diversity and the provision of public goods is subject to the nature of the public goods. Public goods that are not directed towards a specific group, such as electricity or water supply, reduce the willingness of different groups to contribute to this good in a diverse community. On the other hand, public goods that benefit specific groups tend to carry more support from the majority group. For example, education, in which minority groups may be disadvantaged, because cultural practices and the medium of instruction benefit the majority group. Demand for culturally oriented public goods results in a high provision of these public goods (Jackson, 2013). Rulers may be inclined to provide these culturally-driven public goods to a lesser degree if close substitutes are privately provided to the ruler's co-religionists and exclude the followers of other religions (Chaudhary and Rubin, 2016). Grigoriadis (2016) highlights the role of religion in the provision of public goods. Experimental results show that universal discipline played a significant part in the provision of public goods, whereas solidarity and obedience had no such role. Free riding occurred at lower levels of hierarchy in Eastern Orthodox society, thus stressing the need to reform the public sector of lower and middle rank (ibid.).

The paper is structured as follows. Section II deals with the history of Afghan political and economic development, while section III discusses the analytical framework of diversity measurement both in contemporary and historical perspectives. Section IV provides an overview of Afghanistan's ancient civilizations, while section V reports the data and empirical strategy. In Section VI, we discuss the results of the regression discontinuity designs and instrumental variables regressions. Section VII concludes.

1.2. Political and Economic Development of Afghanistan

Since its establishment in 1747, Afghanistan has been a battlefield for many internal and external conflicts.[2] Soon after the death of Ahmad Shah Durrani, Afghanistan lost most of the area that he had conquered during his reign.[3] Afghanistan became a buffer state during the diplomatic conflict between the Russian and British Empires in the 19th century. In this conflict, these two powers attempted to gain control of Central Asia in what came to be known as the Great Game (Perry, 2005).[4] The Great Game resulted in two Anglo-Afghan wars and the occupation of Bukhara, Kokand and Khiwa by Russia (Gelb, 1983). Afghanistan's borders were defined as a result of this Great Game. Its 1800 km long border with neighboring Turkmenistan, Uzbekistan and Tajikistan was determined at the time of Sher Ali Khan in 1873 by declaring Amu Darya (a river) as the border. After Russia occupied Merv (an area in present-day Turkmenistan), the Russian and British Indian frontier commission defined the Ridgeway border with a length of 560 km between contemporary Turkmenistan and Afghanistan. Afghanistan shares its longest border at a total length of 2300 km with Pakistan. This border was defined in the treaty signed by Afghanistan and British India in 1893 and separates the Pashtun belt in Pakistan with that in Afghanistan. This is the reason why Afghanistan still does not recognize it as the international border (Schetter, 2003). The Pamir border between Tajikistan and Afghanistan was fixed in 1895 with the creation of the Wakhan corridor.[5] This corridor connected Afghanistan with China. The 96 km long border between China and Afghanistan was formally accepted by the two countries as the international border in 1964.

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[2] This was the case when Ahmad Shah Durrani laid the foundation of an Afghan kingdom and consolidated Afghan independence from Persian and Mughal rule (Balland, 1982).

[3] As shown in Figure A.1, the Durrani Empire was at its greatest expansion in 1973 and consisted of modern-day Afghanistan, Pakistan, some parts of Northeastern Iran, East Turkmenistan, Northwestern India and Kashmir (Singh, 1959).

[4] Russia gradually increased its control and domain over Central Asia, which was seen by the British East India Company as a hazard to their benefits and interests. The Russian mission to the east was more directed towards Central Asia than India (Eskridge-Kosmach, 2014)

[5] The Pamir border is the border between Afghanistan and the former Soviet Union (present-day Tajikistan, Uzbekistan and Turkmenistan). This corridor served as the buffer zone between British India and the Russian Empire. This small area was gifted to Afghanistan to hold off the two military powers of the 19th century.

Afghanistan and Iran disputed the area around the Hilmand River until the dispute was settled by the Briton McMahon in 1905, defining a 475 km long boundary.[6]

Although Afghanistan was never a colony of any imperial powers, it was heavily influenced by their politics. Britain had a monopoly over opium production in India by the end of 18th century, and exported the opium poppy to Afghanistan for cultivation, since the boundary between Afghanistan and British India was not defined until 1893 (Visalli, 2013). Most of the provinces adjacent to the Pakistan (former British India) border, such as Hilmand, Kandahar and Zabul, saw high levels of opium production. During the 20th century, two attempts were made in Afghanistan to introduce sweeping reforms and liberal policies. However, these reforms faced strong opposition from conservative Afghan tribes. The first effort was made in the 1920s by King Amanullah, who introduced many reforms, most of which were discontinued with his abdication in 1929.[7] According to Fitzgerald and Gould (2009), Britain resented the liberalization policies of Amanullah, fearing that liberalization of Afghan society could challenge British rule in India. Britain supported extremist Islamists and conservatives in their efforts to challenge Amanullah's rule (Fitzgerald and Gould, 2009). Afghanistan went into a civil war in 1929, with Amanullah being forced to resign and seek exile first in British India and later in Europe (Ritter, 1990). Many years later, the United States continued this approach of supporting the militants who were fighting against occupation by the USSR by spreading Jihadi literature in Operation Cyclone (Bergen, 2001). A second attempt at reform was made by the PDPA government in 1978. PDPA introduced many reforms, but these were opposed by the conservatives with the view that the reforms were against Islam (Ishiyama, 2005). Land reforms by means of the elimination of usury was strongly opposed by the landlords (although usury is forbidden in Islam). The PDPA

[6] By signing the Paris agreement, Iran accepted Afghanistan's freedom and sovereignty. The province of Sastan was divided between the two countries, and this, with few changes, is still the Fakhri boundary between the two countries.

[7] Amanullah's reforms included dissuading the wearing of the veil by women and the isolation of women, the requirement to wear western dress, adoption of the solar calendar, eradication of slavery and forced labor, introduction of secular education for both boys and girls, adult education, tax reforms, anti- corruption and anti-smuggling campaigns, the first budget, a livestock census, Bank-I-Melli, an Afghani currency, the establishment of the Afghan air force, introduction of the first constitution of Afghanistan in 1923, guarantee of civil rights, elimination of subsidies to the tribal chiefs and the establishment of a legislative assembly (Omrani, 2007).

government also promoted women's rights and ethnic minorities (Amstutz, 1994). From 1978 to 1992, the PDPA government adopted the policies of socialism and was fully backed by the USSR, with the Soviet Union thus considering Afghanistan a state with a socialist orientation (Saikal and Maley, 1989). Rebellion against the liberal government started in 1979, spreading to 24 provinces (Goodson, 2001) and resulting in the Soviet invasion of Afghanistan.[8]

Afghanistan has suffered external invasions as well as civil conflict in the last five decades. One reason behind the civil unrest in the country may be the high level of ethnolinguistic diversity and polarization. Civil conflict and natural disasters in the country have resulted in a high level of internal and external migration, which has reshaped the ethnolinguistic distribution in the different regions. Civil war, the Soviet incursion and the US invasion resulted in the enormous migration of Afghans to their neighboring countries, Pakistan and Iran. By the end of 2012, Pakistan hosted more than 1.64 million Afghan refugees, according to UNHCR, even after the return of several thousand Afghans to their homeland after the end of the Talban regime in 2001. Iran had given refuge to around a million Afghans by the end of 2012. Many Afghans migrated to Iran and Pakistan to acquire religious education, whereas many Afghans went to Egypt, France, Germany, the United States, the United Kingdom and Russia to obtain secular education after the emergence of the 1920s secular education group (ISSA, 2011). Many Afghans migrated to the Middle East, European countries and Australia for economic reasons. The urbanization rate in Afghanistan is one of the highest in the world due to increasing job opportunities in cities (Ahmadi, 2019). Apart from external and rural to urban migration, a significant proportion of the Afghan population are nomads. It is also important to keep in mind that Afghanistan is one of the poorest countries in the world with an annual per capita income of 563.83 US dollars (World Bank, 2018). Afghanistan has historically emphasized strengthening its government and military to counter internal and external threats. Particularly at the time of Abdul Rahman and Habib Ullah from 1880 to 1919, high levels of taxes were imposed on Afghan commerce and state monopolies were established

[8] Amid the unstable situation in Afghanistan, Soviet Union forces entered the country at the request of the PDPA government. The US Central Intelligence Agency (CIA) and Saudi Arabia provided the Mujahedeen with weapons with the help of Pakistan. Almost 2 million Afghanis were killed and 6 million displaced, mainly to Pakistan and Iran. After suffering 15 thousand casualties, the Soviet forces left Afghanistan in 1989 (Reisman and Norchi, 2017).

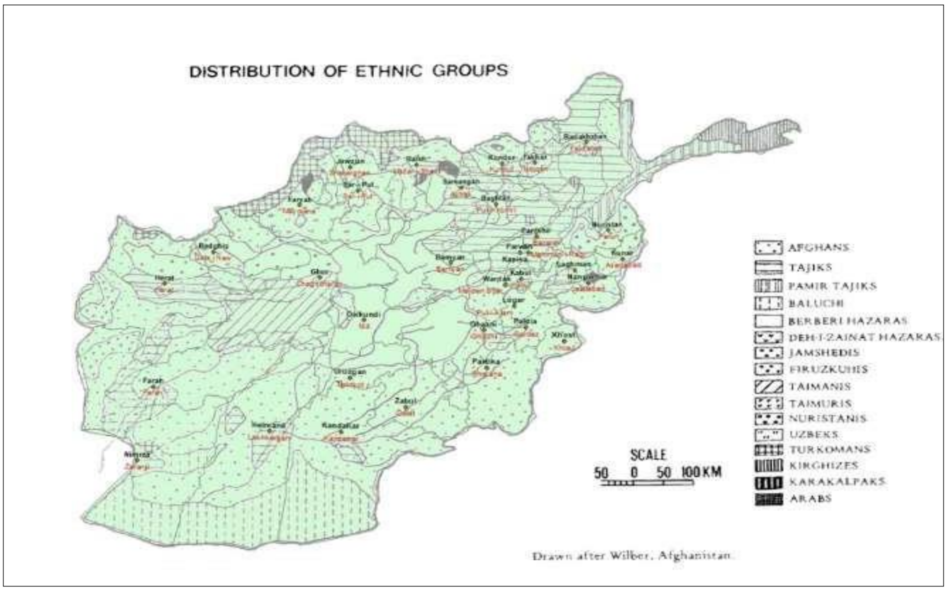
to accumulate money, a policy that hampered the economic growth of Afghanistan (Omrani, 2012). The industrial sector of Afghanistan grew significantly after the Saur revolution in 1978. The state share in total industrial production increased to 45% in 1985 with the textile industry being the largest sector of Afghanistan. Kabul was the center of all industrial activities with almost ten thousand workers in 1979.

Nowadays, the provinces of Baglan, Balkh, Kunduz in the north and the Parwan province in the center are industrially developed. However, provinces in the south and east have made only a minor contribution to national industrial production. The handicraft industry is also important with a share of overall industrial production of 42.7% (National Atlas of Democratic Republic of Afghanistan, 1985). Balkh in the north, Herat in the west, Kabul in the center and Kandahar in the south are centers of business activities.

1.3. Measures of Diversity in Afghanistan

Afghanistan is a multiethnic and landlocked country that shares borders with Pakistan to the east, Iran to the southwest, Turkmenistan to northwest, Uzbekistan to north and Tajikistan and China to the northeast. Pashtuns are the largest ethnic group in Afghanistan, while Tajiks are the second largest group, followed by Hazaras, Uzbeks and Balochis.

Figure 1.1. Ethnic composition



Source: Historical and Political Gazetteer of Afghanistan 1971.

Figure 1.2. Languages of Afghanistan

Source: Ethnologue 2012.

Ethnic polarization is considered to be the basis for the civil conflict in Afghanistan. According to Fearon and Laitin (2003), civil war is not a result of ethnic divide. Montalvo and Reynal-Querol (2005), however, suggest that ethnic and linguistic polarization is a major factor in civil unrest. An ethnic culture of violence transmits to the next generations only if institutional quality is poor (Grosjean, 2014). Afghanistan was largely devastated during the Soviet invasion. It then faced a severe civil war in the 1990s after the departure of Soviet forces in 1989. Different warlords who had fought against the Soviet Union then started to fight against each other to gain control of the center. After 9/11 and the Afghan war in 2001, Afghanistan restarted its reconstruction and new institutions were built. The spread of education and media awareness led to the reduction of Afghan ethnic disintegration and fragmentation. This is the reason that during Afghan presidential elections, each Afghan ethnic group was divided from within and supported Afghan presidential candidates of different ethnicities (Malikyar, 2014). As the ethnolinguistic maps in Figures 1.1 and A.2 show, most of the areas in the east, southeast and southwest adjacent to the Pakistan and Iranian borders are inhabited by Pashtuns. Balochis live in small numbers in the south and southwest of Afghanistan. Most of the areas in the northeast, center and northwest belong to Tajiks. The Hazara population is mostly located in the west of Afghanistan close to the Iranian border, while the Uzbek population is concentrated in the north next to the Uzbekistan border.

A total of forty-one languages are spoken in Afghanistan (Ethnologue, 2018). The major languages are Pashtu, Dari (Afghan Persian), Uzbek and Tajik, with Pashtu and Dari being Afghanistan's main languages. As the linguistic map of Afghanistan in Figures 1.2 and A.3 as well as the linguistic tree in Figure A.4 show, there are two major groups of languages that are spoken in Afghanistan. The Indo- Iranian group of languages includes Balochi and dialects of Pashto and Persian. Pashto has two dialects, northern Pashto and southern Pashto, whereas Persian has the dialects Dari, Hazaragi, Tajik and Aimaq. The Turkic languages share no branches with the Indo-Iranian family. The major Turkic languages in Afghanistan are Uzbek and Turkmen. Pashto shares three out of a maximum of six of branches with the Persian dialects and Balochi. However, Balochi is closer to Dari as it shares four branches.

Different methods have been used to measure cultural complexity, ethnolinguistic diversity and polarization. Murdock and Provost (1973) developed a scale-based measure for cultural complexity. They used 10 different scales in which each respective scale was a way to assess the complexity of any given culture based on a score from 0 to 4, with 4 being the highest, i.e. the higher the score, the more complex that society is. As per their study, aspects of social organization are closely related to cultural complexity and this measure of cultural complexity can prove very useful in studying various concepts of social organization. Lohmann (2011) developed a measure of language barriers using the Language Barrier Index, which had a value from 0 to 1, with 0 indicating no barrier and 1 specifying extreme language differences or, in other words, no similarities between the two languages. The index was constructed using data from the World Atlas of Language Structures (WALS; Dryer and Haspelmath, 2008), and was created by taking the average of dichotomous variables of 139 characteristics of each language, with 1 representing that the pair of languages shared a common feature, and 0 otherwise. An ethnolinguistic diversity measure was introduced by Alesina et al. (2016). Baldwin and Huber (2010) introduced a new measure of between-group inequality and compared it with more conventional measures of diversity, such as cultural fractionalization and ethnolinguistic fractionalization. They further stressed the need to search for a more refined measure of between-group inequalities and a measure of cultural differences that could incorporate factors other than language, such as religion. Montalvo and Reynal-Querol (2005) introduced a new measure of ethnic diversity that satisfied the properties of polarization:

$$ELF = 1 - \sum_{i=1}^{N} \pi_i^2$$

ELF is fractionalization and π is the proportion of people in the total population belonging to ethnic group *i* and *N* is the number of groups (Montalvo and Reynal-Querol 2005).

$$RQ = 4\sum_{i=1}^{N} \pi_i^2(1-\pi_i)$$

RQ is the polarization index. The above formulas can also be used to measure linguistic or religious fractionalization or polarization by replacing the ethnic proportion by the linguistic or religious proportion, respectively.

$$A(0,T) = \sum_{j=1}^{K}\sum_{k=1}^{K} s_k\, s_j \tau_{jk}$$

Presented by Greenberg (1956), this index considers the linguistic distance between any two groups:

$$A(0,T) = \sum_{j=1}^{K}\sum_{k=1}^{K} s_k\, s_j^2 \tau_{jk}$$

Esteban and Ray (1994) introduced an index that takes linguistic distance into account while measuring linguistic polarization. If the linguistic distance is same across all groups, then the ER index and the above RQ index of polarization are perfectly correlated.

$$A(0,T^c) = 2\sum_{j=1}^{K} s_j s_c \tau_{cj}$$

The index of Desmet, Ortuno-Ortín, and Weber (2005) considers the distance between central and peripheral groups:

Figure A.5 shows the ethnic and linguistic fractionalization in Afghanistan. It indicates that most of the areas in the north and west of the country adjacent to the former Soviet Union border are highly diverse. Over the years, ethnic Pashtuns have been settled in the north of the country to strengthen the Pashtun rule in these areas. Similar to the fractionalization, the ethnolinguistic polarization maps in Figure A.6 also show that most areas in the north and west are polarized. In Afghanistan, Tajiks, Aimaq and Hazaras speak different dialects of Dari. Most areas with a high Uzbek population have a higher level of linguistic fractionalization and polarization with linguistic distance because both these languages do not share any branches with the other major languages of Afghanistan, as is evident in Figure A.7. Figure A.8 shows the maps of different measures of peripheral heterogeneity. Provinces that have a significant share of Uzbek and Turkmen populations are more diverse since Uzbek and Turkmen are linguistically more distant from other languages of Afghanistan. All three major linguistic groups of Afghanistan belonging to Dari, Pashto and Uzbek languages have been taken as the central groups.

1.4. Afghanistan's Ancient Civilizations

Afghanistan has been ruled by different empires and dynasties during the last three millennia. This was particularly the case in ancient times. The term Ariana was used for the area covering contemporary Afghanistan, eastern Iran and the area to the west of the Indus River in contemporary Pakistan (Sagar, 1992). The Achaemenide Empire, extended from the Indus River in the east to the Balkans and Eastern Europe to the west from 550 BC to 330 BC (Turchin et al., 2006). The Kushan Empire encompassed most parts of present-day Afghanistan and the northern part of the Indian subcontinent. Kushano-Sasanians (a modern term used for the Sassanid Persians) captured the northwestern part of the Indian subcontinent (present-day Pakistan) in the third and fourth centuries from the declining Kushan Empire (Yarshater, 1983). This province or kingdom was situated to the east of the Sasanian Empire, a powerful state between 245 and 651 AD, which was the last Persian Empire before the emergence of Islam. This empire included contemporary Iran, Pakistan, Afghanistan, most parts of Central Asia, the Middle East, some parts of Eastern Europe and major parts of Egypt and Turkey (Wiesehofer, 1996). The nomadic empire of the Hephthalites spread to some parts of central Asia, Afghanistan and Persia. The Sassanid Empire ruled Afghanistan and most parts of Central Asian states, Iran and Pakistan from 819 to 999 AD (Taagepera, 1997). The Ghaznavid Empire, also known as the Muslim dynasty of Mamluks (slave origin), encompassed the areas of Afghanistan, the greater part of Iran and the area between the Amu Darya and Syr Darya rivers and most of Pakistan for most of the 11th and 12th centuries (Bosworth, 2006).

This paper divides the ancient empires that ruled over Afghanistan into five categories. Old Persian includes the empires of the Achaemenids, Parthians and Sasanians with Persian as their official language. The Hellenistic era is categorized as the Greek period. The East Iranian category includes mainly Kushans who used Bactrian (a language of the East Iranian group of languages) as their official language. The fourth category is Islamic

Persian, which includes the Muslim empires of Samanids, Ghaznavid, Seljuks and Ghurids. The Timurid and Chughtai dynasties have been classified as the empires of Turkic origin. Civilization diversity is measured by using the same formula as that used for ethnolinguistic fractionalization by taking a share of archaeological sites belonging to each of the above-mentioned group of dynasties. Figures A.9 to A.13 depict the ratio of archaeological sites belonging to each category and Figure A.14 shows civilization diversity.

1.5. Data and Methodology

Data Description

This study uses both historical and contemporary data. Historical data of the ethnolinguistic distribution of various regions of Afghanistan have been taken from the Historical and Political Gazetteer of Afghanistan (Adamec, 1972). The Gazetteer was originally printed for secret official purposes during the late 19th and early 20th century and edited by Ludwig W. Adamec. This gazetteer has six volumes that correspond to six different regions of Afghanistan and it includes the former official gazetteer compiled in 1914 with the addition of new maps and developments up to the 1970s. The six regions defined in the six volumes of the gazetteer are the following. The Northeastern region adjacent to the border of Kashmir, China, and Tajikistan contains mainly the provinces of Badakhshan and Baglan; the Northern region attached to the Uzbekistan border includes the provinces of Balkh, Bamiyan and Samangan; the Northwestern region shares a border with Iran and consists of Herat and the surrounding areas. The Southwestern region shares a border with Iran and the Pakistani province of Baluchistan and includes the Helmand and Farah provinces; the Southeastern region along with a border with Pakistan includes the province of Kandahar; and the Central region includes the capital Kabul and ten surrounding provinces of Afghanistan. Historical ethnic borders used for the regression discontinuity design have been taken from this gazetteer.

Details of archaeological sites in Afghanistan are taken from the Archaeological Gazetteer of Afghanistan, which was published in 1982. The gazetteer has the information of 1286 archaeological sites of Afghanistan (Ball, 1982). These sites cover the period from the Palaeolithic epoch to the Safavid dynasty. It includes details of palaces, shrines, religious cemeteries, monasteries, mosques, roadside inns, statues, old bridges, towers and places of sherds and coins. The archaeological sites are of a ceramic, architectural, numismatic, lithic, epigraphic or stylistic nature, and they are facing various threats. Apart from natural deterioration, these sites are at risk from civil conflict, looting and Taliban attacks. This study uses a microdata set called “Survey of the Afghan People”, which was collected every year from 2006 to 2017 by the Asia Foundation (Mulakala & Hongbol, 2017). Over the 12 years, more than 97 thousand people were surveyed. This unique data set covers various socio-economic and political issues.

Table 1.1. Descriptive Analysis of the Key Variables.

Variable	Mean	Std. Dev.	Median	Min.	Max.	n	Description	Source	Year
Trust Level	0.401	0.128	0.403	0.01	0.78	100	Ratio (0-1)	Asia Foundation Survey	2006-08
Individualism	0.639	0.122	0.639	0.354	1	100	Ratio (0-1)	Asia Foundation Survey	2006-08
Education	0.06	0.073	0.032	0	0.388	338	Ratio (0-1)	Asia Foundation Survey	2006-15
Political preferences	0.598	0.261	0.580	0.006	1.000	68	Ratio (0-1)	Asia Foundation Survey	2015-16
Violence or crime	0.190	0.118	0.189	0	0.775	406	Ratio (0-1)	Asia Foundation Survey	2016-17
Pashtun	0.426	0.398	0.240	0	1	170	Ratio (0-1)	Asia Foundation Survey	2013-17
Electricity provision	0.704	0.242	0.701	0.185	1.538	306	Index (0-2)	Asia Foundation Survey	Various years 2006-17
Average monthly income	7336.338	3455.675	6629.894	1560.606	24807.41	406	Afghanis	Asia Foundation Survey	2006-17
Ethnic fractionalization	0.304	0.232	0.326	0	0.672	34	Index (0-1)	Asia Foundation Survey	2013-17
Ethnic polarization	0.488	0.341	0.581	0	0.943	34	Index (0-1)	Asia Foundation Survey	2013-17
Linguistic fractionalization	0.301	0.211	0.293	0	0.692	34	Index (0-1)	Asia Foundation Survey	2006
Linguistic polarization	0.130	0.083	0.144	0	0.250	34	Index (0-1)	Asia Foundation Survey	2006
ELF distance	0.194	0.166	0.157	0	0.573	34	Index (0-1)	Asia Foundation Survey	2006
RG distance	0.081	0.061	0.074	0	0.221	34	Index (0-1)	Asia Foundation Survey	2006
PH Pashto	0.117	0.095	0.120	0	0.359	34	Index (0-1)	Asia Foundation Survey	2006
PH Dari	0.159	0.120	0.150	0	0.442	34	Index (0-1)	Asia Foundation Survey	2006
PH Uzbek	0.079	0.153	0	0	0.498	34	Index (0-1)	Asia Foundation Survey	2006

PH majority group	0.176	0.139	0.154	0	0.498	34	Index (0-1)	Asia Foundation Survey	2006
Historical ELF	0.476	0.229	0.533	0.028	0.755	34	Index (0-1)	Historical and Political Gazetteer of Afghanistan	1914-1971
Historical RQ	0.633	0.260	0.731	0.056	0.885	34	Index (0-1)	Historical and Political Gazetteer of Afghanistan	1914-1971
Old Persian	0.226	0.193	0.222	0	0.610	34	Ratio (0-1)	Archaeological Gazetteer of Afghanistan	Antiquity
Greek	0.059	0.107	0.000	0	0.5	34	Ratio (0-1)	Archaeological Gazetteer of Afghanistan	Antiquity
East Iranian	0.321	0.365	0.200	0	1	34	Ratio (0-1)	Archaeological Gazetteer of Afghanistan	Antiquity
Islamic Persian	0.149	0.254	0.000	0	1	34	Ratio (0-1)	Archaeological Gazetteer of Afghanistan	Antiquity
Turkic	0.245	0.270	0.186	0	1	34	Ratio (0-1)	Archaeological Gazetteer of Afghanistan	Antiquity
Civilization diversity	0.442	0.287	0.553	0	0.757	34	Index (0-1)	Archaeological Gazetteer of Afghanistan	Antiquity
Access to safe drinking water	2.920	0.472	2.871	2.046	3.724	34	Index (0-4)	Asia Foundation Survey	2006

Table 1.1. shows the descriptive analysis of the variables used for the IV, SEM and RD estimations. A large majority of the people are reluctant to trust others and a majority believe that most people are self- centred. The variable of violence or crime depicts the law and order situation in Afghanistan. About one- fifth of the respondents are of the opinion that their families have faced some kind of violence or crime. Ethnolinguistic fractionalization and polarization measured at the provincial level reveal a very high standard deviation. As illustrated in Table A.1, almost 80% of the Afghan population is either Pashtun or Tajik. Just over six percent are Uzbeks, whereas the share of Hazaras is 10%. The remaining four percent of the population is divided into many minority ethnic groups. Almost half of the Afghans speak Dari as their first language. Roughly 39% speak Pashto, whereas the Uzbek language is spoken by 10% of the people as their mother tongue.

Regression Discontinuity Design

Discontinuity can be defined as an observation near any threshold or cut off, the continuity of which is discontinued at the point of the threshold. This threshold may be a policy intervention, selection criteria or a geographic/administrative border. The idea behind introducing discontinuity in the regression framework is to remove selection bias that may arise due to the observations that are very much homogeneous in characteristics, but they lie on either side of the threshold, and they are divided into treatment and control groups.

Geographic regression discontinuity design divides the geographic area into treatment and control zones based on geographic, administrative or ethnolinguistic borders (Keele and Titiunik, 2015), with the idea that people living close to the geographic border on either side are more or less similar in characteristics. But based on geographic borders, they are in either the control or treatment group. Applying normal non-experimental methods may lead to the problem of selection bias, whereas RDD with its very few assumptions is the best econometric model in such a situation (Keele and Titiunik, 2015).

Different econometric models will be estimated using regression discontinuity design. With the geographic regression discontinuity design, we have:

$$Outcome_{it} = \gamma_1 Distance_i + \gamma_2 X_t + \varepsilon_{it}$$

Where γ is the contemporary outcome variable, X is the set of covariates and *Distance* is the distance of each provincial capital from the ethnic/linguistic border. Historical ethnic borders are taken from the Historical and Political Gazetteer of Afghanistan (1972) and linguistic borders are taken from the linguistic map from the National Atlas of the Democratic Republic of Afghanistan (1985).

This study uses a sharp geographic RD design, which divides the data into treatment and non- treatment groups at the cutoff. We have estimated the regression discontinuity with bias-corrected coefficients and robust standard errors as proposed by Calonico, Cattaneo, and Titiunik (2014, 2015, 2017).

Instrumental Variables (IV) Estimation

This study uses IV estimation to examine the relationship between different measures of diversity and different socio-economic and political outcome variables. To instrument the measures of diversity, the index of civilization diversity and other variables of the ratio of the number of archaeological sites belonging to the different groups of ancient empires, as discussed in the previous section, are taken as the instrument variables. Instrument variable regressions are widely used to overcome the problem of endogeneity. An endogeneity problem arises when any regressor correlates with the error term, which violates the assumption of exogeneity and leads to biased estimators (Wooldridge, 2009). Simultaneity due to reverse causation, any omitted variable correlating with both the dependent and the independent variable and measurement error in the independent variable are the three sources of the endogeneity problem (Johnston, 1972). Two-stage least squares (2SLS) and the generalized method of moments (GMM) are the two most common methods that are used to obtain unbiased estimators in the presence of an endogeneity problem.

First stage

$$Diversity_i = \alpha_0 + \alpha_1 Z_i + \alpha_2 X_{it} + \mu_{it}$$

Second stage

$$Y_{it} = \beta_0 + \beta_1 Diversity_i + \beta_2 X_{it} + \mu_{it}$$

where Y_{it} is the outcome variable, $Diversity_i$ is the measure of ethnolinguistic diversity, Z_i is the set of instrumental variables related to ancient empire/civilizations and X_{it} is the set of covariates.

$$\mu_{it} = v_{it} + w_{it}$$

where v_{it} is the cross-section or province-specific error component and w_{it} is the combined cross-section and time series error component.

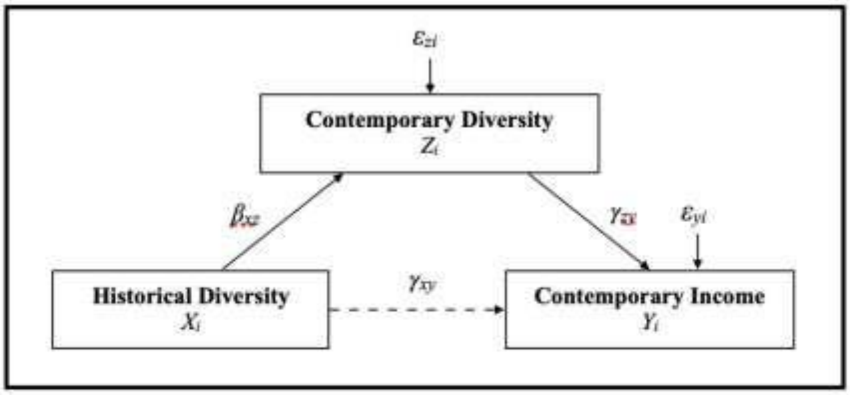
Structural Equation Modeling

This study uses mediation analysis with the help of structural equation modeling (SEM). Mediation analysis allows us to estimate the direct and indirect effect of the independent variable on the dependent variable in the presence of a mediating variable. SEM is a preferred technique in the presence of the simultaneity problem, multiple independent variables and latent variables (Gunzir, 2013).

$$z_i = \beta_0 + \beta_{xz} x_i + \varepsilon_{zi}$$
$$y_i = \gamma_0 + \gamma_{zy} z_i + \gamma_{xy} x_i + \varepsilon_{yi}$$

(Gunzler et al. 2013)

Figure 1.3. Pathway Diagram of Mediation Analysis



1.6. Results and Discussion

Correlation results

The correlation results are given in Table A.2. Provinces on the border of Pakistan/former British India have significantly less freedom of expression, less access to electricity and face significantly more violence and crime. These areas are highly ethnolinguistically homogenous and least ethnolinguistically polarized. Provinces on the border of Iran have less access to safe drinking water. Provinces on the border of the former Soviet Union are highly ethnolinguistically diverse and polarized, as revealed by the correlation result. They face lower provision of safe drinking water. Interestingly, people in these border areas have a higher level of trust in the people of their area and have a strong perception that the people in their area are generally not selfish. People in the border areas with the states of the former Soviet Union enjoy more freedom of expression than the people in the rest of Afghanistan. Moreover, the law and order situation in these areas is significantly better than in the other areas. Pashtuns have a better level of income but suffer from violence or crime. The general trust level and freedom of expression are low among Pashtun people. Dari-speaking people are generally quite positive towards democracy and enjoy the freedom of expression positively. They have no sympathy for militant groups and enjoy a better law and order situation. Tajiks suffer from a low provision of safe drinking water, but similar to Dari-speaking people, they enjoy more freedom of expression. Furthermore, Tajiks have better level of education. The measures of diversity are negatively correlated with access to safe drinking water and positively correlated with the provision of electricity. Interestingly, linguistically diverse and polarized areas in Afghanistan have lower levels of violence and crime. The correlation results of historical ethnic fractionalization and polarization from a reduced sample measured from the gazetteer data are very much consistent with the contemporary ethnic fractionalization and polarization.

Regression Discontinuity Design (RDD)

The regression discontinuity (RD Robust) results were obtained in three different ways. Firstly, they were obtained without covariates at the bandwidth chosen by the MSERD[9] criterion. Secondly, the results were acquired without covariates at a bandwidth of 100 kilometers. Thirdly, the covariates were included at the bandwidth selected by the MSERD criterion. According to the MSERD criterion, there are different bandwidths selected for each equation, generally from eight to fifty kilometers, as many of the provincial capitals were very close to ethnolinguistic borders. A bandwidth of one hundred kilometers was selected for the robustness check.

Linguistic Pashtun vs non-Pashtun

Table 1.2. Linguistic Pashtun vs non-Pashtun; BW: MSERD

Outcome variable	Method	Coefficient	Std. Err	Z	95% Confidence Interval		N
average monthly income	Conventional	2592***	602.1	4.305	1411.88	3772.08	406
	Bias-corrected	2857***	602.1	4.745	1676.94	4037.13	406
	Robust	2857***	734.87	3.888	1416.71	4297.36	406
lny	Conventional	0.362***	0.085	4.283	0.196	0.528	406
	Bias-corrected	0.331***	0.085	3.921	0.166	0.497	406
	Robust	0.331***	0.095	3.475	0.145	0.518	406
violence or crime	Conventional	0.039*	0.022	1.775	-0.004	0.082	406
	Bias-corrected	0.03	0.022	1.362	-0.013	0.073	406
	Robust	0.03	0.027	1.095	-0.024	0.084	406
trust level	Conventional	0.008	0.058	0.143	-0.105	0.122	100
	Bias-corrected	0.001	0.058	0.025	-0.112	0.115	100
	Robust	0.001	0.065	0.022	-0.127	0.13	100
individualism	Conventional	0.052	0.051	1.022	-0.048	0.152	100
	Bias-corrected	0.038	0.051	0.748	-0.062	0.138	100
	Robust	0.038	0.058	0.654	-0.076	0.153	100
political preferences	Conventional	0.283**	0.121	2.341	0.046	0.521	68
	Bias-corrected	0.277**	0.121	2.287	0.04	0.514	68
	Robust	0.277**	0.127	2.172	0.027	0.527	68
electricity	Conventional	0.145***	0.053	2.739	0.041	0.248	306
	Bias-corrected	0.142***	0.053	2.696	0.039	0.246	306
	Robust	0.142**	0.065	2.184	0.015	0.27	306
access to water	Conventional	0.762***	0.210	3.623	0.350	1.174	34
	Bias-corrected	0.768***	0.210	3.655	0.356	1.180	34
	Robust	0.768***	0.249	3.085	0.28	1.256	34

** indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

[9] Mean Square Error Regression Discontinuity (MSERD) is a criterion used for the bandwidth selection in the regression discontinuity framework. The use of optimum bandwidth based on the MSERD criterion make the robust bias-corrected estimators valid (Calonico, 2020).

Table 1.3. Linguistic Pashtun vs non-Pashtun; BW: 100 km

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
average monthly income	Conventional	3057***	510.1	5.993	2057.21	4056.77	406
	Bias-corrected	2583.3***	510.1	5.064	1583.56	3583.12	406
	Robust	2583.3***	604.14	4.276	1399.25	3767.43	406
lny	Conventional	0.399***	0.062	6.489	0.279	0.520	406
	Bias-corrected	0.350***	0.062	5.690	0.230	0.471	406
	Robust	0.350***	0.072	4.885	0.210	0.491	406
violence or crime	Conventional	0.042***	0.015	2.757	0.012	0.071	406
	Bias-corrected	0.029*	0.015	1.915	-0.001	0.058	406
	Robust	0.029	0.019	1.501	-0.009	0.067	406
trust level	Conventional	-0.052	0.042	-1.255	-0.134	0.029	100
	Bias-corrected	-0.023	0.042	-0.552	-0.105	0.059	100
	Robust	-0.023	0.053	-0.431	-0.128	0.082	100
individualism	Conventional	0.072*	0.039	1.833	-0.005	0.150	100
	Bias-corrected	0.065*	0.039	1.657	-0.012	0.143	100
	Robust	0.065	0.050	1.304	-0.033	0.164	100
political preferences	Conventional	0.278***	0.081	3.448	0.120	0.437	68
	Bias-corrected	0.308***	0.081	3.811	0.149	0.466	68
	Robust	0.308***	0.106	2.906	0.100	0.515	68
electricity	Conventional	0.073*	0.043	1.707	-0.011	0.157	306
	Bias-corrected	0.155***	0.043	3.601	0.070	0.239	306
	Robust	0.155***	0.056	2.749	0.044	0.265	306
access to water	Conventional	0.761***	0.140	5.421	0.486	1.036	34
	Bias-corrected	0.716***	0.140	5.102	0.441	0.991	34
	Robust	0.716***	0.183	3.914	0.357	1.074	34

** indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

Since Afghanistan has been ruled exclusively by Pashtun-speaking leaders for the last 270 years, Pashtun speakers are expected to have an advantage over other linguistic groups. As Tables 1.2-1.4 and bandwidth to one hundred kilometers or include such covariates as level of education and violence or crime, the results remain similar both in terms of magnitude and statistical significance. The results of average monthly income remain consistent when taking the natural logarithm of income, *lny*. The Pashtun areas exhibit significantly higher levels of socio-economic development in Afghanistan. The uninterrupted rule of Afghanistan by Pashtun leaders since Ahmad Shah Durrani established the Durrani Empire in 1747 is the reason why ethnic Tajiks, despite being the second largest ethnic group, and Dari speakers, despite being the largest linguistic group, earn significantly less than the Pashtuns. This is also evident in the map in Figure A.18, where it can be seen that most areas in the Southeast have higher income levels. This area is the Pashtun belt of Afghanistan. Moreover, Pashtuns appear to have better access to safe drinking water and provision of electricity. These results are confirmed by all three methods with conventional, bias- corrected and robust confidence intervals and at bandwidths based on the MSERD criterion with and without covariates.

Table 1.4. Linguistic Pashtun vs non-Pashtun; BW: MSERD with Covariates

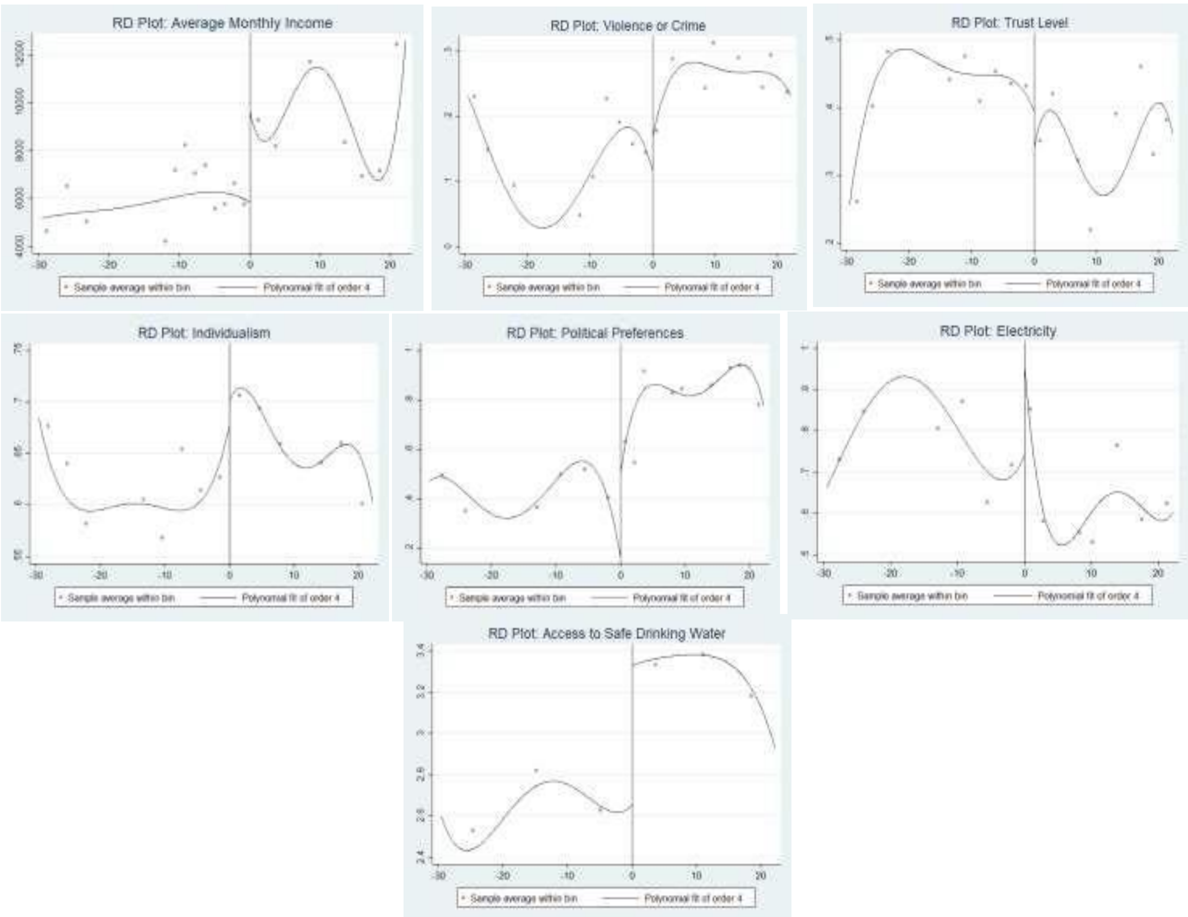
Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
average monthly income	Conventional	3142.2***	647.81	4.85	1872.54	4411.92	338
	Bias-corrected	3473.7***	647.81	5.362	2204.02	4743.39	338
	Robust	3473.7***	706.67	4.915	2088.65	4858.75	338
lny	Conventional	0.337***	0.07	4.807	0.199	0.474	338
	Bias-corrected	0.405***	0.07	5.78	0.268	0.542	338
	Robust	0.405***	0.088	4.612	0.233	0.577	338
violence or crime	Conventional	0.100**	0.047	2.147	0.009	0.192	134
	Bias-corrected	0.113**	0.047	2.424	0.022	0.204	134
	Robust	0.113**	0.055	2.046	0.005	0.221	134
trust level	Conventional	0.045	0.079	0.575	-0.109	0.199	100
	Bias-corrected	0.048	0.079	0.613	-0.106	0.202	100
	Robust	0.048	0.084	0.575	-0.116	0.212	100
individualism	Conventional	0.025	0.056	0.442	-0.085	0.134	100
	Bias-corrected	0.003	0.056	0.055	-0.106	0.112	100
	Robust	0.003	0.063	0.048	-0.120	0.126	100
political preferences	Conventional	0.416***	0.149	2.791	0.124	0.709	68
	Bias-corrected	0.461***	0.149	3.094	0.169	0.754	68
	Robust	0.461***	0.164	2.809	0.139	0.784	68
electricity	Conventional	0.228***	0.061	3.743	0.109	0.348	238
	Bias-corrected	0.240***	0.061	3.945	0.121	0.36	238
	Robust	0.240***	0.076	3.148	0.091	0.39	238
access to water	Conventional	0.744***	0.209	3.569	0.336	1.153	34
	Bias-corrected	0.764***	0.209	3.665	0.356	1.173	34
	Robust	0.764***	0.256	2.988	0.263	1.266	34

** indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

The mean difference in the share of support in favor of Ashraf Ghani, the current president of Afghanistan, in the Pashtun-speaking areas is 0.27 (27 percentage points) with an MSERD-based bandwidth, 0.30 (30 percentage points) at a bandwidth of 100 kilometers and 0.41 (41 percentage points) when we control for education, income level and violence or crime. All three coefficients have been estimated with bias-corrected and robust CIs and they are statistically significant at the 5-percent (Table 1.2) and the 1-percent (Tables 1.3 and 1.4) levels. When it comes to violence or crime, the mean difference in favor of the Pashtun-speaking areas is 2.9 percentage points and this is significant at the 10- percent level with a bias-corrected CI. The inclusion of such covariates as level of income, education and freedom of expression increases the mean difference in the Pashtun-speaking areas, which is now statistically significant at the 5-percent level both with a bias-corrected and a robust CI.

Pashtuns suffered more violence and crime than other language groups due to the imperial legacies and foreign involvement in Afghanistan, as has been discussed in detail in Section II of this paper. During the 1920s, the British Empire spread radicalism in Afghanistan, especially in the Pashtun areas adjacent to former British India border, to counter the massive reforms and liberal policies of King Amanullah. Later on, American intelligence with the assistance of Pakistani intelligence propagated the Jihadi literature in Afghanistan to fight the Soviet occupation. These results are also confirmed by the map in Figure A.19, which shows that most provinces with a higher Pashtun population suffer more from conflict. The results of linguistic Pashtun are consistent with those of ethnic Pashtuns, as provided in Tables A.3 to A.5.

Figure 1.4. RD Plots for Linguistic Pashtun vs non-Pashtun. BW: MSERD.



Ethnic Tajik vs non-Tajik

Although Tajiks are the second largest ethnic group in Afghanistan, they earn significantly less than other ethnicities. Using 100 kilometers as the bandwidth, it may be concluded that the mean income difference between Tajiks and non-Tajik areas of Afghanistan is -3703 Afghanis, significant at the 1-percent level with bias-corrected and robust confidence intervals. This finding is also confirmed by taking the natural logarithm of income. Moreover, the Tajiks lack access to the provision of basic needs such as safe drinking water and electricity. Access to safe drinking water is lower by a mean difference of -1.745 scale points, which is statistically significant at the 5-percent level with both bias-corrected and robust CIs (Table 1.7). Similar observations can be found in Tables 1.5 and 1.6. Furthermore, Tajiks are less egocentric and more altruistic, as evidenced by the covariates model. As the map in Figure A.21 shows, areas in the center and center-west and center-east have a higher perception of individualism.

Table 1.5. Ethnic Tajik vs non-Tajik; BW: MSERD

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
trust level	Conventional	0.045	0.059	0.754	-0.071	0.16	100
	Bias-corrected	0.081	0.059	1.364	-0.035	0.196	100
	Robust	0.081	0.106	0.761	-0.127	0.288	100
individualism	Conventional	0.045	0.062	0.720	-0.077	0.167	100
	Bias-corrected	0.036	0.062	0.586	-0.086	0.159	100
	Robust	0.036	0.085	0.429	-0.13	0.203	100
political preferences	Conventional	-0.806***	0.262	-3.074	-1.319	-0.292	68
	Bias-corrected	-0.883***	0.262	-3.370	-1.397	-0.37	68
	Robust	-0.883**	0.352	-2.507	-1.574	-0.193	68
electricity	Conventional	0.033	0.118	0.276	-0.199	0.265	306
	Bias-corrected	0.113	0.118	0.953	-0.119	0.345	306
	Robust	0.113	0.146	0.775	-0.173	0.398	306
access to water	Conventional	-1.558***	0.475	-3.278	-2.490	-0.627	34
	Bias-corrected	-1.872***	0.475	-3.939	-2.804	-0.941	34
	Robust	-1.872***	0.672	-2.787	-3.190	-0.555	34

** indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

Figure 1.5. RD Plots for Ethnic Tajik vs non-Tajik. BW: MSERD

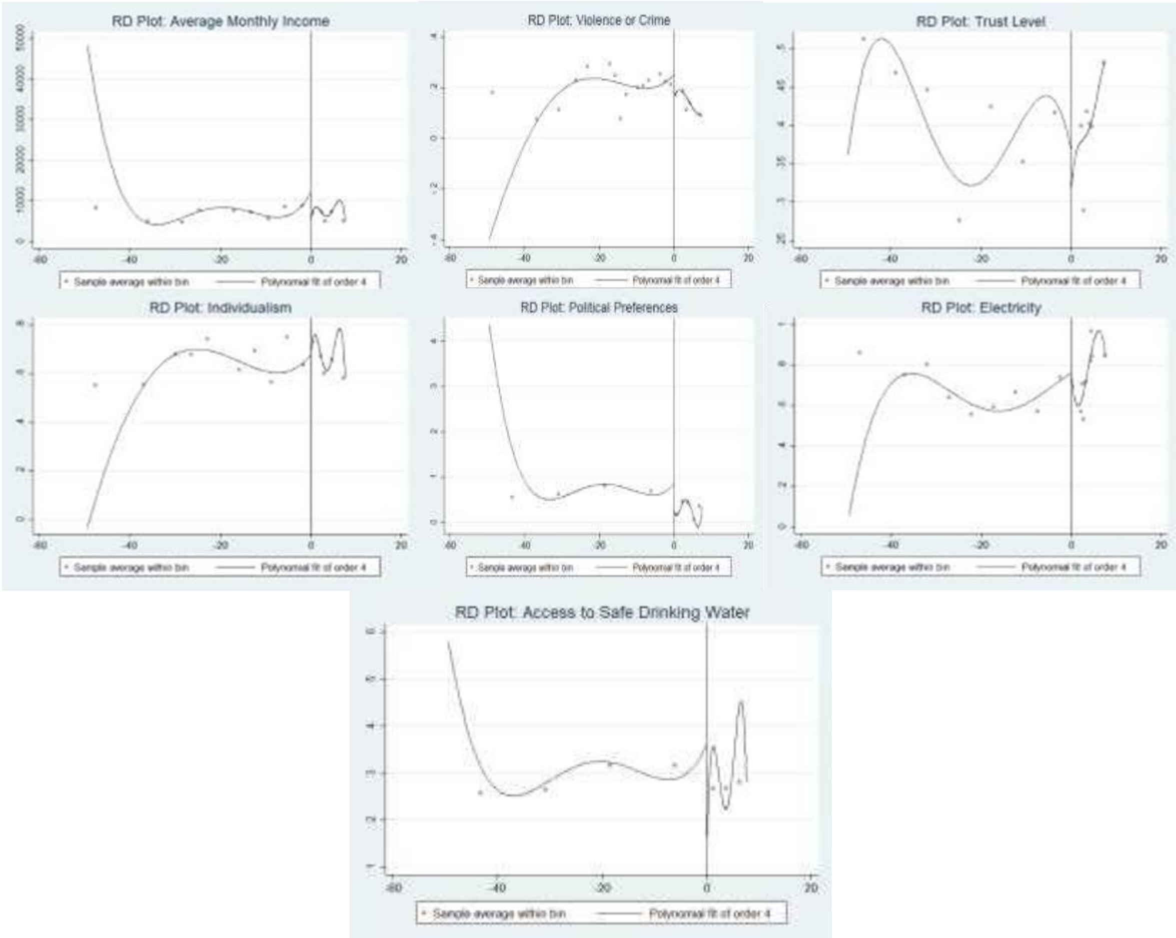


Table 1.6. Ethnic Tajik vs non-Tajik; BW: 100 km

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
average monthly income	Conventional	-1699.8***	535.4	-3.175	-2749.15	-650.428	406
	Bias-corrected	-3703.4***	535.4	-6.917	-4752.79	-2654.07	406
	Robust	-3703.4***	786.02	-4.712	-5243.99	-2162.86	406
lny	Conventional	-0.208***	0.074	-2.816	-0.353	-0.063	406
	Bias-corrected	-0.424***	0.074	-5.737	-0.569	-0.279	406
	Robust	-0.424***	0.107	-3.948	-0.634	-0.213	406
violence or crime	Conventional	-0.021	0.021	-0.992	-0.063	0.021	406
	Bias-corrected	-0.051**	0.021	-2.401	-0.093	-0.009	406
	Robust	-0.051	0.036	-1.410	-0.122	0.020	406
trust level	Conventional	-0.086**	0.040	-2.155	-0.165	-0.008	100
	Bias-corrected	-0.067*	0.040	-1.667	-0.145	0.012	100
	Robust	-0.067	0.057	-1.172	-0.178	0.045	100
individualism	Conventional	0.065*	0.037	1.782	-0.006	0.137	100
	Bias-corrected	0.063*	0.037	1.712	-0.009	0.134	100
	Robust	0.063	0.052	1.191	-0.040	0.165	100
political preferences	Conventional	-0.315***	0.115	-2.726	-0.541	-0.088	68
	Bias-corrected	-0.510***	0.115	-4.420	-0.736	-0.284	68
	Robust	-0.510***	0.194	-2.626	-0.891	-0.129	68

electricity	Conventional	-0.154***	0.059	-2.614	-0.270	-0.039	306
	Bias-corrected	-0.184***	0.059	-3.115	-0.299	-0.068	306
	Robust	-0.184**	0.088	-2.094	-0.356	-0.012	306
access to water	Conventional	-0.619***	0.217	-2.850	-1.044	-0.193	34
	Bias-corrected	-0.812***	0.217	-3.742	-1.237	-0.387	34
	Robust	-0.812**	0.395	-2.057	-1.586	-0.038	34

** indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

Table 1.7. Ethnic Tajik vs non-Tajik; BW: MSERD with Covariates.

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
violence or crime	Conventional	0.03	0.047	0.635	-0.062	0.122	134
	Bias-corrected	0.053	0.047	1.116	-0.04	0.145	134
	Robust	0.053	0.063	0.840	-0.07	0.175	134
individualism	Conventional	-0.054	0.045	-1.205	-0.143	0.034	100
	Bias-corrected	-0.114**	0.045	-2.524	-0.203	-0.025	100
	Robust	-0.114	0.078	-1.464	-0.267	0.039	100
political preferences	Conventional	-0.851***	0.173	-4.912	-1.190	-0.511	68
	Bias-corrected	-0.882***	0.173	-5.092	-1.222	-0.542	68
	Robust	-0.882***	0.212	-4.163	-1.297	-0.467	68
electricity	Conventional	-0.002	0.151	-0.015	-0.299	0.294	238
	Bias-corrected	0.09	0.151	0.598	-0.206	0.387	238
	Robust	0.09	0.188	0.480	-0.279	0.459	238
access to water	Conventional	-1.423**	0.580	-2.456	-2.56	-0.287	34
	Bias-corrected	-1.745**	0.58	-3.01	-2.881	-0.609	34
	Robust	-1.745**	0.782	-2.231	-3.278	-0.212	34

** indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

Support for Ashraf Ghani in the 2014 presidential elections was the lowest in the Tajik areas as the Tajiks voted for the Tajik candidate Abdullah Abdullah. The mean difference in the support for a Pashtun leader is -0.883 percentage points without covariates and -0.882 percentage points with income, education and violence or crime as covariates. Both differences are statistically significant with bias-corrected and robust CIs. This is clear evidence that Afghan society is strongly divided along ethnic lines in terms of political preferences. Afghanistan's present president, Ashraf Ghani, won the second round of the 2014 presidential election with the narrowest of margins after both the leaders failed to gain a simple majority in the first round. Our RD results, presented both graphically and numerically, suggest that Afghanistan's people voted for ethnicity and there is a strong ethnolinguistic border effect.

Dari- vs non-Dari-speaking areas

Dari is spoken by ethnic Tajik, Hazara and Aimaq people. Dari-speaking people represent the largest linguistic group of Afghanistan. Their average income level is, nevertheless, less than that of other linguistic groups in Afghanistan, with a mean difference of -2974 Afghanis, significant at the 1-percent level. As the map in Figure A.20 indicates, most areas adjacent to the former Soviet Union border have higher levels of trust. The RD results show that there is some evidence that Dari-speaking people enjoy a higher trust level, as evidenced by the results in Tables A.9 to A.11 and Figure A.16.

Uzbek- vs non-Uzbek-speaking areas

Uzbeks are the third largest linguistic and ethnic group of Afghanistan. From Tables A.6 to A.8, at higher level bandwidths (100 kilometers), it is evident that Uzbek speakers have higher levels of income and endure lower levels of violence and crime. These findings are significant at the 1-percent level with both bias-corrected and robust CIs. Moreover, individualism, with a mean difference of 0.128 points, is significantly lower among Uzbeks.

Instrumental Variables (IV) Estimation

Different equations are estimated using different techniques of instrumental variable methods: random effect 2SLS, between effects 2SLS and the instrumental variable generalized method of moments (IVGMM). In each equation, measures of diversity are instrumented by using the index of civilization diversity and the ratios of the number of archaeological sites belonging to Old Persian, Greek, East Iranian, Islamic Persian and Turkic civilizations. Other predetermined/exogenous variables, such as lagged income level, violence or crime and education, are also used as covariates.[10]

Income level and measures of diversity

The IV estimation results suggest that diversity is a positive determinant of level of income. Ethnically or linguistically diverse provinces exhibit higher levels of income than provinces with a lower level of diversity. As demonstrated in the above table, ethnic fractionalization induces a higher level of income at the 10-percent level in the BE (between effects) model. However, ethnic polarization is a positive and significant determinant of income according to the BE 2SLS, RE 2SLS and IVGMM models. Moreover, the level of education is also a positive and significant determinant of income at the provincial level in Afghanistan as evidenced by the results of all the above equations.

[10] We report specifications that produce statistically significant results and we provide the full code and data for all specifications in the online appendix paper. Standard error in parentheses.

Table 1.8. IV Estimation of Income Models

	BE 2SLS	RE 2SLS	IV GMM		BE 2SLS	RE 2SLS	IV GMM
Ethnic Fraction-alization	0.131*	0.179	0.182	**Ethnic Polarization**	0.091*	0.146*	0.143*
	(0.075)	(0.124)	(0.116)		(0.051)	(0.083)	(0.078)
Education	0.665*	1.608***	1.489***	**Education**	0.707*	1.633***	1.507***
	(0.366)	(0.304)	(0.291)		(0.375)	(0.304)	(0.290)
Lag_1 Income	1.020***	0.372***	0.460***	**Lag_1 Income**	1.010***	0.365***	0.448***
	(0.051)	(0.049)	(0.056)		(0.053)	(0.049)	(0.056)
Violence or Crime	0.097	0.810***	0.825***	**Violence or Crime**	0.104	0.820***	0.838***
	(0.190)	(0.193)	(0.218)		(0.192)	(0.191)	(0.216)
Constant	-0.286	5.198***	4.429***	**Constant**	-0.201	5.240***	4.513***
	(0.410)	(0.416)	(0.470)		(0.424)	(0.414)	(0.470)
R-squared	0.264	0.324	0.317	**R-squared**	0.267	0.3291	0.3224
Between R- square	0.961	0.842		**Between R- square**	0.9607	0.8404	
Wald Stat	720.640	158.860	177.930	**Wald Stat**	714.290	161.080	179.700
	0.000***	0.000***	0.000***		0.000***	0.000***	0.000***
1st stage F-stat	4.380		182.460	**1st stage F-stat**	4.820		227.220
	0.002***		0.000***		0.001***		0.000***
Obs	335	335	335	**Obs**	335	335	335
Civilization Diversity	0.461**	0.464***	0.464***	**Civilization Diversity**	0.793***	0.768***	0.768***
	(0.177)	(0.047)	(0.056)		(0.252)	(0.069)	0.081
Old Persian	-179.28**	-162.171***	-162.171***	**Old Persian**	-241.562**	-213.482***	-213.482***
	(68.920)	(18.592)	(19.743)		(98.104)	(26.883)	24.652
Greek	-178.86**	-161.819***	-161.819***	**Greek**	-241.245**	-213.335***	-213.335***
	(68.870)	(18.581)	(19.728)		(98.083)	(26.867)	24.631
East Iranian	-179.20**	-162.156***	-162.156***	**East Iranian**	-241.383**	-213.466***	-213.466***
	(68.893)	(18.586)	(19.737)		(98.104)	(26.872)	24.647
Islamic Persian	-179.19**	-162.174***	-162.174***	**Islamic Persian**	-241.450**	-213.565***	-213.565***
	(68.879)	(18.583)	(19.735)		(98.083)	(26.869)	24.647
Turkic	-179.04**	-161.943***	-161.943***	**Turkic**	-241.190**	-213.166***	-213.166***
	(68.915)	(18.589)	(19.740)		(98.135)	(26.878)	24.653

** indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

Violence or crime and measures of diversity

Table 1.9. IV Estimation of Violence and Crime

	BE 2SLS	RE 2SLS	IV GMM		BE 2SLS	RE 2SLS	IV GMM
Ethnic	-0.092	-0.112*	-0.073	**Ethnic**	-0.068*	-0.080**	-0.057*
Fraction-alization	(0.063)	(0.065)	(0.045)	**Polarization**	(0.041)	(0.042)	(0.030)
Education	0.145	0.044	0.248	**Education**	0.105	0.042	0.226
	(0.667)	(0.353)	(0.322)		(0.651)	(0.352)	(0.317)
Ln Income	0.081***	0.070**	0.084***	**Ln Income**	0.086**	0.074***	0.088***
	(0.039)	(0.022)	(0.021)		(0.038)	(0.022)	(0.021)
Freedom of Expression	-0.193**	0.006	-0.047	**Freedom of Expression**	-0.197**	0.000	-0.049
	(0.094)	(0.050)	(0.052)		(0.092)	(0.050)	(0.051)
Constant	-0.403	-0.407**	-0.521***	**Constant**	-0.437	-0.427**	-0.545***
	(0.358)	(0.200)	(0.192)		(0.350)	(0.199)	(0.189)
R-squared	0.200	0.233	0.217	**R-squared**	0.208	0.243	0.229
Between R-square	0.501	0.428		**Between R-square**	0.525	0.458	
Wald Stat	23.270	13.790	29.940	**Wald Stat**	24.950	14.820	31.500
	0.000***	0.008***	0.000***		0.000***	0.005***	0.000***
1st stage F-stat	3.830		59.830	**1st stage F-stat**	4.520		64.350
	0.004***		0.000***		0.002***		0.000***
Obs	134	134	134	**Obs**	134	134	134
Civilization	0.532**	0.506***	0.510***	**Civilization**	0.910***	0.817***	0.842***
Diversity	(0.190)	(0.077)	(0.081)	**Diversity**	(0.265)	(0.109)	(0.114)
Old Persian	-151.622**	-152.129***	-152.764***	**Old Persian**	-191.575*	-199.495***	-199.307***
	(70.546)	(30.367)	(30.576)		(98.511)	(43.250)	(37.744)
Greek	-151.193**	-151.743***	-152.373***	**Greek**	-191.231*	-199.304***	-199.086***
	(70.537)	(30.351)	(30.541)		(98.497)	(43.230)	(37.698)
East Iranian	-151.532**	-152.076***	-152.715***	**East Iranian**	-191.391*	-199.442***	-199.234***
	(70.550)	(30.356)	(30.561)		(98.516)	(43.237)	(37.732)
Islamic Persian	-151.528**	-152.090***	-152.725***	**Islamic Persian**	-191.434*	-199.523***	-199.303***
	(70.541)	(30.353)	(30.556)		(98.503)	(43.233)	(37.728)
Turkic	-151.314**	-151.852***	-152.501***	**Turkic**	-191.103*	-199.127***	-198.940***
	(70.557)	(30.361)	(30.565)		(98.525)	(43.243)	(37.737)

*Standard error in parentheses; * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

Diversity is negatively associated with the scale of violence or crime. Ethnic fractionalization causes a lower level of violence or crime, as clearly can be seen from the results of the random effect two stage least squares. Diversity measured by ethnic polarization has a significant and inverse relationship with the level of violence or crime and this finding is consistent in all three models of IV estimation. Provinces with a higher level of income suffered more violence and crime as revealed by all of the above models. Moreover, freedom of expression is another strong determinant of violence or crime as the provinces that enjoy a higher level of freedom of expression experience a lower level of violence or crime.

IV estimation for Political Preferences

The IV estimation given in the Table A.12 provides strong evidence that the popularity of the Pashtun leader Ashraf Ghani declines significantly with an increase in the level of diversity at the provincial level. This finding of an inverse relationship between the level of support for Ghani and the level of diversity in 2014 presidential elections is consistent with all the diversity indices. Provinces that are more diverse have a greater population proportion of Tajiks, Uzbeks and Hazaras, who are in general more inclined towards a non-Pashtun leader. There is strong evidence that provinces with a higher level of education have a lower level of support for Ashraf Ghani, whereas provinces with a higher level of income have greater support for Ashraf Ghani.

Trust level and measure of diversity

There is strong evidence that diversity indices of linguistic fractionalization and linguistic fractionalization with linguistic distance (GI distance) have a positive impact on the level of trust in Afghanistan. Provinces with a higher share of Uzbek and Turkmen populations have a greater level of linguistic distance as both Uzbek and Turkmen belong to Turkic group of languages, whereas other major languages spoken in Afghanistan are from the Indo-European language family. This means that provinces with higher levels of linguistic fractionalization in the form of linguistic distance enjoy higher levels of general trust. This finding is consistent in all of the models of IV estimation. Moreover, the level of income is negatively associated with general trust.

Table 1.10. IV Estimation of Trust Level Models

	BE 2SLS	RE 2SLS	IV GMM		BE 2SLS	RE 2SLS	IV GMM
Linguistic Fraction-alization	0.261*	0.229	0.292***	**GI Distance**	0.364**	0.337**	0.391***
	(0.152)	(0.143)	(0.089)		(0.175)	(0.168)	(0.108)
Education	0.399	0.040	0.014	**Education**	0.543	0.115	0.098
	(0.785)	(0.487)	(0.331)		(0.707)	(0.469)	(0.313)
Ln Income	-0.125***	-0.059*	-0.056*	**Ln Income**	-0.111**	-0.053*	-0.048
	(0.048)	(0.032)	(0.033)		(0.044)	(0.031)	(0.031)
Violence or Crime	0.441**	0.084	0.190	**Violence or Crime**	0.473**	0.132	0.193
	(0.220)	(0.136)	(0.128)		(0.204)	(0.134)	(0.125)
Constant	1.305***	0.824***	0.768***	**Constant**	1.190***	0.765**	0.701***
	(0.400)	(0.279)	(0.272)		(0.378)	(0.276)	(0.253)
R-squared Between	0.072	0.069		**R-squared Between**	0.107	0.114	0.063
R-square	0.155	0.147		**R-square**	0.299	0.255	
Wald Stat	10.620	7.050	11.980	**Wald Stat**	13.600	9.190	14.070
	0.031**	0.133	0.018**		0.009***	0.056*	0.007***
1st stage F-stat	1.080		8.020	**1st stage F-stat**	1.320		7.570
	0.411		0.000***		0.278		0.000***
Obs	100	100	100	**Obs**	100	100	100
Civilization	0.306	0.321***	0.316**	**Civilization**	0.277	0.263***	0.262***
Diversity	(0.234)	(0.112)	(0.128)	**Diversity**	(0.179)	(0.087)	(0.090)
Old Persian	-50.059	-51.564	-51.655	**Old Persian**	-11.338	-17.169	-16.643
	(84.016)	(42.851)	(47.899)		(64.028)	(33.111)	(37.915)
Greek	-49.647	-51.184	-51.280	**Greek**	-10.900	-16.794	-16.266
	(84.000)	(42.832)	(47.881)		(64.015)	(33.097)	(37.876)
East Iranian	-49.902	-51.425	-51.523	**East Iranian**	-11.162	-17.047	-16.521
	(84.018)	(42.840)	(47.870)		(64.029)	(33.102)	(37.909)
Islamic Persian	-50.058	-51.562	-51.668	**Islamic Persian**	-11.262	-17.130	-16.609
	(84.011)	(42.836)	(47.883)		(64.024)	(33.099)	(37.921)
Turkic	-49.824	-51.347	-51.452	**Turkic**	-11.140	-17.021	-16.499
	(84.030)	(42.846)	(47.890)		(64.038)	(33.108)	(37.917)

*Standard error in parentheses; * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%.*

Individualism and measures of diversity

Individualism as the perception that most people around are self-centered is more obvious in those provinces of Afghanistan where the level of diversity is the lowest, as revealed by the IV estimation results. Measures of ethnic fractionalization and polarization are found to be statistically significant in five of the above six equations. The level of income is positively associated with the level of individualism. Provinces affected by violence have a lower level of individualism and a higher percentage of people with altruistic attitudes.

Table 1.11. IV Estimation of Individualism Models

	BE 2SLS	RE 2SLS	IV GMM		BE 2SLS	RE 2SLS	IV GMM
Ethnic	-0.164*	-0.143*	-0.147**	**Ethnic**	-0.106*	-0.089	-0.090**
Fraction-alization	(0.089)	(0.081)	(0.062)	**Polarization**	(0.061)	(0.056)	(0.043)
Education	0.907	0.540	0.838*	**Education**	0.833	0.507	0.800*
	(0.735)	(0.444)	(0.433)		(0.749)	(0.447)	(0.436)
Ln Income	0.092**	0.087***	0.068**	**Ln Income**	0.104**	0.091***	0.073**
	(0.047)	(0.029)	(0.033)		(0.051)	(0.030)	(0.035)
Violence	-0.281	-0.267**	-0.233*	**Violence**	-0.292	-0.265**	-0.224
or Crime	(0.229)	(0.128)	(0.137)	**or Crime**	(0.241)	(0.130)	(0.141)
Constant	-0.076	-0.030	0.118	**Constant**	-0.166	-0.066	0.071
	(0.375)	(0.243)	(0.271)		(0.400)	(0.246)	(0.284)
R-squared	0.124	0.124	0.118	**R-squared**	0.108	0.107	0.102
Between R-square	0.157	0.163		**Between R-square**	0.114	0.127	
Wald Stat	7.300	13.110	12.790	**Wald Stat**	6.670	12.470	10.500
	0.121	0.0108**	0.0123**		0.155	0.014**	0.031**
1st stage F-stat	6.550		42.640	**1st stage F-stat**	8.920		55.110
	0.000***		0.000***		0.000***		0.000***
Obs	100	100	100	**Obs**	100	100	100
Civilization	0.415**	0.456***	0.443***	**Civilization**	0.724***	0.749***	0.741***
Diversity	(0.165)	(0.088)	(0.093)	**Diversity**	(0.216)	(0.125)	(0.130)
Old Persian	-170.781***	-158.403***	-161.215***	**Old Persian**	-225.356***	-209.356***	-213.870***
	(59.073)	(33.872)	(34.456)		(77.387)	(47.959)	(41.000)
Greek	-170.320***	-158.020***	-160.827***	**Greek**	-224.983***	-209.176***	-213.668***
	(59.062)	(33.857)	(34.438)		(77.372)	(47.937)	(40.972)
East Iranian	-170.773***	-158.392***	-161.217***	**East Iranian**	-225.324***	-209.363***	-213.882***
	(59.075)	(33.862)	(34.439)		(77.389)	(47.945)	(40.982)
Islamic Persian	-170.800***	-158.426***	-161.253***	**Islamic Persian**	-225.393***	-209.465***	-213.982***
	(59.070)	(33.859)	(34.434)		(77.382)	(47.941)	(40.981)
Turkic	-170.635***	-158.197***	-161.037***	**Turkic**	-225.158***	-209.089***	-213.639***
	(59.083)	(33.868)	(34.446)		(77.400)	(47.953)	(40.994)

*Standard error in parentheses * indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.*

Mediation Analysis with Structural Equation Modeling (SEM)

Mediation results reveal that historical empires have had a significant and long-lasting effect on Afghan socio-economic development. The Turkic empires of Timurids and Chugtai have had a strong positive impact on Afghanistan, while the same observation holds for the Old Persian empires of the Achaemenids, Parthians and Sasanians. This is because the Sasanians as well as the Timurids were major powers in the region and fully integrated Afghanistan into their respective imperial structures. This was not the case for the Islamic Persian empires of the Samanids, Ghaznavids, Seljuks and Ghurids, whose rule was less stable and more focused on warfare.

Table 1.12. **Mediation Analysis with SEM**

Mediating variable	Independent Variable	Direct Effect	Indirect Effect	Total Effect	% Direct Effect	% Indirect Effect
Old Persian	Ethnic fractionalization	0.051	0.072	0.123	41.102	58.898
Greek		0.138	-0.015	0.123	112.097	-12.097
East Iranian		0.057	0.066	0.123	46.252	53.748
Islamic Persian		0.093	0.030	0.123	75.819	24.181
Turkic		0.034	0.089***	0.123	27.896	72.104
Civilization diversity		0.065	0.058	0.123	52.674	47.326
Overall		0.048	0.075	0.123	39.263	60.737
Ethnic fractionalization	Old Persian	0.209*	0.025	0.234**	89.164	10.835
	Greek	-0.096	0.097	0.001	-10851.67	10951.672
	East Iranian	-0.100	-0.015	-0.115*	87.189	12.811
	Islamic Persian	-0.182**	-0.012	-0.194**	93.662	6.338
	Turkic	0.278***	0.008	0.286***	97.047	2.953
	Civilization diversity	0.075	0.033	0.108	69.695	30.305

** indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.*

1.7. Conclusions

This study examines how history relates to contemporary socio-economic and political outcomes in Afghanistan. With the help of RDD analysis, mediation analysis with structural equation modeling (SEM) and IV estimation, we have, in particular, explored how historical ethnolinguistic borders, antiquity and diversity relate to these outcomes. Diversity at the provincial level contributes positively to Afghan society by reducing the level of individualism and violence or crime and by boosting the level of income and trust. This is due to the fact that contemporary ethnolinguistic diversity is strongly correlated with historical ancient civilization diversity. Provinces where different civilizations or different historical empires left their impact are not only richer than the other provinces, but their social values are also stronger. Historical ethnolinguistic borders are persistent. Pashtuns have ruled all over Afghanistan for the last 270 years, and this has resulted in an improvement in their economic wellbeing. Pashtuns are not only richer than the other ethnolinguistic groups, but also have better access to some basic needs, such as electricity provision and safe drinking water. This finding supports the hypothesis that a ruler tends to promote the welfare of his own ethnic group. Afghan voters still vote along ethnic lines and are strongly divided across ethnolinguistic boundaries regarding their political preferences. This ethnic division with regard to political inclinations toward different presidential candidates may further increase, or at least will not decrease, until the minority ethnic groups that together make up the majority of the country gain a substantial say in the decision-making process. The historical empires of old Persian, including the Achaemenids, the Parthians and most importantly the Sasanians, have had a positive impact on the modern-day level of income, whereas the opposite holds for the Islamic Persian empires of Samanids, Ghaznavids, Seljuks and Ghurids. Furthermore, the central Asian Mongol empires of the Timurids and Chughtai have also left a long-lasting positive impact on the economic wellbeing of Afghan society. Both the Sasanian and the Timurid Empires can be considered the superpowers of their time, having a strong influence not only on present-day Afghanistan, but also on the surrounding countries. This is the reason that the provinces where these empires left a greater impact are economically more prosperous than the others.

Essay 2

Measuring the Ecological Efficiency of Thermal Power Plants: Evidence from Pakistan[1]

Abstract

This paper assesses the environmental and economic efficiency of thermal plants operating on fossil fuels in Pakistan using methods based on data envelopment analysis. Using the material balance principle, we find that cost- and carbon-efficient points can only be obtained simultaneously by switching to gas. However, under an assumption of variable returns to scale, these points can still be obtained without this conversion through the application of best practices. Furthermore, about 26% of costs and about 34% of carbon emissions can be reduced without a switch to gas and by using technically efficient inputs; the latter would also lead to a significant reduction in electricity prices and considerable environmental benefits. Power plants operating on residual fuel oil are significantly more technically efficient than plants operating on gas. Nonetheless, both types of plants have an equal share in forming the metafrontier as exhibited by the meta-technology ratio. There is a definite need to make plants more efficient by using the best possible combination of inputs and overhauling. Bootstrap results also suggest that further improvement in efficiency is possible.

Keywords: carbon dioxide emission, cost efficiency, environmental efficiency, material balance principle

JEL codes: B21, C61, D61, Q53

2.1 Introduction

Pakistan has faced a severe electricity crisis in recent years. Since 2006, the country has been confronted with power breakages and regular load-shedding that lasts for several hours per day. Electricity demand has increased over the years, but power generation has not seen a corresponding increase in the last 2 decades. Moreover, many plants are producing electricity

[1] This chapter is a result of joint work with Theocharis Grigoriadis (Freie Universität Berlin). To honor his contribution, “we” will be used throughout this chapter.

below their capacity for the following reasons: (i) a shortage of gas and oil, (ii) circular debt and late payments to electric utilities, and (iii) delayed overhauling.[2] As a result, the regular maintenance of power- plant machinery, which should take place regularly at intervals of 5 years, generally does not. This omission has led to the deterioration of the machinery and a loss of fuel efficiency. This, in turn, has resulted in a reduction in plant efficiency and production and increased fuel costs. Moreover, low efficiency and excessive fuel usage have led to additional carbon dioxide (CO_2) emissions and environmental degradation.

In recent years, emphasis has been given to reducing greenhouse gas (GHG) emissions; yet the main obstacle to controlling air pollution is the tradeoff between cost and carbon efficiency. Chen, Yeh, and Lee (2013) revealed a significant difference in the efficiency scores obtained by two specifications with and without CO_2 emissions under the framework of data envelopment analysis (DEA). Welch and Barnum (2009) explored a wide gap between the cost and carbon efficiency of electric utilities in the United States (US). An increase of 78.9% was found in the transition cost from the cost-efficient point to the carbon-efficient point. At the same time, there was an increase of 38% in carbon emissions to reach a cost-efficient point from a carbon-efficient point. Sarica and Or (2007) concluded that the empirical relationship between environmental cost and scale efficiency is weak, as indicated by the low R-squared. According to Murty et al. (2007), the technical and environmental inefficiency of thermal power plants in the Indian state of Andhra Pradesh was 0.1, which revealed that production could be increased by 10% while reducing the generation of GHGs by 10%.

Electricity generated by thermal plants that use fossil fuels is the main source of global CO_2 emissions.[3] Furthermore, electricity generation in South Asia mainly depends on fossil fuels. Plants that produce electricity from natural gas are carbon-efficient but bear more costs than those plants that are carbon inefficient (Welch and Barnum, 2009). However, there may be few firms that are both cost- and carbon-inefficient and similarly there may exist plants that are both carbon and cost efficient. A key goal of this paper is to explore plants that are simultaneously cost- and carbon- efficient, as well as plants that are cost- and carbon-inefficient under the assumption of variable returns to scale. Furthermore, it is important to find out how much extra cost must be borne to reach the carbon-efficient point. Cost

[2] The *State of Industry* is an annual report compiled by the National Electric Power Regulatory Authority. The report analyzes the current situation of power generation, distribution, and demand, and elaborates on the various challenges facing the energy sector.

[3] Global Manmade Greenhouse Gas Emissions by Sector, 2013 accessed from https://www.c2es.org/content/international-emissions/.

efficiency helps to locate points on the efficient frontier that minimize output, while estimating the potential of cost reduction with current output (Farrell, 1957). Färe, Grosskopf, and Lovell (1985) used input prices and the quantity of both input and output to estimate cost efficiency with linear programming. Camanho and Dyson (2005) introduced a measure of cost efficiency that uses weight-restricted DEA (see Jahanshahloo, Mirdehghan, and Vakili [2011]) for an overview of methods and a simplified modeling approach).

Song et al. (2012) highlight three classes of DEA efficiency models that incorporate undesirable outputs. The first class of models treats undesirable outputs as inputs (Berg, Forsund, and Jansen, 1992; Hailu and Veeman, 2001); however, it does not reveal the true production process at any point (Seiford and Zhu, 2002). The second class of models focuses on data transformation into undesirable outputs. Environment efficiency is then estimated with standard DEA modeling (Seiford and Zhu, 2002; Hua, Bian, and Liang, 2007). This class of models is solvable only under the variable-returns-to-scale assumption due to convexity constraints (Song et al., 2012). In the third class of models, the disposability of production technology is included in the DEA model (Färe et al., 2005). Given its focus on the output of pollution abatement activities, the directional output distance function is the appropriate DEA model if desirable and undesirable outputs are optimized simultaneously (Chung, Färe, and Grosskopf, 1997). The inclusion of the material balance principle (MBP) into the DEA framework relates to the first law of thermodynamics: material inputs are either incorporated into desirable outputs or emitted as undesirable byproducts (Ayres and Kneese, 1969). Furthermore, Coelli, Lauwers, and Van Huylenbroeck (2007), Forsund (2009), and Lauwers (2009) introduced the MBP into efficiency analysis for pollution.

The purpose of DEA efficiency analysis is to estimate the distance between efficient and actual production points. By doing so, DEA methodology allows the computation of cost efficiency and GHG emissions reduction potential for Pakistan. Moreover, reductions in emissions and cost per unit are not linearly related to the use of fossil fuels but depend on the best market and industry practices that have developed under the assumption of variable returns to scale. The distance of each production unit from the technically efficient point on the production frontier is estimated to determine the degree of technical efficiency. Similarly, the distance of each decision-making unit (DMU) from the isocost line is estimated to find the cost efficiency, whereas the distance of each production unit from the carbon efficient point on the isocarbon line is used for carbon efficiency. The potential cost and carbon emissions savings are, therefore, determined by the distance to the efficient frontier, which lies at the core of the DEA approach.

Our paper uses the material balance principle used by Welch and Barnum (2009) for US electric utilities to estimate costs and carbon-efficiency. Furthermore, we use the meta-technology ratio previously applied by Seifert, Cullmann, and Hirschhausen (2016) on German thermal power plants to explore which type of fuel has the major share in shaping the technically efficient production frontier. Therefore, our work is the first evaluation study for South Asia that comprehensively discusses the ecological efficiency of the power industry in Pakistan that produces electricity from fossil fuels.

Most of the literature has focused on the estimation of technical efficiency or total factor productivity (TFP) change through DEA methods, where undesirable output from these plants was ignored; it was taken either as a negative output or as an additional input, since a cost must be borne to dispose of the undesirable output. In our paper, we provide a method that identifies how both carbon and cost efficiency can be increased simultaneously by changing the combination of carbon inputs and therefore suggest a novel definition of ecological efficiency.

This paper concentrates on GHG emissions produced by thermal power plants. However, electric utilities operating on fossil fuels emit many other types of gases and substances. While these are not GHGs, they pollute the environment and may pose a significant danger to people's health, including gases such as sulfur dioxide (SO_2) and nitrogen oxide (NO_x) as well as particulate matter (PM). SO_2 may exacerbate heart disease and respiratory illnesses, particularly among children and elderly people. NO_x can cause lung diseases, while PM causes hazy conditions and thus asthma, lung cancer, and chronic bronchitis (United States Energy Information Administration [EIA] 2018). The estimation of CO_2 emissions as a result of combustion processes is comparatively simpler as it requires a CO_2 emission factor as a function of the fuel property, whereas non-GHG emissions require additional parameters such as the type of technology or boiler, combustion process, fuel properties, operating and maintenance condition, size of the equipment, and emissions control policy (Amous et al., 2014). Hence, the estimation of non-CO_2 emissions requires more data on the production process. Very few studies have been carried out on the estimation of non-CO_2 emissions from selected power plants by monitoring engine emissions. Athar, Ali, and Kahn (2010) estimated pollutant emissions by monitoring four thermal power plants for 6 months. They found that emissions were high in the diesel-engine-based power plants, while turbine-based power plants emitted lower levels of pollutants. Sulfur emissions were high under both technologies due to the high sulfur content of the fuel. Ali, Athar, and Ali (2007) estimated non-CO_2 emissions by monitoring fossil-fuel-based power plants working near

Raiwind, Pakistan, with some of the emissions parameters being higher than the World Bank standards and National Environment Quality Standards for power plants.

We estimate technical efficiency by assuming variable returns to scale. An estimation of TFP change; technological change; and pure, scale, and technical efficiency changes over time are also considered. This paper has been organized as follows. Section II discusses energy markets and environmental policy in Pakistan. Section III describes data sources and variables. Section IV provides the empirical strategy of the paper. Results are illustrated in Section V. Conclusions and policy recommendations are offered in Section VI.

2.2. Energy Markets and Environmental Policy in Pakistan

Natural gas in Pakistan is not only less costly but is also more environmentally friendly than other fossil fuels in terms of power generation (Table 1 and 2). However, due to shortages and the inaccessibility of natural gas, many plants cannot use it as their fuel input. Thus, the power industry cannot completely switch over to natural gas. Gas prices are not determined by market mechanisms since the Pakistani gas market is fully regulated. The federal government of Pakistan is responsible for natural gas pricing as well as for natural gas development, allocation, and distribution. Energy policy determination occurs on the basis of the government's socioeconomic and political agenda rather than profit maximization. Long-term agreements between the government and gas-producing companies constitute the financial basis for the cost of production, which is linked to the international prices of crude oil and high-sulfur fuel oil. Gas companies operating under the gas tariff regime face significant gas losses, which have increased over the last few years.[4] This has serious implications for their profits. The Pakistani Oil and Gas Regulatory Authority (OGRA) is the main administrative body for regulating energy markets and activities related to all stages from exploration and development to transmission and distribution. Distribution and transport of the natural gas through pipelines is carried out by two public sector companies, the Sui Northern Gas Pipeline Limited and the Sui Southern Gas Company Ltd. OGRA sets the price for natural gas upon federal government approval.

Natural gas resources in Pakistan are rapidly depleting. Significant growth in the compressed natural gas (CNG) industry has further widened the gap between demand and

[4] Under the gas tariff regime, OGRA determines the tariffs of all regulated activities given the OGRA ordinance in 2002 (OGRA, 2017). The difference between the total volume of the gas supplied and the gas volume sold or billed is defined as Unaccounted For Gas (Sui Northern Gas Training Institute, 2016).

supply. Nevertheless, due to the measures taken by the Hydrocarbon Development Institute of Pakistan, the CNG industry has grown significantly. The government of Pakistan has established various incentives for the growth of this industry in order to provide cost- and environment-efficient fuel for the transportation sector. According to the report of the International Association of Natural Gas Vehicles. According to National Electric Power Regulatory Authority (NEPRA) reports, the power industry alone requires more than twice the quantity of natural gas than is currently available. The few power plants that can use multiple types of fuel — such as Thermal Power Station Jamshoro (850 megawatts [MW]), Thermal Power Station Muzaffargarh (1350 MW), and Gas Power Station Multan (195 MW) — have to switch to residual fuel oil to overcome natural gas shortages. Thermal Power Station Jamshoro has four electricity units, three of which can use both natural gas and oil. However, these three units rely completely on residual fuel oil (RFO), particularly during winter, due to natural gas shortages.

Due to technological constraints, there are some power plants that cannot easily switch to other fuels. The Government of Pakistan is considering proposals to convert imported oil-fired power plants to LNG- or coal-fired plants. Specifically, one proposal is the conversion of some power plants from RFO-fired to LNG-fired in order to reduce import dependence, the cost of power generation, and CO_2 emissions. A second proposal is to convert some power plants from dual fuel-based to coal-fired in order to overcome natural gas shortages and reduce the cost of production. The International Monetary Fund, under its agreement with the Government of Pakistan in September 2013, recommended the transition of the power industry from RFO to indigenous natural gas. This measure is necessary to reduce the cost of electricity generation, which stands at 12 rupees per unit against the end-user price of PRs 9 per unit (Aftab, 2014). In this paper, we propose a policy solution that simultaneously reduces cost and CO_2 emissions in the presence of natural gas shortages.

The first ordinance on environmental protection led to the establishment of the Pakistan Environment Protection Council in 1984. In 1997, Parliament introduced the Pakistan Environment Protection Act, which created the country's Environmental Protection Agency (EPA). The EPA was granted authority to undertake legal action against environmental polluters. Despite the imposition of national environmental standards in 1999 under the Environment Protection Act, 1997, the World Health Organization, Pakistan Council of Research in Water Resources, and Health Effect Institute have observed that environmental regulation has been ineffective and unable to achieve its goals due to poor implementation (Sohail et al., 2014).

NEPRA has set standards for pollutant emissions by thermal power plants that are in compliance with national and World Bank environmental quality standards. Table 2.1 provides NEPRA emissions standards as reported in the licenses of some thermal power plants.

Nevertheless, Ali, Athar, and Ali (2007) and Athar, Ali, and Kahn (2010) argue that most Pakistani thermal plants have failed to comply with the standards of the EPA and NEPRA. Figure 1 indicates seasonal fluctuations in pollutant emissions. Pollutant emissions are high in June and July due to high demand for electricity. Natural gas is more environmentally friendly as it emits lower levels of pollutants than the other fuels. Based on evidence from the licenses of the Jamshoro Company, natural gas has negligible emissions of SO_2 and PM. On the other hand, furnace oil produces SO_2, NO_x, and PM emissions at considerable rates.

Evidence from the Global Energy Observatory (2016) shows the territorial distribution of Pakistani thermal power plants, most of which are located in Sindh province and South Baluchistan, as well as in Central and South Punjab. The Northwest Frontier Province of Khyber Pakhtunkhwa as well as the North Punjab and Kashmir regions are known for their hydropower projects. Emissions monitoring stations have been established throughout the

Table 2.1. NEPRA Environmental Quality Standards

Plant Name	Pollutants and Fuel	SO_x	NO_x	CO	PM_{10}
Attock Gen Limited, Morgah Rawalpindi (165 MW)	RFO	20 g/s	67 g/s		1.7 g/s
Atlas Power, Sheikhupura (225 MW)	RFO	0.35 t/dMWe (Max)	1,700 ppm	90 ppm	70 ppm
Nishat Chunian Power (200 MW)	Primary Fuel (RFO)	Max. 2,030 (mg/Nm^3)	Max. 2,000 (mg/Nm^3)	Max. 100 (mg/Nm^3)	Max. 110 (mg/Nm^3)
Nishat Power Limited (200 MW)	Primary Fuel (RFO)	Max. 2,030 (mg/Nm^3)	Max. 2,000 (mg/Nm^3)	Max. 100 (mg/Nm^3)	Max. 110 (mg/Nm^3)
Engro Energy Limited, Karachi (217 MW)	Natural Gas	54 (mg/Nm^3)	79 (mg/Nm^3)	103.3 (mg/Nm^3)	53.3 (mg/Nm^3)
	High Speed Diesel	400 (mg/Nm^3)	143 (mg/Nm^3)	86.7 (mg/Nm^3)	43.3 (mg/Nm^3)

CO = carbon monoxide, g/m = gram/second, mg/Nm^3 = milligrams per cubic meter, NOx = nitrogen oxide, RFO = residual fuel oil, PM_{10} = particulate matter (diameter 10 micrometer), SO_x = sulfur oxide, t/d MWe = tons/day Megawatt electricity.
Note: Engro Energy Limited Karachi uses both natural gas and high-speed diesel.
Source: National Electric Power Regulatory Authority Licenses. https://nepra.org.pk/licensing/lic_gencos.php.

country under the government's Clean Air Program. However, plant-level emissions data are not accessible for Pakistan on a full scale (other than what is shown in Figure 1).

Furthermore, information on the specification of boiler configurations at the unit level and on emission factors for each fuel is not publicly available either. The provision of these datasets would help researchers immensely in estimating pollutant emissions. Policymakers would also be in a position to make more informed decisions toward the achievement of sustainable development goals.

2.3. Data

Data for Pakistan have been collected from the *State of Industry* reports for 2010–2014 published by NEPRA. *Power System Statistics* is an annual publication of the National Transmission and Dispatch Company Limited. The heat content or the calorific value of each fuel to convert the original units to million British thermal units (MMBTU) was gathered from the OGRA and EIA websites.[5] The source of fuel in Pakistan for electricity generation during the review period was domestic natural gas and imported oil from the Gulf countries.

Table 2.2 Carbon Dioxide Emission Factors

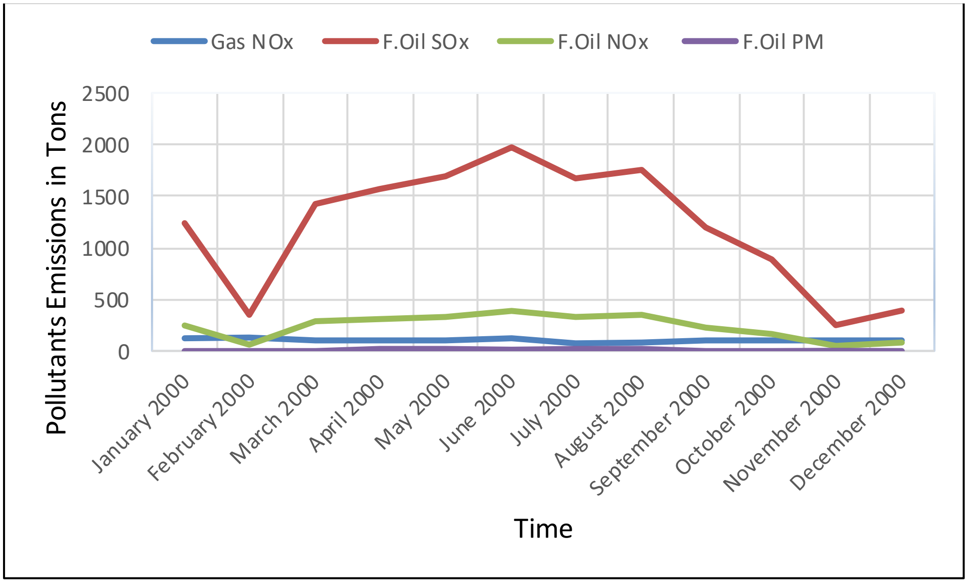
No.	Fuel	CO_2 Emission Factor
1	Bituminous Coal and Waste Coal	93.3
2	Distillate Fuel Oil	73.2
3	Lignite Coal	97.7
4	Natural Gas	53.1
5	Residual Fuel Oil	78.8

Source: United States Energy Information Administration. 2016. "Carbon Dioxide Emission Coefficients." https://www.eia.gov/environment/data.phphttps://www.eia.gov/environment/emissions/co2_vol_mass.php.

Hence, the CO_2 emission factor for each fuel has remained stable. Table 2.2 shows that the natural gas is the most climate friendly fuel whereas coal has the highest CO2 emission factor.

[5] The data on the heat rate of each plant is computed using the following EIA formula: $\text{Heat rate} = \frac{\text{total fuel inputs in MMBTU}}{\text{total output in KWH}}$. Heat rate is the amount of energy that a plant requires to produce 1 kilowatt-hour of electricity (EIA 2016). Total CO_2 emissions per 1 kilowatt-hour of electricity are calculated by dividing the product of the CO_2 emission factor for each fuel per MMBTU and the heat rate by 1 million.

Figure 1. Seasonal Variation of Pollutant Emissions from Jamshoro Company Thermal Power Plants



CO = carbon monoxide, g/m = gram/second, mg/Nm³ = milli grams per cubic meter, NO_x = nitrogen oxide, RFO = residual fuel oil, PM_{10} = particulate matter (diameter 10 micrometer), SO_x = sulfur oxide.
Source: National Electric Power Regulatory Authority (2000). https://nepra.org.pk/licensing/lic_gencos.php.

Table 2.3. Descriptive Statistics

	Installed Capacity (MW)	Unit Generated (GWh)	Gas Consumed (MMBTU)	RFO Consumed (MMBTU)	Cost per Unit (PRs)
Sum	1.32E+04	5.89E+04	3.18E+08	3.17E+08	---
Average	3.89E+02	1.73E+03	9.36E+06	9.31E+06	1.24E+01
Minimum	3.10E+01	7.60E+01	0.00E+00	0.00E+00	3.69E+00
Maximum	1.64E+03	7.80E+03	1.01E+08	7.38E+07	2.53E+01
Std. Deviation	4.33E+02	2.00E+03	1.94E+07	1.70E+07	5.53E+00

GWH = gigawatt hours, MMBTU = million British thermal unit, MW = megawatts, RFO = residual fuel oil, PRs = Pakistan rupees.
Source: Authors' calculations.

The plants covered in this study have more than 13,000 MW of total capacity, or almost two-thirds of the total capacity of the electric utilities in Pakistan, which stood at almost 21,000 MW at the end of 2014. These plants produce almost 59,000 gigawatt hours of electricity as shown in the above table 2.3. The smallest plant included in this study is Altern Energy Limited in Attock, with only 31 MW capacity, and the largest is Kot Addu Power Company Limited (Privatized) with 1,639 MW capacity. The shares of RFO and natural gas in Pakistan's power generation sector are almost equal. The cost per unit in terms of kilowatt hour is 12.34 PRs, but it has a large standard deviation due to differences in fuel prices and technical efficiency. Thermal Power Station Bin Qasim with a capacity of 1,260 MW enjoys the lowest cost per unit at 3.29 PRs, which makes it the most cost-efficient. The Saba Power Company, Sheikhupura, with a plant capacity of 114 MW, has the highest cost per unit, which results in low cost-efficiency.

An output-oriented DEA under a variable-returns-to-scale assumption (Banker, Charnes, and Cooper, 1984) was applied to the data of 34 plants over a 5-year span while keeping electricity units generated as the output and fuel consumption (both natural gas and RFO consumption have been added using MMBTU as unit of analysis), plant capacity and other costs as the inputs to derive the technical efficiency summary, and the Malmquist Index summary.

Table 2.4. Frequency Distribution of Returns

	Increasing Returns to Scale	Constant Returns to Scale	Decreasing Returns to Scale
Gas	6	3	5
Residual fuel oil	2	1	10
Gas and residual fuel oil	5	1	1
Total	13	5	16

Source: Authors' calculations.

Table 2.4 shows that a large majority of thermal plants are working either at increasing returns to scale or decreasing returns to scale. Only five plants are fully efficiently using the scale of the plant. Ten of thirteen thermal plants that use RFO as the prime fuel input overutilize the scale of the plant, which in return requires reducing the scale of the plant to be scale efficient. On the other hand, a significant proportion of the plants using gas or both gas and RFO as fuel inputs operate at increasing returns to scale. This may be because in recent years Pakistan faced severe gas shortages, particularly during the winter season. According to NEPRA, the power generation sector is supplied 133 million cubic feet of gas, while the demand is 372 million cubic feet.

The scores in Table 2.5 indicate that the power sector in Pakistan can increase its production by 20.8% according to constant returns to scale technical efficiency and 12.8% according to variable returns to scale technical efficiency without increasing current resources. The scale efficient point is obtained when a firm or power plant is working at constant returns to scale. Only five plants are fully efficient. Overall, the scale efficiency of the power sector in Pakistan is 0.907. Plants operating on RFO are significantly more efficient than plants operating on natural gas under both the constant-returns-to-scale and variable-returns-to-scale assumptions. The gap between constant returns to scale technical efficiency and variable returns to scale technical efficiency points for the plants using RFO is much smaller than that of the plants running on gas. Hence, plants operating on RFO have the highest scale efficiency score.

Table 2.5. Mean Efficiency Scores

	Constant RSTE	Variable RSTE	Scale Efficiency
Gas	0.76	0.836	0.904
Residual fuel oil	0.856	0.891	0.96
Gas and residual fuel oil	0.736	0.906	0.812
Grand Mean	0.792	0.872	0.907

RSTE = returns to scale technical efficiency, RFO = residual fuel oil.
Source: Authors' calculations.

Table 2.6. Sectoral Mean Efficiency Scores

	Constant RSTE	Variable RSTE	Scale Efficiency
Water and Power Development Authority	0.639	0.845	0.770
Karachi Electric Supply Corporation	0.711	0.802	0.868
Independent power producers	0.862	0.894	0.963

RSTE = returns to scale technical efficiency.
Source: Authors' calculations.

Table 2.6 indicates that independent power producers are most efficient according to both the constant returns to scale and variable returns to scale assumptions. The gap between the mean scores of the constant returns to scale technical efficiency and variable returns to scale technical efficiency is trivial for independent power producers because they all operate at either constant returns to scale or close to that level. In contrast, plants working under the Karachi Electric Supply Corporation and the Water and Power Development Authority operate under increasing returns to scale and have a very low scale efficiency score because of a huge gap between constant returns to scale technical efficiency and variable returns to scale technical efficiency.

2.4. Methodology

There are various techniques to estimate the ecological efficiency of thermal power plants in Pakistan and these can be both parametric and nonparametric (Berger and Humphrey, 1997). DEA and stochastic frontier analysis (SFA) are the two most commonly used approaches to measure the efficiency of DMUs. The former is a nonparametric approach based on linear programming, whereas the latter is a parametric approach requiring a functional form: either a production function or a cost function. DEA is purely deterministic, and the production function is endogenously determined. However, it does not take statistical noise into consideration, thus making it susceptible to noise and measurement error. SFA has the advantage of separating statistical noise from inefficiency. However, it requires assumptions regarding the shape of the production frontier.

The deterministic method has performed relatively better than SFA in panel data analysis, as it has not been possible to use stochastic frontier analysis in a number of simulations. Moreover, the only advantage of SFA over DEA is that it allows measurement error, which can be overcome in DEA by taking averages with respect to time. This means that SFA has, in fact, no advantage over DEA, whereas DEA holds the advantage of being nonparametric (Ruggiero, 2007). Efficiency scores measured by the two approaches have low levels of correlation, whereas technological change scores measured by the two approaches moderately correlate (Odeck, 2007). DEA and SFA methods produce conflicting efficiency scores due to measurement issues, the nature of environmental variables, and other random factors (Katharakis et al., 2014). The bias-corrected DEA estimator proposed by Kneip, Simar, and Wilson (2008) performs best when the efficiency-to-noise variation ratio is large. Furthermore, both DEA and SFA have performed equally well when the efficiency-to-noise variation ratio is equal to one (Badunenko, Henderson, and Kumbhakar, 2012).

DEA and Sample Size

According to Boussafiane, Dyson, and Thanassoulis (1991), the minimum number of DMUs required should be equal to the product of the number of outputs and the number of inputs. Dyson et al. (2001), however, stated that sample size should be at least greater than or equal to twice the product of inputs and outputs. Golany and Roll (1989) recommended that the number of DMUs must be at least twice the sum of inputs and outputs, while Bowlin (1998) argued that the sample size should be at least three times the sum of inputs and outputs. On the one hand, a large sample size increases the probability of capturing high-performance production units that determine the efficient frontier; on the other hand, it may reduce the homogeneity of the dataset (Golany and Roll, 1989). Our study uses a sample size based on all the criteria mentioned above in order to achieve sufficient discriminatory power. Furthermore, we implement bootstrap DEA as per Simar and Wilson (2000) that corrects bias as a result of a small sample size (for an overview of methods, see Sarkis, [2007]).

Malmquist Productivity Index

The TFP change over time can be estimated by using the Malmquist productivity index, which is based on linear programming with the DEA framework. This method has the capability of dealing with multiple inputs and outputs; it associates productivity change with the effects of economies of scale (Hollas, Macleod, and Stansell, 2002). The Malmquist productivity index was presented by Färe, Grosskopf, and Tyteca (1996) as

$$m_0(Y_{t+1},\ X_{t+1},\ X_t,\ Y_t) = \left[\frac{d_0^t(X_{t+1},\ Y_{t+1})}{d_0^t(X_t, Y_t)} \times \frac{d_0^{t+1}(X_{t+1},\ Y_{t+1})}{d_0^{t+1}(X_{t,} Y_t)}\right]^{1/2}$$

The above equation shows the productivity of production point $(Y_{t+1},\ X_{t+1})$ relative to production point $(X_t,\ Y_t)$. If its value is greater than 1, it shows a positive TFP change from the current period (t) to the next period $(t+1)$. The TFP change can be less than, greater than, or equal to 1. If it takes a value equal to 1, then it shows no change in TFP. If it is larger than 1, then it suggests an increase; if less than 1, it postulates a drop in TFP. Per Färe et al. (1992, p. 90–96), “the total factor productivity is the product of technical efficiency change and technological change, whereas technical efficiency change can be further divided into pure efficiency change and scale efficiency change.” Scale efficiency shows whether a firm operates at the peak productive scale size (Bruno and Erbetta, 2014). A scale efficiency score of less than unity indicates that a firm is under- or over-utilizing the scale of the plant. Efficiency that compares DMUs of the same scale is called pure technical efficiency (Farrell, 1957). Technical efficiency refers to the production point that gives maximum output with minimum possible inputs. It is located on the isoquant, or the production frontier. The degree by which the level of production of a DMU or a production unit approaches its maximum level of production is termed technical efficiency (Färe and Lovell, 1978).

Environmental Efficiency and DEA

Since environment degradation has become one of the most pressing issues in human development, the incorporation of environmental factors into efficiency analysis has become a key element of research. In this paper, we include environmental factors into the DEA, as the latter can deal with multiple outputs and does not require a specific function form (Berger and Humphrey, 1997). Färe, Grosskopf, and Tyteca (1996) introduced an activity analysis model and applied it to US electric utilities. Furthermore, they compared that model with the more conventional pollution index of Jeggi and Freedman (1992). The TFP is decomposed into input efficiency, output efficiency, and a pollution index to compute an environmental performance indicator. Korhonen and Luptacik (2004) introduced the concept of eco-efficiency into DEA. Metafrontier DEA was used by Seifert, Cullmann, and Hirschhausen (2016) to estimate the reduction of CO_2 emissions and energy-saving potential. The material balance condition was introduced by Coelli, Lauwers, and Van Huylenbroeck (2007) and later used by Welch and Barnum (2009) to explore the costs and carbon efficiency of US electric utilities.

The introduction of the MBP is relevant, as this approach not only explores the ecological efficiency of thermal plants, but also helps the DMUs to locate the production point that could simultaneously reduce cost and carbon emissions. Furthermore, this method identifies the best combination of fossil fuel inputs where a gap between cost and carbon efficiency is minimized. In this method, carbon efficiency is estimated by treating the CO_2 emission factor for each fuel like a price (Coelli, Lauwers, and Van Huylenbroeck, 2007). It is important to point out that the MBP has not been included in many production and environmental models (Lauwers, 2009). According to Pethig (2003), the absence of MBP methodology from production and environmental policy analysis may lead to incorrect policy advice. An improvement in technical efficiency can simultaneously reduce both cost and emissions. This simultaneous reduction rejects the notion of early environmentally adjusted productivity analysis that emissions reduction is costly (Lauwers, 2009).

According to Coelli, Lauwers, and Van Huylenbroeck (2007), a DMU produces a vector of $m = 1, 2, ..., M$ outputs, $y \in \mathbf{R}_+^M$, using a vector of $k = 1, 2, ..., K$ inputs, $x \in \mathbf{R}_+^M$. The achievable production set, T, is defined as

$$T = \{\langle y, x\rangle \in \mathbf{R}_+^{M+K} | \text{ x can produce y}\}$$

The production technology has been assumed convex and nondecreasing in outputs, nonincreasing in inputs, and shows strong disposability in outputs and inputs. The surplus measure is defined as $z \in \mathbf{R}_+$ calculated using a material balance equation that is a linear function of the output and input vectors (Coelli, Lauwers, and Van Huylenbroeck, 2007). It is defined as

$$z = a'x - b'y$$

where a and b are (K x 1 and M x 1) vectors of known nonnegative constants. The carbon efficiency of a firm equals the ratio of minimum carbon emissions over observed carbon emissions:

$$EE = \mathrm{a}'\mathrm{x}_e / \mathrm{a}'\,\mathrm{x}$$

Environment, or carbon, efficiency is the product of its two components, one of which is attributable to technical efficiency, *TE*, and the other a result of environmental allocative efficiency, *EAE*, where

$$TE = \theta$$

and

$$EAE = \mathrm{a}'\mathrm{x}_e / \mathrm{a}'\,\mathrm{x}_t$$

where *EAE* basically relates to consuming the accurate input mix, given the observed level of carbon content relativities, while *TE* is related to operation on the production frontier. All the efficiency measures can take a value within a range from 0 to 1, with 1 being the maximum efficiency score. *EE* is the environmental, or carbon, efficiency (Coelli, Lauwers, and Van Huylenbroeck, 2007).

Meta-Technology Ratio

Battese, Rao, and O'Donnell (2004) introduced the concept of the meta-technology ratio as the technology gap ratio. It is the ratio of the group frontier technical efficiency score to the metafrontier efficiency score. According to this method, technical efficiency scores are first obtained by applying DEA to the group of DMUs or the firms having the same technology (Zhu and Cook 2007). In our paper, three plant types are defined: (i) plants that use RFO as the only fuel, (ii) plants that use gas as the only fuel, and (iii) plants that use both gas and RFO as their fuel inputs. In the second stage, DEA is applied to the combined data of thermal plants from all the technologies. Since this ratio lies between 0 and 1, the higher the value of the technology gap ratio, the lower the gap with the most efficient technology. To avoid any ambiguity, the concept of the technology gap ratio was renamed as the meta-technology ratio by O'Donnell, Rao, and Battese (2008).

Bootstrapping Data Envelopment Analysis

Bootstrapping in DEA was introduced by Simar and Wilson (1998) and Simar and Wilson

(2000). The properties of DEA bootstrapping are defined by Kneip, Simar, and Wilson (2008).

DEA bootstrapping is performed in three steps. First, a random subsample is drawn from the original sample with replacement, uniformly, and independently. In the second step, DEA estimation is performed on the subsample. Finally, a large number of repetitions is required to obtain bias corrected efficiency scores (Kneip, Simar, and Wilson, 2008).

With the help of DEA bootstrapping, it is possible to draw an inference and calculate the confidence interval. Moreover, the bias in efficiency scores may also be corrected by the DEA bootstrapping approach. The true data-generating process for bootstrapping is defined as

$$\hat{P} = P\,(\hat{T}, \hat{f}\,(x, y))$$

A new data sample (pseudo sample) is defined as

$$X_n^* = \{(x_i^*, y_i^*), i = 1, \ldots, n\}$$

The above-mentioned sample can be drawn from the data-generating process $\hat{P} = P\,(\hat{T}, \hat{f}\,(x, y))$. The true world $\hat{\theta}_{DEA}$ is an estimate of the unkown θ based on X_n, whereas in the bootstrap world $\hat{\theta}_{DEA}^*$ is an estimator for $\hat{\theta}_{DEA}$ based on X_n^*:

$$\widehat{(\theta_{DEA}^*} - \hat{\theta}_{DEA})|\, \hat{P} \sim \left(\hat{\theta}_{DEA} - \theta\right)|\, P$$

Normal efficiency scores are upward biased. Therefore, bootstrapping efficiency scores are always less than normal efficiency scores. The bias is defined as

$$BIAS\left(\hat{\theta}_{DEA}(x, y)\right) \equiv E\left(\hat{\theta}_{DEA}(x, y)\right) - \theta(x, y)$$

The (1-α) percent confidence interval for bootstrap DEA efficiency scores given by Simar and Wilson (2000) is

$$\hat{\theta}_{DEA}(x_0, y_0) + \hat{a}_\alpha \leq \theta(x_0, y_0) \leq \hat{\theta}_{DEA}(x_0, y_0) + \hat{b}_\alpha$$

2.5. Results

Malmquist Data Envelopment Analysis

As the results in Table 2.6 indicate, TFP increased by almost 64% in 2011, mainly because of a sharp improvement in technology of about 87% and despite a fall of about 13% in technical efficiency. Technical efficiency improved by 21% in the next year, predominantly because of an improvement in scale efficiency and marginally because of an improvement in pure efficiency. TFP and efficiency remained unchanged in 2013. On average, an increase of 3.9% in technical efficiency was recorded every year in the given period. TFP increased by almost 12% on average each year, largely because of an annual improvement in technology of 7.9%.

Table 2.7. Annual Malmquist Index Summary

Year	Efficiency Change	Technological Change	Pure Efficiency Change	Scale Efficiency Change	TFP Change
2011	0.877	1.874	1.003	0.874	1.643
2012	1.213	0.817	1.06	1.145	0.991
2013	1.006	0.971	0.995	1.011	0.977
2014	1.088	0.911	1.004	1.084	0.992
Mean Gas	1.055	1.074	1.031	1.023	1.136
Mean RFO	1.018	1.076	1.011	1.008	1.096
Mean Gas and RFO	1.055	1.105	0.998	1.057	1.170
Mean	1.039	1.079	1.015	1.023	1.121

RFO = residual fuel oil, TFP = total factor productivity.
Source: Authors' calculations.

As table 2.7 suggests, plants operating on RFO enhanced their TFP by more than 9%, mainly attributable to a more than 7% improvement in technology. The efficiency change in plants running on RFO is negligible on average. Plants operating on gas showed an increase of more than 13% in their TFP because of improvements of more than 5% and 7% in efficiency and technology, respectively. Plant level results are given in Appendix Table B1.

Material Balance Condition

A cost DEA was implemented on a dataset of 5-year averages, keeping electricity units generated in gigawatt hours as the output and gas and RFO consumption in MMBTU as the two inputs. Annual averages of the variables were taken, thus helping to minimize the measurement error (Ruggiero, 2007). The cost DEA was run in two different ways: first, with the isocost line and by using average prices of gas and RFO; second, with the isocarbon line and by using the CO_2 emission factor for the fuels. The material balance approach was implemented in four steps. First, technically efficient inputs were estimated by multiplying actual quantity of inputs by the value of technical efficiency. Second, the cost DEA was run using the prices of each fuel. Third, carbon efficiency was estimated using the CO_2 emission factor of each fuel. Finally, the technically efficient inputs were multiplied by the prices and CO_2 emission factors to estimate how much the respective costs and carbon emissions could be reduced by transitioning toward the technically efficient point.

As Table 2.8 shows, the power sector in Pakistan that produces power from fossil fuels is highly cost- and carbon-inefficient. The cost-efficient point can be reached by using almost 60% less fuel inputs, whereas the carbon efficient point could be obtained by consuming almost 48% less fuel inputs. In Pakistan, gas is also cheaper than RFO because it is exploited from within the country, whereas RFO is by and large imported from Gulf countries. At the same time, gas also has a lower CO_2 factor than RFO, thus there is no trade-off between cost and carbon efficiency. The carbon-efficient point can be reached by using cost-minimizing inputs as revealed by the results of DEA. There is a certain necessity to switch to the technology that uses gas as the prime input. In any case, the cost- and carbon-efficient points can even be reached by plants using RFO as the only input, as demonstrated by Plant 13 in Appendix Table B2.1. Plants 8, 12, and 13 are the only super-efficient plants that are simultaneously cost- and carbon-efficient as indicated in Table B2.1.

Table 2.8. Cost and Carbon Efficiency with Variable Returns to Scale Assumption

Plant	Cost DEA with Price Specification			Efficiency Scores with Isocarbon Line		
	Technical Efficiency	Allocative Efficiency	Cost Efficiency	Technical Efficiency	Allocative Efficiency	Carbon Efficiency
Mean	0.728	0.591	0.393	0.728	0.748	0.520

DEA = data envelopment analysis.
Source: Authors' calculations.

Table 2.9. Mean Cost and Carbon Efficiency for Each Fuel

Fuel type	Technical Efficiency	Allocative Efficiency	Cost Efficiency	Technical Efficiency	Allocative Efficiency	Carbon Efficiency
Gas	0.621	1.000	0.621	0.621	1.000	0.621
RFO	0.885	0.280	0.256	0.885	0.552	0.496
Gas and RFO	0.650	0.349	0.191	0.650	0.607	0.366

RFO = residual fuel oil.
Source: Authors' calculations.

Plants using gas as the only input have low cost and carbon efficiency owing to low technical efficiency despite being allocatively efficient, whereas plants using RFO as their prime input have low cost and carbon efficiency because of their low allocative efficiency. In Table B2.1, Plant 13 is the only plant using RFO as the only fuel input, but it is completely allocatively efficient and sets an example that a thermal plant operating on RFO can be cost- and carbon-efficient at the same time.

Table 2.10. Comparison of Technically Efficient and Original Production Technology

	Original	Technically Efficient	Percentage Change (%)
Gas Consumption	3.18E+08	1.24E+08	–61.2
RFO Consumption	3.17E+08	2.66E+08	–16.1
Fuel Consumption	6.35E+08	3.89E+08	–38.7
Average Heat Rate	1.16E+04	7.45E+03	–36.0
Fuel Cost	6.15E+11	4.54E+11	–26.2
CO_2 Emissions	2.59E+07	1.74E+07	–32.8
Cost Efficiency	3.90E–01	5.90E–01	50.4
Carbon Efficiency	5.20E–01	7.50E–01	43.9

CO_2 = carbon dioxide, RFO = residual fuel oil.
Source: Authors' calculations.

Technically efficient inputs and output were obtained by implementing a single-stage DEA on the data with electricity production as the output and natural gas and RFO consumption as inputs. The target output is almost the same as the actual output due to using an input-oriented DEA, which minimizes the cost (or level) of inputs at given outputs. Achieving cost- and carbon-efficient points in Pakistan is highly difficult because it requires an almost complete switch to power production entailing the use of gas as the only fuel. Since Pakistan faced a severe gas shortage in recent years that almost shut down the CNG industry and severely affected the industrial, household, and commercial sectors, switching the technology to gas will be a challenging task in the short run. Moreover, switching to gas may also require modifications in plant design. Nevertheless, even without changing the production technology, plants can still reduce a significant amount of their costs and carbon emissions, and increase their cost and carbon efficiency, as shown in Table 2.9.

As the results in Table 2.10 show, about 61% less natural gas can be conserved by achieving a technically efficient point, which may be used in other sectors. Furthermore, about 16% of RFO consumption can be reduced. Almost 39% of fuel consumption can be cut and approximately 36% of the heat rate can be reduced. Fuel costs can be cut about 26%, which would ultimately lead to a significant fall in electricity prices. Most interestingly, carbon emissions can be reduced by about 33%, which would be a boon to the environment. Table 2.10 also shows that cost and carbon efficiency can be boosted by significant proportions as well. Plant level results are reported in Appendix Table B2.2.

Group and Metafrontier Data Envelopment Analysis

In this section, overall eco-efficiency is explored by keeping electricity produced and CO_2 emissions as the outputs, while fuel consumption, plant capacity, and the other costs are the inputs. Efficiency scores were obtained in two different ways: first, by applying an input-oriented DEA, named metafrontier DEA, to all 34 plants; second, by applying a group frontier DEA, which is also an input-oriented DEA, to three different types of plants (gas, RFO, and gas and RFO) separately. Meta-technology ratios were obtained by dividing the metafrontier efficiency scores by the group frontier efficiency scores.

By and large, Table 2.11 shows a similar pattern of the returns as discussed in the section I.

Table 2.11. Returns under Metafrontier Data Envelopment Analysis

	Increasing Returns to Scale	Constant Returns to Scale	Decreasing Returns to Scale
Gas	6	3	5
Residual fuel oil	2	2	9
Gas and residual fuel oil	6	1	0
Total	14	6	14

Source: Authors' calculations.

Table 2.12. Results of Metafrontier and Group Frontier Data Envelopment Analysis

Fuel Type	Metafrontier DEA			Group Frontier DEA		
	Constant RSTE	Variable RSTE	Scale Efficiency	Constant RSTE	Variable RSTE	Scale Efficiency
Gas	0.807	0.862	0.930	0.929	0.965	0.961
RFO	0.857	0.894	0.957	0.990	0.997	0.993
Gas and RFO	0.753	0.949	0.798	0.898	0.949	0.945
Grand Mean	0.815	0.892	0.913			

DEA = data envelopment analysis, RFO = residual fuel oil, RSTE = returns to scale technical efficiency.
Source: Authors' calculations.

Similar to the results of output-oriented DEA, the metafrontier results shown in Table 2.12 reveal that plants operating on RFO are more efficient, with an efficiency score of 0.85. However, the gap between the mean efficiency of plants operating on RFO and gas is narrowed due to the higher CO_2 factor of RFO. The group frontier DEA of the RFO plants also provides interesting results because the efficiency of RFO again appears to be the highest.

Table 2.13. Metafrontier Technology Ratio

	Constant RSTE	Variable RSTE	Scale Efficiency
Gas	0.869	0.893	0.967
Residual fuel oil	0.866	0.896	0.964
Gas and residual fuel oil	0.839	1.000	0.845

RSTE = constant returns to scale technical efficiency.
Source: Authors' calculations.

Although plants operating on RFO tend to be more efficient, Table 2.13 shows that the metafrontier technology ratio for both plant types is similar, which implies that they both have a significant share in the metafrontier.

Table 2.14. Bootstrapping Data Envelopment Analysis Results

Type of Sampling	Scale Assumption	M	B	Mean TE	CIL	CIU	TEBC	Bias	Specific-ation
With Replacement	CRS	170	2000	0.6547	0.5958	0.6547	0.6341	0.0206	1 output 3 inputs
Without Replacement	CRS	100	2000	0.6547	0.5743	0.6547	0.6362	0.0202	1 output 3 inputs
With Replacement	VRS	170	2000	0.7788	0.6967	0.7788	0.7582	0.0206	1 output 3 inputs
Without Replacement	VRS	100	2000	0.7788	0.6708	0.7788	0.7577	0.0211	1 output 3 inputs
With Replacement	CRS	34	2000	0.5612	0.4521	0.5612	0.4870	0.0742	1 output 2 inputs
Without Replacement	CRS	25	2000	0.5612	0.4454	0.5612	0.5169	0.0443	1 output 2 inputs

B = number of bootstrap replications, CIL = lower confidence interval, CIU = upper confidence interval, CRS = constant returns to scale, M = sample size, VRS = variable returns to scale, TEBC = bias-corrected technical efficiency.
Source: Authors' calculations

Table 2.14 reports the results of bootstrapping. A total of 2,000 bootstrap replications were performed in each case. In the case of 1 output (electricity generation) and 3 inputs (fuel consumption, plant capacity, and miscellaneous cost), where the replications are performed on panel data containing 170 observations, the bias is slightly above 2%, which suggests that bias-corrected technical efficiency scores are about 2% less than the scores calculated without bootstrapping. However, for 1 output (electricity generation) and 2 inputs (gas and RFO consumption), where the replications are performed on annual averages containing 34 observations, the bias is 4.4% and 7.4% for without replacement and with replacement sampling, respectively.

2.6. Conclusions and Policy Implications

In this paper, we apply various methods of DEA. In Pakistan, natural gas is an ideal fuel to achieve the goal of cost- and carbon-minimization simultaneously. However, both carbon and cost efficiency can also be achieved by using RFO as the only input combined with best practices and optimal use of the plant under the assumption of variable returns to scale. The plants running on RFO are technically more efficient than the plants operating on gas. Hence, there is a need to reduce the price of RFO to make RFO plants more cost-efficient. Second, it is imperative to import gas either through a pipeline or in the form of liquid petroleum gas so that the plants can obtain an uninterrupted supply of gas and can make better and more efficient use of the plant's scale. Since plants in Pakistan are highly technically inefficient, there is a need to overhaul these plants to improve their technical efficiency so that they can reduce both costs and CO_2 emissions. According to the NEPRA *State of Industry* reports, overhauls must be carried out every 5 years, whereas in Pakistan the overhauling of most of the plants has been delayed by more than a decade.

Pollutant emissions can be reduced significantly by burning low-sulfur coal, using PM emission control devices and fluidized-bed combustion technology to control SO_2 emissions, and introducing low-NO_x burners during the combustion phase (EIA, 2018). More research can be done toward identifying pollutant efficiency as well as the effectiveness of pollution control policies and technologies. Since thermal power plants in Pakistan are highly technically inefficient, producing at technically efficient points on the isoquant can simultaneously reduce both costs and carbon emissions significantly. A reduction in carbon emissions can generate positive externalities in relation to a cleaner environment and a better climate, while significant cost reductions will result in lower electricity tariffs and a less import dependence for Pakistan's economy. Reducing electricity tariffs can have further positive effects on consumer welfare and industrial growth by lowering the cost of doing business.

Essay 3

Determinants of Sustainable Energy Transition: Evidence from South Asia

Abstract:

Over the years, governments of South Asia have faced the challenge of achieving the goal of sustainable development. On the one hand, they must satisfy the ever-growing demand for energy and, on the other hand, the interminable deterioration of the environment is causing great concern among political economists. The widening gap between the demand and supply of energy, over-reliance on the use of fossil fuels, and increasing import bills due to rising global prices are the challenges that South Asia is facing. These can be overcome by using its great potential in renewables. Empirical results based on panel and time series methodologies suggest that poor economic growth and depreciating exchange rates are the most crucial impediments to the development of the renewable energy sector in South Asia. Furthermore, this paper uses SWOT methodology to identify that the poor financial situation of the distribution companies, due to power losses and non-cost-reflective tariffs, and the lack of credit opportunities, due to high interest rates and inaccessibility of loans for the long-term, are the major impediments to the growth of the renewable energy sector of the region. Moreover, there is a conflict of interest between the manufacturers of renewable energy equipment and the developers of renewable energy projects in terms of government policy concerning the imposition of import duties. India is moving towards protection of the former, while the latter see opportunities in the renewable energy sector of Pakistan.

Keywords: Sustainable energy, energy transition, South Asia
JEL Codes: Q42; Q43

3.1. Introduction

South Asia, which makes up one-fifth of the world's population, is one of the most vulnerable regions in the world to climate change. Pakistan, despite making a negligible contribution to global GHG emissions, is one of the most susceptible countries in the world to climate change (Government of Pakistan, 2012). Natural disasters due to climate change caused a loss of 149 billion US Dollars to the economy of South Asia between 2000 and 2017 (Fallesen et al., 2019). According to the World Bank report, 62 million people in South Asia may fall below the poverty line due to climate change by 2020. In the last decade, Pakistan has faced many floods and unexpected weather events that have affected the agriculture of the country. India on the other hand is also suffering badly due to the increase in environment pollution. According to the report of the International Renewable Energy Agency (Gielen et al., 2017), Indian GDP suffers a loss of 3% every year due to the health impacts of ambient air pollution. Environment degradation was the cause of 700,000 deaths in India during 2010 according to a WHO report (Gielen et al., 2017). Energy demand in the region is growing rapidly due to economic growth in recent years. This increase in energy demand can be met by the immense renewable energy resources that this region is blessed with. Most of the area has intense sunshine for most of the year. Moreover, most of the countries in this region have coastal areas, which is advantageous for wind energy. The economy of South Asia relies heavily on livestock and agriculture. Therefore, this sector can provide substantial waste for biomass energy production. Moreover, the whole of South Asia is highly favorable for both small- and large-scale hydropower. However, these countries have not been able to make the best use of their renewable energy potential. Although hydropower has a substantial share in the total energy mix, especially in Nepal, Pakistan, Afghanistan, and India, this is declining. The share of other renewable energy resources in the total energy mix is not worth mentioning. Nevertheless, rigorous efforts have been taken in recent years to make the energy transition to sustainable resources, especially in India, Pakistan, and Sri Lanka. According to the report of the Renewable Energy Country Attractiveness Index[1] (RECAI, 2019), India is the third most attractive country in the world, while Pakistan stands 36th on this list. Sri Lanka is one of the forty-three countries in the Climate Vulnerable Forum that have agreed to a 100% switch in power generation to renewables by 2050. Pakistan and India are making massive progress in the sustainable energy sector. However, other South Asian countries still lag behind and have not been successful in making use of their alternative and renewable energy potentials. There are several challenges that the countries of South Asia are coping with, with these challenges being of both an internal and external nature. One of the objectives of this study is to underline these challenges with possible solutions using both

[1] The Renewable Energy Country Attractiveness Index is measured on the basis of various parameters related to natural resource potential, power transmission and the distribution network and its capacity to connect with the renewable energy projects, political support, economic stability, decarbonization, and political stability, etc.

qualitative and quantitative data.

Furthermore, various policies initiated by the governments of these countries for the development of the renewable energy sector are critically examined. The state of the renewable energy sector of the different South Asian countries is compared while evaluating both internal and external factors. This study aims to identify the determinants of sustainable energy growth in South Asia at the macro-level with the application of an econometric model on the dynamic empirical data. Moreover, this study also analyzes the internal and the external environment of the renewable energy sector of Pakistan, India, Sri Lanka, and Bangladesh with the help of SWOT methodology to explore such factors that are key drivers of or impediments to the adoption of renewable energy at both the micro- and macro-levels.

3.2. Literature Review

There are various researchers that have explored the determinants of renewable energy consumption and production at the macro-level with the application of different econometric methodologies. By using the PMG ARDL model, Silva et al. (2018) concluded that GDP per capita was the only positive determinant of growth in the renewable energy sector of Sub-Saharan Africa, whereas imports, growth in population, price of fossil fuels, and CO2 emissions were negatively associated with the adoption of renewable energy. Rafiq and Allam (2010) analyzed the drivers of renewable energy consumption in emerging economies with the help of dynamic least squares, fully modified OLS for the panel data and the autoregressive distributed lag approach for time series data. The level of emissions and pollutants were found to be the main shifters of renewable energy consumption in China, India, Brazil, and Indonesia. However, income was the only determinant of renewable energy consumption in the Philippines and Turkey. This study also confirmed the bidirectional causality between renewable energy consumption and income, on the one hand, and between renewable energy consumption and pollutants, on the other (ibid). On the basis of panel data from the BRICS countries, Aguirre and Ibikunle (2014) argued that environment degradation was a key factor behind growth in the renewable energy sector, whereas energy security was not a significant driver of renewable energy growth due to the fact that these countries preferred fossil fuels over renewable energy to ensure energy supply because of their cost advantage.[2] Mehrara et al. (2015) explored the determinants of renewable energy with the

[2] BRICS: Brazil, Russia, India, China, and South Africa.

implementation of weighted-average least squares and Bayesian model averaging.
The share of the urban population, government effectiveness, school enrollment, political instability, and violence were the key determinants of renewable energy consumption in the countries of the Economic Cooperation Organization (ECO). Corruption was found to be negatively associated with renewable energy consumption since the firms could enjoy the rent-seeking activities to reduce the initial cost (ibid). According to Papiez et al. (2018), the presence of abundant domestic fossil fuels was the most significant factor in EU countries behind poor growth in the renewable energy sector. GDP per capita, the cost of fossil fuels, and energy concentration were other significant determinants of renewable energy development.

Coal prices, oil prices, carbon emissions, and GDP per capita were found to be key determining factors for renewable energy consumption in the study conducted by Apergis and Payne (2014) using the vector error correction model on Central American countries.

There are various factors that influence the adoption of renewable energy policies, according to a study by Stadelmann and Castro (2014). Domestic energy security reduced the probability of the adoption of financial incentives schemes for the renewable energy sector. Countries with a higher income level had a higher probability of adopting those policies, such as feed-in tariff and economic incentives that were not economically feasible for low-income countries. Stronger democracies also have a positive influence on the adoption of such policies (ibid). According to Lao et al. (2018), economic growth and Foreign Direct Investment (FDI) were the positive determinants, while trade openness was a negative determinant, of renewable energy consumption in Malaysia. Several researchers over the years have used the SWOT methodology to identify the strengths and weaknesses of the internal environment and the opportunities and threats of the external environment of the renewable energy sector. Shi (2015) highlighted the strengths, weaknesses, opportunities, and threats of green energy policies in the ASEAN countries. The major strength of green energy in this region was that it had great potential in terms of low-carbon energy resources, especially hydroelectricity. Abundant supplies of the fossil fuel resources oil, gas, and coal in the ASEAN countries and the lack of interest of the ASEAN governments in renewable energy resources contributed negatively to the growth of renewable energy resources. Fast growing demand for energy due to rapid economic growth in the region was an opportunity for the renewable energy sector to grow faster to overcome the demand-supply gap and to reduce the oil import bill in the oil deficient countries. However, fragmented energy networks and markets, lack of cooperation and energy trade among ASEAN countries and subsidies on the fossil fuels were threats to the renewable energy sector (ibid). Fertel et al. (2013) revealed inconsistent federal and provincial strategies, the lack of coordination between provincial and federal energy and environmental policies, and the absence of long-term policy for sustainable resource management in Canada. Resource exploitation was conducted by private companies. Therefore, market forces of production and price were the decision variables. Federal and provincial regulations and social acceptability were the constraints in adopting an integrated policy. Markovska (2009) used a SWOT analysis to analyze the present situation and future course of action towards sustainable energy in Macedonia. The advantageous geo-strategic position of Macedonia in the region, potential for renewables, and espousal of EU energy policy and EU standards were the strengths of the Macedonian energy situation. The important weaknesses of the energy sector in the country were identified as the increasing demand for imported oil and gas, over-reliance on electricity produced from highly polluting lignite, under-valued and stagnant electricity prices, energy intensive industry, inferior insulation both in residential as well as in commercial sectors, inefficient technology in the industrial sector, and lacking institutional and human capacity in the ministries. The platform of the European common energy market and Clean Development Mechanism (CDM) provided the potential to attract foreign investment in the renewable energy sector (ibid). Chen et al. (2014) analyzed the state of renewables in Japan, Taiwan, and South Korea using the SWOT method. They identified the strengths of the renewable energy sector as being, in Japan, the highly advanced manufacturing industry of geothermal turbine and solar PV modules with a significant share of the world's renewable energy patents; in South Korea, the ample potential of renewable energy and the potential synergy of renewable energy industry with the advanced industries of information technology, auto manufacturing, and ship building; and finally, in Taiwan, the great potential of renewable energy, one of the most well-recognized solar PV industries in the world, and a comprehensive legal framework. The following were documented as the weaknesses of the renewable energy sector: in Japan, the lack of competition in the electricity market and monopolistic behavior of the electric utilities; in South Korea, low electricity prices and the dependence on the import of most renewable technologies; and, in Taiwan, a lack of land for renewable energy projects, of long-term government energy mix goals, and of interest of Taiwan PV manufacturing companies in the domestic market. Deregulation of the energy market in Japan, the provision of finance for domestic technologies and free trade agreement with the European Union in South Korea and increasing cooperation between China and Taiwan were identified as the major opportunities. The major threat for the renewables were listed as, in Japan, the revival of nuclear energy as a result of high electricity prices and the emergence of more cost effective companies than local Japanese companies in the global market; and in Taiwan, competition in the domestic renewable energy market as result of free trade with the EU, and over-reliance on nuclear and fossil fuels for the provision of stable electricity to industry (ibid). Jaber et al. (2015) used a SWOT analysis to analyze the development of renewable energy in Jordan and identified the politically stable environment, strong legal framework, availability of sufficient wind and solar resources, the regional hub, and the open market for private investment as the strengths. Lack of knowledge of renewable technologies, the high initial cost of renewable projects in comparison with conventional technologies, and lack of finance for renewable projects were seen as the major obstacles. The most important opportunities were considered to be the power connection with Syria and Egypt with the prospect of connecting with six more countries, the investment friendly environment, and good national relationships with the donor countries that produce renewable technologies, and a possible reduction in the fiscal and trade deficit due to cuts in the import of fossil fuels. Finally, the threats for this sector in Jordan consisted of the over-reliance on foreign funding, the unstable security and political situation in the region, the involvement of many government institutes in the approval of renewable projects, and the absence of fairness in official procedures. Graser (2012) studied the renewable energy sector of Kleinregion Tullnerfeld-West, a region in the central south of Austria, and identified the strong economy, advantageous demographic development (fastest in the country), intercommunal collaboration, the development of diverse forms of biogas, high acceptance of solar PV together with its installation rate, and the presence of private financing as the strong points of the region for the development of renewable energy sector. The tight communal budget situation, the low rate of public acceptance of wind energy, the low level of subsidies, and the high level of installation costs of renewable energy projects were identified as impediments to the development of the renewable energy sector in the region. While the vision and the goals regarding renewable energy technologies of higher level administration and the subsidies for biogas were identified as the opportunities for this sector, lack of harmonization among regions and prolonged and illogical licensing procedures for small water and wind plants were established as the threats (ibid). Shakeel et al. (2014) evaluated the energy sector of Pakistan by means of SWOT methodology and highlighted that great potential of renewables and substantial domestic reserves of coal as the strengths of the energy sector of the country. Incompetent administration of the public institutions, ineffective and underutilization of domestic resources, and transmission, distribution and network losses were identified as the shortcomings of the energy sector. The development of a smart grid was seen as an opportunity, whereas the high cost of power generation and over-reliance on imported fuels were the major threats for the energy sector.

3.3. Data and Methodology Data

The SWOT analysis was conducted by reviewing various studies, including research papers, institutional reports, and articles on the state of sustainable energy in Pakistan. Furthermore, personal observation based on the critical review of the sustainable energy sector by various news articles and studies is also part of the analysis and the recommendations.

Table 3.1. Descriptive Analysis

Country		*Mean*	*Median*	*Maximum*	*Minimum*	*Std. Dev.*
Pakistan	***Renewable energy (Generation in TWh)***	21.90520	21.50480	41.51067	5.316538	9.496862
	Real GDP per capita ($)	815.9648	808.2078	1197.843	490.5628	187.8832
	Exchange rate (LCU/$)	47.58159	41.11153	121.8241	9.900000	33.87009
	Political globalization (Index 0-100)	73.14500	78.60000	85.55000	55.49000	11.86195
India	***Renewable energy (Generation in TWh)***	100.1268	74.62937	261.1701	41.49817	57.82011
	Real GDP per capita ($)	896.5475	727.0432	2100.801	404.2351	480.9073
	Exchange rate (LCU/$)	33.76005	36.31329	68.38947	7.862945	19.44087
	Political globalization (Index 0-100)	78.47786	82.25000	92.96000	63.40000	11.78426
Bangladesh	***Renewable energy (Generation in TWh)***	0.761474	0.750900	1.307640	0.372000	0.207937
	Real GDP per capita ($)	575.3853	481.1225	1203.216	343.9482	236.3738
	Exchange rate (LCU/$)	47.83895	43.89212	83.46620	15.01612	22.22648
	Political globalization (Index 0-100)	60.35310	66.88500	75.11000	34.95000	14.04776
Sri Lanka	***Renewable energy (Generation in TWh)***	3.404599	3.251900	7.204596	1.109500	1.501261
	Real GDP per capita ($)	1876.514	1602.936	3936.450	780.1846	964.7080
	Exchange rate (LCU/$)	70.59084	58.99461	162.4649	8.412000	45.42281
	Political globalization (Index 0-100)	61.70024	56.32500	78.12000	45.21000	12.06691
Average	***Renewable energy (Generation in TWh)***	31.54951	6.711447	261.1701	0.372	49.87357
	Real GDP per capita ($)	1041.103	822.7885	3936.45	343.9482	745.5331
	Exchange rate (LCU/$)	49.94286	43.86087	162.4649	7.862945	34.32589
	Political globalization (Index 0-100)	68.41905	69.83	92.96	34.95	14.54697
	International oil prices ($)	40.48837	28.78	111.67	12.72	29.53776

TWh = terawatt-hours, LCU = local currency unit

Panel data for the empirical analysis was taken from different sources. Data on real

GDP per capita and the exchange rate were taken from World Development Indicators (WDI) of the World Bank. Data on renewable energy and international oil prices were taken from the Statistical Review of World Energy. Data on political globalization was taken from the Global Economy website.

Pakistan, India, Sri Lanka, and Bangladesh were selected for the analysis. Nepal, due to its almost 100% share of hydropower, the Maldives, Bhutan, and Afghanistan, due to insufficient data, were dropped from the analysis. India leads South Asia in renewable energy production, followed by Pakistan and Sri Lanka. Sri Lanka has the highest GDP per capita in the region with an income of almost 4000 US Dollars, followed by India. India has the strongest democracy in the region; thus, it has the highest value of political globalization. Pakistan has the second highest value of political globalization. Apart from India, all the other selected South Asian countries have experienced political instability over the years. Bangladesh has the highest volatility of political globalization followed by Sri Lanka, as is reflected in the respective figures for the standard deviation. Sri Lanka's exchange rate is the most volatile in the region followed by that of Pakistan.

SWOT Methodology

The SWOT methodology is widely used to evaluate any project, policy, business, or plan. It helps to identify the strengths, weaknesses, opportunities, and threats associated with a project or business. The weaknesses and strengths of an organization are evaluated by assessing its resources and capabilities, whereas examining the environment of the organization identifies its opportunities and threats (Stacey, 1993). The strengths and weaknesses are related to the internal environment of a project or business, whereas opportunities and threats concern its external environment (Dyson, 2004).

The SWOT methodology has been proposed by Shi (2016) and Chen et al. (2014) for the analysis of the renewable energy sector. The strengths and weaknesses are identified by examining the present internal state of the renewable energy sector of each country. The strengths are related to the potentials, technical advancement, and the financial strengths of the sector. The weaknesses are related to infrastructure, cost of doing business, financial liquidity of the distribution companies, tariff structure and cost and availability of debt, etc. Opportunities and threats are identified by analyzing the external environment of the renewable energy sector. Opportunities are concerned with government schemes/policies, green financing, and international trade, etc., while threats are associated with the political environment, the energy supply, macroeconomic stability, the presence of fossil fuel reserves and the international scenario. Some of the factors at the macro-level identified in the SWOT analysis are analyzed with the application of the following econometric models to explore the impact of macro-level variables on the adoption of renewable energy.

Unit Root Tests

Augmented Dickey-Fuller (ADF) Test

The augmented Dickey-Fuller (ADF) test an extension of the Dickey-Fuller test proposed by Dickey and Fuller (1979) with the introduction of lags of the dependent variable to overcome the problem of the autocorrelation.

Null hypothesis: the variable has the unit root, or the variable is not stationary, or $\sigma = 0$.

Alternative hypothesis: the variable does not have the unit root, or the variable is stationary, or $\sigma < 0$

It consists of the following three equations:

$$\Delta Y_t = \sigma(Y_{t-1}) + \sum_{j=0}^{p} \left(\gamma_j \Delta Y_{t-j}\right) + \mu_t$$

$$\Delta Y_t = \alpha + \sigma(Y_{t-1}) + \sum_{j=0}^{p} \left(\gamma_j \Delta Y_{t-j}\right) + \mu_t$$

$$\Delta Y_t = \alpha + \beta t + \sigma(Y_{t-1}) + \sum_{j=0}^{p} \left(\gamma_j \Delta Y_{t-j}\right) + \mu_t$$

T-statistics of the value of σ are compared with ADF critical values proposed by Engle and Yoo (1987) using a one-tailed test.

Panel Unit Root Test

Three different panel unit root tests are conducted in this paper. These are the LLC test of Levin, Lin, and Chu (2002), the IPS test of Im, Pesaran and Shin (2003) test, and the ADF Fisher Chi Square test of Maddala and WU (1999).

The LLC test assumes a common unit root for all the cross sections. It uses the following equation:

$$\Delta Y_{i,t} = \rho_i Y_{i,t-1} + \sum_{L=1}^{p_i} \theta_{iL} \Delta Y_{it-L} + \alpha_{mi} d_{mt} + \varepsilon_{it}$$

The IPS test and the Fisher ADF test assume an individual unit root that may change in each cross section. The IPS test uses the following equation:

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{i,t-j} + \varepsilon_{it}$$

The IPS test takes the average of the t-statistics from the above equation using the following formula:

$$\bar{t}_{NT} = \frac{1}{N} \sum_{i=1}^{N} t_{iT}(p_i \beta_i)$$

The Fisher ADF test combines the p-values from individual ADF test statistics for each cross section such that it follows the Chi square distribution:

$$\gamma = -2 \sum_{i=1}^{N} \log(\pi_i) \rightarrow \chi^2_{2N}$$

ARDL Model

The autoregressive distributed lag (ARDL) model was developed by Pesaran and Shin (1995) and Pesaran (2001). This test allows the variables to be used even if they are integrated of different order.It takes the following form:

$$\Delta Y_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta x_{t-i} + \varphi_1 y_{t-1} + \varphi_2 x_{t-1} + \mu_t$$

Pooled Mean Group ARDL

Pesaran, Shin, and Smith (1999) introduced the pooled mean group method of autoregressive distributed lag, which restricts the long-run coefficients to be similar across all groups but differentiates the short-run relationship across all cross-sectional entities. In this model, the β_i are the long-run parameters and θ_i are the equilibrium error correction coefficients.

$$\Delta y_{it} = \theta_i \left(y_{i,t-1} - \beta'^{x_{i,t-1}} \right) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=1}^{q-1} \gamma'_{ij} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it}$$

3.4. Results and Discussion SWOT Analysis

This section discusses the strengths, weaknesses, opportunities, and threats associated with the development of sustainable energy in Pakistan, India, Sri Lanka, and Bangladesh.

SWOT Analysis of the Renewable Energy Sector of Pakistan

A summary of the SWOT analysis of the renewable energy sector of Pakistan is given in Table 3.2.

Strengths of Sustainable Energy in Pakistan

The Government of Pakistan, under its 2019 renewable energy policy, set an ambitious target to increase the share of the renewables in the total power generation to 60%. Half of this 60% is targeted at hydropower, whereas the other half is targeted at alternative energy resources, such as solar energy, wind, and biomass. Pakistan has an enormous potential for renewables. Most of the country is highly suitable for the production of solar energy. According to Farooq and Kumar (2013), the potential of power generation from solar energy was estimated to be 149 GW in 2010, which may increase to 169 GW in 2050. The coastal area of the Sindh and Baluchistan provinces is highly conducive for wind energy. Studies by Farooqui (2014) and Baloch et al. (2016) state that Pakistan has the potential to produce 346 GW of electricity from wind energy, of which 120 GW is actually feasible. The northern part of the country has a great potential for hydroelectric power that can be obtained from both micro- and macro-hydroelectric plants. Ghafoor et al. (2016) state that the potential of power generation from small hydropower and micro-hydropower plants is possible in excess of 1200 MW, whereas 30000 to 50000 MW of electricity generation is possible from large-scale hydropower plants. Pakistan also has great potential in biomass. Possible generation from biomass energy is estimated to be 5 GW, which could be increased to 15 GW in 2050 (Farooq and Kumar, 2013). The sugar cane industry alone has the potential to add 3000 MW of electricity to the grid (Kamran, 2018). Biogas produced from crop residues and animal dung can be used to produce 2700 MW of electricity (Ghafoor, 2016). Moreover, solid and kitchen waste and biofuel have enormous potential for the generation of power.

There are various bodies working in the government sector for the development and promotion of renewable energy technologies in the country. The Pakistan Council for Renewable Energy Technologies (PCRET) was established in 2001 to promote these technologies and coordinate research and development activities with the merger of the Pakistan Council of Appropriate Technologies and the National Institute of Silicon Technologies. PCRET has designed various types of solar dryers based on solar tunnel technology and greenhouse technology, ten hybrid unglazed collectors based on biomass and solar technology for drying dates, solar cookers, solar lights and torches, solar mobile chargers, solar fountains, etc. PCRET has also installed 560 micro-hydropower plants with a collective capacity of 9.8 MW to electrify 80000 houses in Pakistan (PCRET, 2019). PCRET has electrified many off grid remote villages using solar technology. The Alternative Energy Development Board (AEDB) was established in 2003 to facilitate, develop, and promote renewable technologies in the country. The AEDB formulates policies for the development and promotion of the renewable energy sector. In the meantime, it has installed a solar thermal plant and has electrified hundreds of villages using renewable technologies (Rafique and Rehman, 2017). Apart from the PCRET and the AEDB, there are other organizations working in the public sector for the promotion, facilitation, and development of renewable technologies. Among these organizations are the Solar Energy Research Center (SERC), the National Commission for Alternate Technologies (NCA), the National Engineering and Science Commission (NESCOM), and the Solar Energy Center (SEC). These organizations are working on the technologies of flat-plate water heating systems, air conditioning, thermal power generation, and water desalination all based on solar energy. These public sector departments are working with the private sector to produce different renewable products for commercial purposes such as cookers, lights, water heaters, battery chargers, etc. all using solar energy (Rafique and Rehman, 2017).

Weaknesses of the Sustainable Energy Sector in Pakistan

One of the biggest drawbacks of the renewable energy sector in Pakistan is that it relies heavily on imported technologies. The contribution of its domestic industry to the production of renewable energy equipment is negligible. One of the major reasons behind poor growth in the renewable energy sector in the country is the lack of credit opportunities for projects related to renewable energy. High installation costs and lack of interest in renewable projects among lending institutes are major barriers to the development of this sector (Irfan et al., 2019). The State Bank of Pakistan (SBP) commenced a scheme in 2016 to finance small renewable energy projects at an interest rate of 6%. However, most of the beneficiaries of this scheme are commercial entities that can offer equipment, another plant or land as collateral. Meanwhile, individuals, with their limited capacity to offer anything as collateral, cannot benefit much from this scheme (Malik et al., 2019). Moreover, the uncertainty in resource assessment and high-risk perception of small renewable projects deter lending institutes from financing (Mirza, et al. 2009).

Another big challenge that the renewable energy sector is facing is an inadequate power distribution and transmission network. Before the 18th amendment, only the federal government had the power to issue licenses for electricity generation. However, after the 18th Amendment was passed in 2010, provinces were able to make their own power policy. However, the lack of coordination between the federal and provincial governments and poor National Transmission and Dispatch Company Limited (NTDC) representation in the provincial panels for the issuance of letters of intent can be problematic in terms of connecting the provincial power projects to the national grid (IRENA, 2018). The lack of financial resources available to the National Transmission and Dispatch Company (NTDC) is a serious obstacle to the growth of the renewable energy sector, since substantial investment is required to establish the power distribution and dispatch network to connect the potential sites with the national grid.

Consequently, renewable energy projects are restricted to a few areas, such as Bahawalpur for solar power, and Garo and Jhimpir for wind power. Funding provided by the development partners covers only 30% of the total development expenditures required for the transmission network for the planned 9400 MW electricity capacity in Garo and Jhimpir by 2022 (IRENA, 2018). The major reasons for the poor transmission network are a shortage of public funds and the private sector's non-participation in developing this network. Power System Planning[3] **(**PSP) is facing various challenges. One of these challenges is the governmental policy that restricts public investments in the electricity sector at a time of rapid increase in the power load and the necessity for a comparable grid size (NTDC, 2019). Another big challenge that PSP faces is the brain drain in the form of movement of its highly skilled workers/professionals to other companies or other countries (NTDC, 2019).

There is a huge potential for rooftop solar power systems in Pakistan. However, since the financial situation of distribution companies (DISCOs) in Pakistan is not stable, the existence of a large number of distributed generators may jeopardize the financial liquidity of

[3] NTDC has the mandate for Power System Planning (PSP) in the whole country except Karachi. The formation of a plan for investment in the power transmission network is the major task of Power System Planning (PSP). This plan incorporates forecasts of power demand and load, electricity generation expansion, the plan for the development of transmission network linked to the generation expansion and the plan for the required investment by the National Transmission and Dispatch Company (NTDC, 2019).

the DISCOs (IRENA, 2018). DISCOs' workers lack technical expertise to deal with the matters related to net metering. Moreover, the system's reliability can be vulnerable if there are many distributed generators (IRENA, 2018).

Power System Planning (PSP) faces other challenges that are impediments to significant contributions from alternative energy resources to the total energy mix of the country (NTDC, 2019). These are issues specifically related to renewable technologies, such as the sporadic supply of electricity from renewable resources, the absence of a robust transmission network, and inefficient dispatch owing to insufficient reliable weather forecasts. Moreover, high temperatures in the areas favorable to wind power can cause inefficient energy generation (NTDC, 2019). Wind power plants based on the new technologies and solar power plants both use inverters, and these can cause harmonic distortion[4] (NTDC, 2019).

Opportunities in the Sustainable Energy Sector in Pakistan

Pakistan's renewable energy sector is flourishing and offers several opportunities for investors. The cost of renewable power projects has declined significantly over the last decade mainly due to competitive bidding and the dramatic fall in the price of renewable energy equipment as a result of more competition.

It is also conspicuous by the fact that the upfront tariff has dropped by more than 50% over the last 7 years. Moreover, in contrast to conventional coal- or LNG-based power plants, renewable power projects do not entail substantial investment in infrastructure (IRENA, 2018).

As mentioned above, Pakistan has an immense potential for electricity generation through rooftop solar photovoltaic systems. To encourage people to produce their own electricity, a net metering scheme was introduced by the National Electric Power Regulatory Authority (NEPRA) in September 2015. According to the scheme, distributed generator license holders can produce and sell electricity to the distribution companies. Initially, the process of obtaining the license took from four to six months. However, according to the updated policy of NEPRA of January 2018, licenses can now be obtained within one month.

[4] Harmonic distortion can be defined as current variation due to changes in frequencies in an electrical distribution system due to nonlinear loads (Krarti, 2018).

In order to boost investment in power generation via distribution generators and small renewable energy projects, the State Bank of Pakistan introduced a refinancing scheme for small-scale renewable energy projects in 2016. According to the scheme, distributed generators with a capacity of 4 KW to 1 MW and power production units from renewables with the capacity of 1 MW to 50 MW can benefit from this scheme, which offers financing at a subsidized interest rate of 6%.

There are various tax incentives offered by the government of Pakistan for the manufacture of renewable energy equipment as well as for the import of such equipment. In 2019, the government announced tax exemptions for all local manufacturers of all solar and wind energy equipment for five years. The import of all renewable energy technology, equipment, and products is duty-free. Moreover, there is a sales tax exemption for all importers of renewable energy equipment. Under the 2019 Alternative and Renewable Energy Policy, no income tax will be levied on sales of electricity from the Alternative and Renewable Energy projects (GoP, 2019). In addition to these tax incentives, the Pakistan government is committed to promoting renewable energy by providing protection against any political risk, making the purchaser responsible for the grid connection and by promising power purchase (AEDB, 2019). The government wants to accelerate growth in this sector by allowing the issuance of corporate registered bonds and the repatriation of dividends and equity (AEDB, 2019).

Carbon credits[5] are widely used all over the world to mitigate carbon emissions resulting from the use of fossil fuels. Under its 2019 Alternative and Renewable Energy Policy, the government of Pakistan strongly encourages developers/contractors of alternative and renewable energy projects to make an application to obtain carbon credits through either a compliance market or voluntary markets. In this regard, the Alternative and Renewable Energy Development Board (AEDB) has been given the task to facilitate the carbon trading process. Furthermore, the Pakistan government has given income tax and duty exemptions on the revenues generated by the trading of carbon credits (GoP, 2019). There are opportunities and strong potential for investment in solar and photovoltaic panels, inverters and dry batteries, equipment for wind power generation on farms (mainly turbines), transmission and distribution equipment, biomass boilers, biogas equipment, and technical consultancies (Export.gov, 2019).

[5] Carbon credit is a tradable certificate that represents a permit to emit one tonne of carbon dioxide or an equivalent amount of another greenhouse gas emission. In the European market, the price of one carbon credit certificate on average in 2018 was 16.21 euros per tonne.

Pakistan is facing various challenges in the areas of the economy, balance of payments, and sustainable development that can be overcome with investment in renewable energy technologies. There are sufficient reasons to motivate policy-makers to think outside the box for the development of the renewable energy industry, including a depreciating exchange rate, increasing oil prices on the international market, the heavy reliance on imported fossil fuels, an increasing trade deficit, depleting domestic natural gas reserves, rapidly growing energy demand, environmental degradation caused by the use of fossil fuels, and expensive electricity.

Threats to Sustainable Energy Growth in Pakistan

There are various external factors that are threat to the renewable energy sector in Pakistan. One serious threat is political instability. The hydropower sector is the most vulnerable to political instability as large hydropower projects require substantial investments of money and time – longer than the tenure of a government. Therefore, governments prefer to invest in fossil fuel-based power projects that are less time- consuming so that they can present the effective performance of those projects at the next election. In addition, small provinces in Pakistan have strong objections to the construction of large dams.

Pakistan relies heavily on imported oil and coal. The domestic production of oil and coal still has only a minor share in the total energy consumption of the country despite Pakistan's coal reserves being the seventh largest in the world. The coal reserves were discovered in 1991 by the United States Agency for International Development and the Geological Survey of Pakistan. They are equivalent to the combined oil reserves of Iran and Saudi Arabia, providing sufficient coal for the next 300 years. These reserves are not only a threat to the environment but also a great threat to the renewable energy sector in the country. A further threat is the duty-free import of all renewable energy equipment and products, which has an adverse impact on the local renewable industry. Solar panels and other renewable energy equipment imported from China attract buyers due to their low price despite the questionable quality. In addition, even though Pakistan's depreciating exchange rate makes imported oil products more expensive, forcing policymakers to think about switching to renewable technologies, it also makes imported renewable energy equipment expensive. According to a study by Shahbaz et al. (2015), there is bidirectional causality between economic growth and renewable energy consumption in Pakistan. Therefore, the slow economic growth that Pakistan has observed over recent years can have an adverse impact on the growth of the renewable energy sector.

Table 3.2. SWOT Analysis of the Renewable Energy Sector of Pakistan

Strengths	Weaknesses
• Enormous potential of renewable energy • Presence of research and policy institutes such as the Pakistan Council of Renewable Energy Technologies (PCRET) and the Alternate Energy Development Board (AEDB) • Ambitious targets to increase the share of renewables	• Foreign dependence and over-reliance on imported technologies • Lack of collateral to benefit from the lending schemes for small projects • High installation cost and lack of financing opportunities due to the uncertainty in resource assessment of small projects • Lack of coordination between provincial and federal government and lack of NTDC representation in the provincial panels to issue LOI • Lack of financial resources available to NTDC • Lack of investment of the private sector in transmission and distribution network • Lack of technical competence of the DISCOs' workers in net metering • Weak financial situation of the distribution companies and the poor transmission network are not enough to deal with large number of distribution generation licenses. • Inadequate public sector investment in the transmission and distribution network • Brain drain of the NTDC workers to other companies or other countries • High temperature in the areas suitable for wind power reduces the efficiency • Harmonic distortion in the inverters
Opportunities	**Threats**
• Falling cost of renewable energy technologies and projects • Net metering scheme by NEPRA • Refinancing scheme of SBP for small projects with subsidized interest rate • Import of renewable energy technology is duty free and no sales tax • Protection against risk • Permission for issuance of corporate registered bonds and repatriation of dividends and equity • Availability of carbon credits • Income tax exemption	• Political instability and lack of political consensus on large water reservoirs • Depreciating exchange rate making imported renewable energy equipment expensive • Presence of massive coal reserves in the country • Duty-free renewable energy products are a threat for the domestic industry • Low economic growth

SWOT Analysis of the Renewable Energy Sector of India

The summary of the SWOT analysis of the renewable energy sector of India is given in Table 3.3.

Strengths of the Renewable Energy Sector in India

An ambitious target of generating 175 GW from renewable energy sources by 2022 shows India's commitment to the energy transition to sustainable energy. It includes 100 GW from solar energy, almost one-third of the 175 GW targeted from wind energy, and 15 GW from other sources. Similar to Pakistan, India has a vast potential in renewable energy sources. According to a report by the Ministry of Renewable Energy, India has an overall potential of 1096 GW of renewable energy, with solar energy being the leading source of renewable energy with 5000 trillion KWH of yearly solar insolation (Manju and Sagar, 2017) and a potential generation of 748.99 GW, 302.5 GW of wind energy potential, 19.5 GW of small hydropower potential and more than 22 GW of renewable energy potential from biomass and bagasse (Bandyopadhayay, 2017). India leads the region in terms of renewable energy sector development. According to the report of the RECAI (2019), it stands at the third rank in the world in the Renewable Energy Attractiveness Index after China and the USA. India is the first country in the world to establish a separate ministry for the development of the renewable energy sector, in 1992. Since then, the Ministry of New and Renewable energy (MNRE) has taken several steps for the promotion and development of renewable energy technologies. There are various public sector institutes, such as the Indian Renewable Energy Development Agency (IREDA), working on the development of the renewable energy sector and promoting research and development activities in this sector. IREDA, established in 1987, does this by providing financial support to the renewable energy projects.

India is also developing five of the world's top ten solar parks (Kumar and Majid, 2020), and enjoys the lowest capital cost in the world for the installation of a solar PV project. Furthermore, the cost of installation of solar PV projects in India dropped by 80% from 2010 to 2018, with this reduction in cost being the fastest among the top eight solar PV markets in the world (IRENA, 2018b). Twelve of the world's top wind turbine manufacturers are operating in India, producing and exporting 24 different types of wind turbines to Europe, Asia, USA, and Brazil (Kumar and Majid, 2020).

Weaknesses of the Sustainable Energy Sector in India

The initial cost of renewable projects is still much higher than that of fossil fuel-based power plants, although the cost of installation of renewable energy projects, especially of solar PV, has fallen significantly in recent years (IRENA, 2017). The solar industry is facing various challenges in India. The photovoltaic industry endures the challenges of the lack of provision of funds for research and development activities, the high cost of production, inadequate government support, and the lack of market formation (Manju and Sagar, 2017). High prices of land at potential sites for solar power plants is another big challenge for the renewable energy sector in India. The new dual tax policy announced in 2018 for solar parks has resulted in an increase in the capital cost for these projects (Gupta, 2020). India imports almost 90% of the solar modules and PV it uses. The share of the domestic industry is less than 10%. In 2018, the Indian government introduced a safeguard duty on imports of solar modules and cells to protect the domestic industry for two years. However, this has not improved the situation mainly for two reasons. Firstly, new projects take at least 15 months for their completion. Therefore, they are not covered by this duty (ET report, 2019). Secondly, the increased prices because of the imposition of the duty will certainly have a negative impact on the demand for solar modules.

The cost of debt in India for the investors of renewable energy is one of the highest in the world (Sreenivasan, 2018). Financing options for these investors are available at a high interest rate of 12 to 15%. This interest rate is much higher than those of the USA and Europe, which are around 5 to 7%. Moreover, available financing options are limited to the short term, whereas renewable energy investors require loans for the long term (Nelson et al., 2018; Gupta, 2020). Power transmission and the distribution network in India are also encountering various challenges in relation to distribution losses and financial liquidity of the distribution companies. These challenges are serious impediments to the growth of the renewable energy sector. India faces 26% losses in power transmission, which are among the highest in the world (IRENA, 2017). The poor financial situation of the distribution companies has led to delayed payments to the producers, lack of execution of contracts, and auction cancelations. Consequently, it has undermined the confidence of investors (CSE, 2019).

Opportunities in the Renewable Energy Sector of India

The per unit cost of electricity generated from renewable resources dropped significantly because of the introduction of a policy of competitive bidding (Kumar and Majid, 2020). The federal government of India offered various schemes and tax incentives for the development of the renewable energy sector. After the failure of its first two policies, India relaunched the policy of accelerating depreciation for renewable energy in 2014 at a rate of 80%. Due to lower risk on investment under the accelerated depreciation scheme, this scheme is regarded as the main driver of the development of wind power installation (Sud et al., 2015). Another scheme initiated by the federal government is the Viability Gap Funding Scheme, under which projects that are economically essential but financially not feasible are financed with a proportion of the capital cost. The government provides a maximum subsidy of 30% of the capital cost of renewable energy projects. Recently, in 2019, the Indian government allocated 85 billion Indian rupees for solar projects under this scheme. Another scheme the federal government of India announced in 2008 and reinstated in 2013 is a generation-based incentive for wind power. Under the scheme, a 0.5 Indian rupee subsidy is given per KWH and this is proportional to the amount of electricity generated (Sharmali et al., 2017). Furthermore, there is an income tax exemption on profits during the first ten years of operation of any wind or solar power plants. Selected components required for the manufacture of solar modules and water heaters are given import/custom duty exemption.

India is moving forward in terms of net metering, with many states having formulated policy on this. The policies of each state vary, however. The process of installation of net metering can take several months in some states, whereas the procedure for the approval takes 25 to 30 days in some of the other states, such as Andhra Pradesh, Delhi, and Telangana. A policy of offering a subsidy for rooftop solar PV installation has been initiated (IRENA, 2017). According to this scheme, a subsidy of 30% to 70% is offered for rooftop solar installation in different states depending on whether the state belongs to a general or special category.

Threats to the Renewable Energy Sector of India

The recent UN climate talks came to an end without any conclusion on carbon credits for future trading. This may discourage renewable energy investors. India has over the years acquired millions of carbon credit certificates under the Kyoto protocol and sold these on the international market. Over the years India has invested in renewable energy technologies with the assurance that the Paris Agreement would provide a conclusion on the carbon trading rules. Another external factor that is a threat to the renewable energy sector of India is the presence of massive coal reserves. Presently almost two-thirds of the electricity in India is produced from coal. According to the International Energy Agency, India's coal reserves are estimated to be 186 billion tons, which are the fifth largest in the world, and India stands in third place with respect to coal production and consumption (Manju and Sagar, 2017).

Table 3.3. SWOT Analysis of Renewable Energy Sector of India

Strengths	Weaknesses
• Vast potential in renewable energy sources • Third rank in RECAI (2019) • Separate ministry for the development of renewable energy sector • Developing five of the world's top ten solar parks • Lowest capital cost in the world for solar PV projects • Presence of world's top manufacturers of wind turbines • Financial support available for RE Projects from IREDA • Ambitious targets for energy transition towards sustainable energy	• Lack of funds for R & D activities • Lack of market formation for solar PV industry • High cost of land for solar projects • High interest rate and a possibility of loans only for short term • Dual tax policy • Poor financial situation of distribution companies • Inadequate support of the government for domestic industry • High power transmission losses • High initial cost of RE projects
Opportunities	**Threats**
• Decrease in the cost of production • Net metering and availability of subsidy for rooftop solar PV installation • Policy for accelerating depreciation • Policy of Viability Gap Funding for solar projects • Policy of generation-based incentive for wind power • Income tax incentive • Import duty exemption for solar PV components	• Lack of consensus on carbon credits in UN climate negotiations • Presence of large coal reserves

Strengths

Sri Lanka is situated close to the equator and is surrounded by the Indian Ocean, which makes Sri Lanka an ideal country for renewable energy. Sufficient and strong sunshine, on-shore wind, and the presence of the sea provide Sri Lanka with great potential for solar energy, wind power, and tidal energy. It also has great potential for biomass energy. Being one of the members of the Climate Vulnerable Forum, Sri Lanka has agreed to switch its power industry 100% to renewables by 2050 at the latest. Its power distribution and transmission network faces power losses of less than 10%, which are among the lowest in the region.

Weaknesses

The Sri Lankan power industry faces the challenges of capacity shortage and a serious financial crisis mainly as a result of electricity tariffs lower than per unit cost. Private investment in renewable energy faces legal issues and a lack of clarity from the government on feed-in tariff policy. The policy of competitive bidding for wind and solar power projects has also not yielded significant results (ADB, 2019). The lack of domestic capability to finance the heavy investment required for renewable energy projects on account of electricity transmission, distribution, and generation is an obstacle to the development of the renewable energy sector. To make the best use of renewable energy, pump storage power generation systems need to be developed. The lack of research in the renewable energy sector and the high cost of renewable energy projects and rooftop solar installations are other impediments to the growth of the renewable energy sector (ADB and UNDP, 2017).

Opportunities

Sri Lanka, like other South Asian countries, offers tax incentives for the domestic manufacture of renewable energy equipment. Furthermore, producers of power from renewables can import capital equipment duty-free. Apart from this duty-free import of capital equipment, electric utilities enjoy an exemption from corporate taxes for 5 to 8 years. The renewable energy sector is further incentivized with the procurement of carbon credits in partnership with the World Bank through the program of the Carbon Partnership Facility. Sri Lanka initiated a net metering scheme in 2010 with the target of producing 200 MW of electricity by 2020 and 1000 MW of electricity by 2025 from rooftop solar photovoltaic installations. The Sri Lankan government offers a concession of a 6% interest rate on loans of up to 350,000 SRs for the purpose of installing rooftop solar panels.

As discussed in the empirical analysis, the depreciating and volatile exchange rate of Sri Lanka is contributing negatively to the growth of renewable energy. Sri Lanka depends heavily on imported renewable energy equipment. Therefore, a stable exchange rate is essential for growth in the renewable energy sector.

Sri Lanka relies heavily on hydropower. Disturbance of the monsoon system due to climate change can have a negative impact on Sri Lanka’s hydropower generation (ADB and UNDP, 2017).

SWOT Analysis of the Renewable energy sector of Bangladesh

Bangladesh also has immense potential for renewable energy in the form of solar, wind, and biomass energy due to its geographical location. Sufficient sunshine throughout the year, the presence of coastal areas, an agricultural economy, and the presence of rivers make Bangladesh highly favorable for solar, wind, biomass, and hydropower, respectively.

The Solar Home System program of Bangladesh is one of the largest in the world, with more than 4 million solar home systems having been installed.

Bangladesh is behind all other south Asian countries in terms of renewable energy. The share of renewable energy in the total energy mix and power generation is negligible. A lack of technical knowledge and skills for renewable energy technologies in Bangladesh has resulted in an increase in the cost and delay of renewable energy projects. Furthermore, apart from its feed-in policy, there is no incentive from the government for renewable energy developers (Karim et al., 2019). Moreover, potential land for renewable energy projects is quite costly.

Despite the absence of incentives for the renewable energy developers, the government has, however, given tax incentives to the manufacturers of renewable energy equipment. Yet, these incentives have not yielded much investment in the renewable energy sector. Tax exemptions have been applied to the import of raw materials for the solar PV manufacturing industry and the solar PV industry enjoys a cash incentive on the export of solar panels. However, the solar PV industry of Bangladesh has an annual production of solar panels of 100 MW.

Comparison of the SWOT Analyses of South Asian Countries

All the countries of South Asia have great potential for renewable energy and each country is committed to increasing the share of renewable energy in the total energy mix. This commitment is palpable because Pakistan, India, and Sri Lanka have set ambitious targets for growth in the renewable energy sector. Although there are several institutes and government bodies in all the countries working on the promotion and development of renewable energy technologies and both Pakistan and India are included in the Renewable Energy Country Attractiveness Index (RECAI), it may be concluded that the Indian renewable energy sector is more advanced and developed than that of other South Asian nations. This can be seen in the fact that India stands third in the RECAI ranking, whereas Pakistan is in 36th place. Moreover, the share of alternative and renewable energy excluding hydropower in the total energy mix is about 9% in India compared to 2% in Pakistan. India is also farther ahead than other South Asian countries in terms of domestic and foreign investment in renewable energy technologies, particularly in solar parks and the manufacture of wind turbines.

However, all the South Asian countries face substantial losses in power distribution. Sri Lanka has nevertheless succeeded in controlling these power losses in recent years. The financial situation of the distribution companies in all the countries is very poor mainly due to power losses and non-cost-reflective tariffs, and this has serious repercussions for power generation on account of delayed payments. Financial institutions are reluctant to invest in renewable energy projects. Interest rates are very high, particularly in Pakistan and India, and only short-term loans are available for renewable energy projects. The domestic industries for the production of solar panels are faced with the challenge of competition from imported solar panels despite government support. Both India and Pakistan are looking for an optimum solution that, on one hand, protects the domestic industry and, on the other hand, provides a cheaper option while investing in renewable energy technologies. Imposing duties on the import of such renewable energy equipment that is also produced domestically will protect the domestic industry, but it will increase costs to developers, and vice versa if tax incentives are provided for any such equipment. India has been following the former model and Pakistan has implemented the latter. There have been various policy initiatives taken by the governments of both countries to promote growth in renewable energy. Apart from tax incentives that are offered in both the countries, policy measures such as accelerating depreciation, generation-based incentives, and viability gap funding were taken by India, while Pakistan introduced an interest rate subsidy for small power generating units and a comprehensive policy for the procurement of carbon credits. According to the study of Shrimali et al. (2017), policies such as loans for longer periods, loans with lower interest rates, and interest rate subsidies can be more effective and would save more government subsidies than the above-mentioned policies in India. Both Pakistan and India have massive coal reserves, but India’s coal reserves are rapidly depleting and may not be as big a threat to the renewable energy sector as those in Pakistan, where the coal industry is still at the developing stage and the energy transition from gas and oil to coal is at an initial stage, with this energy transition towards coal in Pakistan having picked up the pace in recent years. Volatile exchange rates and unstable economic growth in Pakistan and Sri Lanka can be possible factors in the slow growth of the renewable energy sectors there. This study, using econometric analysis, explores some of the factors that have been highlighted in the SWOT analysis and are possibly crucial determinants of renewable energy adoption in South Asia.

Empirical Results

Table 3.4. Panel Unit Root Tests

Variable	Test	Level		1st difference	
		statistics	**probability**	**statistics**	**probability**
Ln renewable energy	LLC t*	-1.20824	0.1135	-7.53816	0.0000
	IPS W-stat	-0.75099	0.2263	-8.28875	0.0000
	ADF - Fisher Chi-square	15.9474	0.0431	76.1322	0.0000
Ln GDP per capita	LLC t*	5.85382	1.0000	-3.38326	0.0004
	IPS W-stat	8.34640	1.0000	-4.56374	0.0000
	ADF - Fisher Chi-square	1.20106	0.9966	47.6158	0.0000
Exchange rate	LLC t*	3.72088	0.9999	-7.80498	0.0000
	IPS W-stat	6.24112	1.0000	-8.28929	0.0000
	ADF - Fisher Chi-square	0.16897	1.0000	73.7549	0.0000
Political globalization	LLC t*	-1.42637	0.0769	-9.15145	0.0000
	IPS W-stat	1.03637	0.8500	-9.71529	0.0000
	ADF - Fisher Chi-square	3.86565	0.8690	88.4380	0.0000
International oil prices	LLC t*	-0.10049	0.4600	-9.40374	0.0000
	IPS W-stat	0.16622	0.5660	-9.04183	0.0000
	ADF - Fisher Chi-square	4.80821	0.7779	73.6827	0.0000

LLC: Levin-Lin-Chu test, IPS: Im-Pesaran-Shin, ADF: Augmented-Dickey-Fuller

As the above table of the panel unit root tests shows, all the variables have a unit root at level and are not stationary at level. However, each variable rejects the null hypothesis of a presence of unit root at its first difference and is integrated of order 1. These results are consistent in all three panel unit root tests, the Levin-Lin-Chu test, the Im-Pesaran-Shin test and the ADF Fisher test.

Table 3.5. Long-run PMG ARDL Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
	Long Run Equation			
Ln GDP per capita	1.493057	0.234264	6.373401	0.0000
Exchange rate	-0.010273	0.005223	-1.966748	0.0513
Political globalization	-0.002850	0.007108	-0.400943	0.6891
International oil prices	-0.042089	0.067317	-0.625241	0.5329

The long-run pooled mean group autoregressive distributed lag (PMG ARDL) results given in the above table suggest that level of per capita real GDP and exchange rate are the most significant determinants of the level of alternative and renewable energy growth in the region in the long run. The political globalization index and international oil prices are insignificant factors. Real GDP per capita is significant at a 1-percent level of significance. Its positive sign reveals that economic growth is the main driver of growth in the renewable energy sector and any deceleration in economic growth will eventually slow down growth in investment in the sustainable energy sector. This finding is consistent with the studies of Silva et al. (2018), Papiez et al. (2018), and Apergis and Payne et al. (2014). The exchange rate is significant at a 10-percent level of significance. Its negative sign implies that a depreciating exchange rate is unfavorable for growth in the renewable energy sector of the region, as South Asian countries depend heavily on imported technologies. Therefore, a depreciating exchange rate makes the imported renewable energy equipment more expensive, and thus increases the cost of capital for renewable energy developers.

Table 3.6. Short-run PMG ARDL Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
	Long Run Equation			
Ln GDP per capita	1.493057	0.234264	6.373401	0.0000
Exchange rate	-0.010273	0.005223	-1.966748	0.0513
Political globalization	-0.002850	0.007108	-0.400943	0.6891
International oil prices	-0.042089	0.067317	-0.625241	0.5329

Table 3.7. Country-specific ARDL Results

		Pakistan		**India**		**Bangladesh**		**Sri Lanka**	
		AIC	**SC**	**AIC**	**SC**	**AIC**	**SC**	**AIC**	**SC**
Long-run Results	**LnRGDPP**	2.998***	2.403***	1.486***	1.690***	1.235	0.579	2.360***	2.212***
		(0.256)	(0.181)	(0.350)	(0.428)	(0.741)	(0.594)	(0.634)	(0.559)
	ER	-0.007***	-0.004***	0.006	-0.013	-0.006	-0.006	-0.012	-0.014*
		(0.001)	(0.001)	(0.010)	(0.012)	(0.019)	(0.016)	(0.009)	(0.008)
	PG	0.002	0.004	-0.035**	-0.008	-0.007	0.008	0.003	0.008
		(0.005)	(0.003)	(0.016)	(0.011)	(0.020)	(0.013)	(0.014)	(0.015)
	LnIOP	0.011	0.001	0.078	-0.013	-0.187	-0.020	-0.462***	-0.325***
		(0.040)	(0.030)	(0.110)	(0.106)	(0.271)	(0.118)	(0.107)	(0.095)
	C	-16.834***	-3.183***	-3.295*	-5.637**	-6.659	-4.066	-13.922***	-13.595***
		(1.366)	(1.088)	(1.722)	(2.462)	(3.906)	(3.549)	(4.407)	(3.888)
Error-correction	**ECM**	-2.395***	-0.986***	-0.626***	-0.416***	-0.824***	-0.868***	-0.785***	-0.750***
		(0.396)	(0.127)	(0.119)	(0.071)	(0.160)	(0.154)	(0.151)	(0.124)
	F-statistic	4.700***	8.744***	3.585**	4.973***	3.684**	4.642***	3.785**	5.348***

Standard error in parentheses, LnRGDPP : natural log of real GDP per capita, LnIOP: Ln International Oil prices, PG: Political Globalization

Critical Values for F-bound test

Signif.	I(0)	I(1)
10%	2.2	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

The error correction term confirms the presence of a long-run equilibrium. The short-run equilibrium converges to its long-run equilibrium with a speed of almost 33% in a period of one year, and this error correction term is significant at a 5-percent level of significance. None of the macro-level factors have any impact on the adoption of renewable energy in the short run.

The Schwarz criterion (SC), and the Akaike information criterion (AIC) were used for the selection of optimum lag length. The F-Bound test statistics in each equation confirm the presence of a long-run equilibrium, as the F-statistics are greater than the critical value of upper bound at a 5-percent level of significance. Country specific time series results are consistent with the results of the panel of South Asian countries. Economic growth is the most significant determinant of growth of the renewable energy sector in most countries. Per capita real GDP has a positive and significant impact on the development of the alternative and renewable energy sectors of Pakistan, India, and Sri Lanka. A depreciating exchange rate has a negative and significant impact on the output of renewable energy in the case of Pakistan and Sri Lanka. Since Pakistan and Sri Lanka rely heavily on imported renewable technologies and the exchange rate of these two countries is highly volatile, as discussed in the descriptive analysis, a depreciating exchange rate contributes negatively to the growth of the renewable energy sector by making imported renewable technologies and services more expensive. The impact of the political globalization index is insignificant, which is perhaps because the democratic era suffers more from instability and uncertainty than the non-democratic era, in which government was more stable. Oil prices also have no impact on the outcome of renewable energy output in Pakistan, India, and Bangladesh, as changes in international oil prices are not completely passed on to the final consumers. This finding suggests that a carbon tax may not be a good option to accelerate growth in the renewable energy sector in South Asia. All the variables have no impact on the adoption of renewable energy in the context of Bangladesh. One possible explanation for this statistically insignificant impact is that Bangladesh lags behind all other South Asian countries in terms of growth in renewable energy. The share of renewable energy, including hydropower, in the total energy mix and total power generation is less than 3%. The negative and significant coefficient of the error correction term in each case confirms the convergence of the short-run equilibrium to its long-run equilibrium.

3.5. Conclusion and Recommendations

Our empirical results suggest that poor economic growth and a depreciating exchange rate are the most significant reasons behind poor growth of the renewable energy sector in South Asia. Country specific results suggest that a depreciating exchange rate has a negative impact on the growth of the renewable energy sector in Pakistan and Sri Lanka, which is due to the fact that both the countries have volatile exchange rates, and renewable energy developers rely on imported equipment due to its quality and cost effectiveness. But with exchange rate depreciation, this imported renewable energy equipment becomes expensive. The promotion and development of a domestic renewables industry and technologies by investing in research and development can cancel out the negative repercussions of a depreciating exchange rate in the long run.

There is some need to take serious action to develop the renewable energy sector of a country. Based on the SWOT analysis, the following recommendations and directions for the development of sustainable energy were identified for South Asia:

The first step for the development of a renewable energy sector is to build a transmission and distribution network that is essential to connect potential sites of renewable energy projects to the national grid. Furthermore, the financial situation of the distribution companies can be improved by reducing power distribution and transmission losses. Green financing schemes with lower interest rates and for a longer duration are essential for the growth of this sector in the region. Pakistan can benefit from the Islamic mode of financing. The development in the sustainable energy sector in Pakistan should focus on small domestic energy units in combination with the availability of Islamic finance in the form of Ijara and Murabaha (Malik et al., 2018), the duty-free import of renewable energy equipment, and incentives to produce one’s own electricity to avoid regular electricity shutdowns in the municipal system.

There is a conflict of interest between the manufacturers of renewable energy equipment and renewable energy developers. The former want the protection of the government with the imposition of tariffs on imported material, whereas the latter want cheap and good quality equipment to reduce the cost. India is following the first model because the domestic industry of renewable energy – despite having a minor share of the market – is growing fast. In contrast to India, Pakistan has adopted the policy that favors the renewable energy developers to boost electricity generation from renewables. In this regard, one possible and optimum solution can be to import only good-quality renewable energy equipment, or duties must be imposed on the import of low-quality renewable energy equipment so that the domestic industry of renewables can flourish. Since the installation cost of renewable energy units is very high, people involved in commercial or industrial activities and interested in generating their own electricity using renewable resources can be given tax incentives.

There is a particular need to integrate industry, universities, and public institutes in the joint research and development of renewable energy technologies.

Conclusions

As discussed above, a robust regression discontinuity design has been applied by taking the distance of each provincial capital from the ethnic and linguistic border. The analysis has been carried out in five different specifications for ethnic and linguistic Pashtuns, ethnic Tajiks, linguistic Uzbeks, and Dari-speaking people. The findings of this part of the research support the hypothesis that historical ethnolinguistic borders in Afghanistan are persistent. Pashtuns have ruled all over Afghanistan since its emergence as the Durrani Empire in 1747. The results prove to be in favor of the hypothesis that Pashtuns have the advantage over the other ethnolinguistic groups in Afghanistan due to the inclination of the Afghan rulers to promote the economic wellbeing of their co-ethnic population in the last 270 years. Robust RDD results suggest that the level of income of the Pashtuns is significantly higher than that of the other ethnolinguistic groups. This finding is consistent at various bandwidths as well as in the co-variates model. The Dari-speaking people, despite being the largest linguistic group in Afghanistan, and the Tajiks, despite being the second largest ethnic group in Afghanistan, both earn significantly less than the Pashtuns. Pashtuns are not only better off in terms of income, but they also have better access to the provision of some public goods, such as electricity and safe drinking water. The Pashtun belt of Afghanistan has suffered more violence and crime than other regions due to earlier interference by the British Empire and later by the USA and Pakistan. Ethnic division in relation to political preferences is also discernible in Afghanistan. Support for the Pashtun leader Ashraf Ghani against the Tajik leader Abdullah dropped significantly across the ethnic border in the Tajik area. This finding is also consistent in all specifications of the RDD.

Ethnolinguistic diversity at the provincial level makes a positive contribution in Afghanistan. Diversity is directly associated with the level of income and general trust, whereas it is inversely correlated with violence or crime and the level of individualism. Different ethnic and linguistic measures of diversity are instrumented by the historical ancient civilization's diversity. Contemporary diversity is strongly associated with historical ancient civilization diversity. The results of the IV estimation reveal that contemporary ethnic fractionalization and polarization are positively and significantly associated with the level of income. The level of education is also a positive determinant of the level of income. Ethnic fractionalization and polarization induce a lower level of violence or crime at the provincial level in Afghanistan. Provinces that enjoy a lower level of freedom of expression suffer more violence or crime. Measures of linguistic fractionalization and linguistic fractionalization in the form of linguistic distance produce a higher level of general trust. Apart from measures of diversity, income and education also cause a significant change in the level of trust. Measures of diversity are negatively associated with the level of individualism. A higher level of violence or crime is associated with a lower level of individualism. Provinces that are more ethnolinguistically diverse have significantly less support for the Pashtun leader Ashraf Ghani. Provinces having a higher level of income show greater support for a Pashtun leader, whereas the level of education is negatively correlated with the level of support for a Pashtun leader.

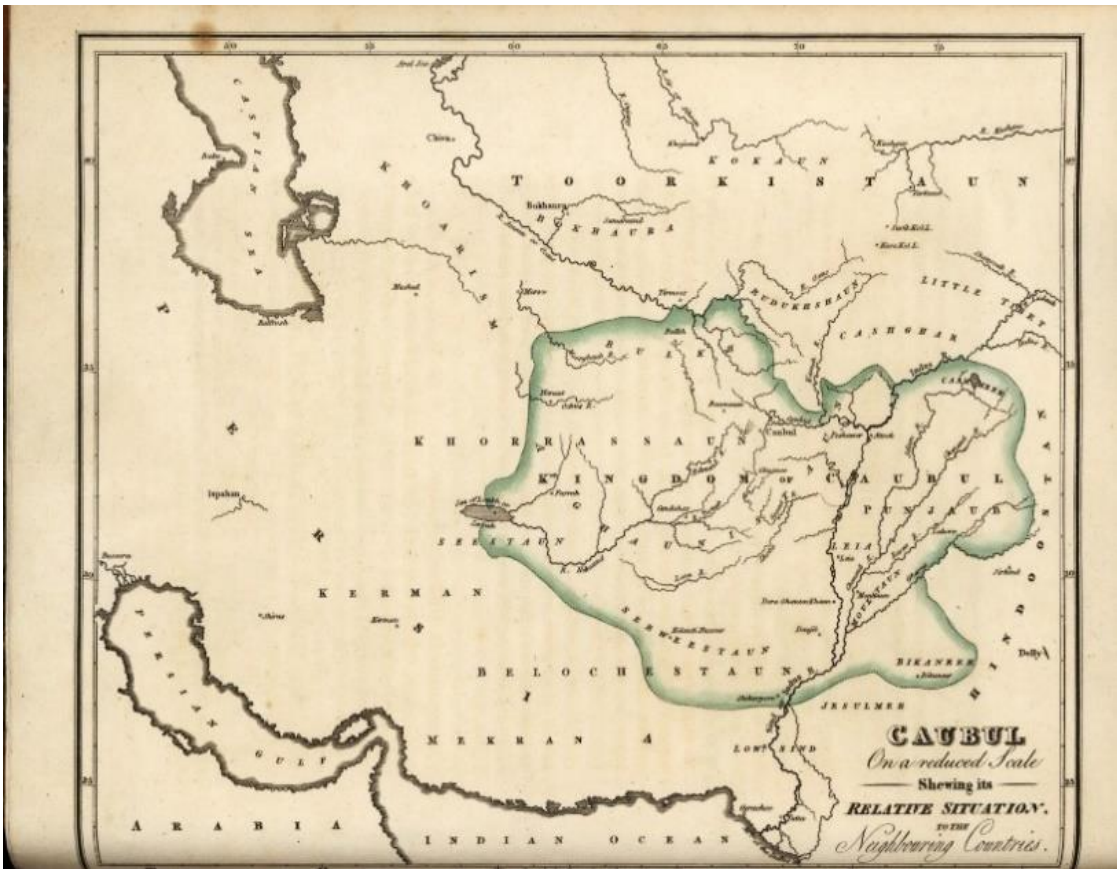
The results of mediation analysis with the help of structural equation modeling suggest that provinces where the Old Persian empires of Achaemenid, Parthian, and Sasanian left a greater impact are more prosperous. Similarly, provinces where the empires of Turkic origin had more influence are also positively linked with a contemporary level of income. This is mainly due to the strong influence of the Sasanian and the Timurid Empires in the region. However, provinces with a greater number of archaeological sites belonging to the Islamic Persian empires of Samanid, Seljuks, Ghaznivid and Ghurid have a lower level of contemporary income.

An efficiency analysis of the thermal plants of Pakistan has been carried out with the application of the Malmquist productivity index, the material balance condition and the meta-technology ratio. The Malmquist productivity index results reveal an improvement of more than 9%in total factor productivity mainly due to technological change in the power plants operating on residual fuel oil, while this total factor productivity change in the power plants running on gas is 13%. The results of the material balance condition based on data envelopment analysis conclude that achieving cost and carbon efficiency simultaneously is only possible by transitioning the technology to natural gas due to the fact that natural gas is not only environmentally more friendly, but it is also cheaper than residual fuel oil. However, the results suggest that cost and carbon efficiency can still be achieved by applying best practices. Producing at technically efficient points on the isoquant can improve both cost and carbon efficiency concurrently. According to the DEA results, 34%of the carbon and 26%of the cost can be saved by reaching the technically efficient points. Thus, this finding negates the earlier notion that the process of reducing carbon emissions is costly. This reduction in cost and carbon emissions with the use of technically efficient inputs can have not only further implications in terms of an improvement in the environment and the financial situation of the electric utilities, but also a positive impact on the sustainable development of the country by reducing the import bill for oil, by lowering electricity prices, and by saving domestically produced gas, which can then be used for the other industries. Therefore, there is a particular need to take such measures as overhauling power plants and providing an uninterrupted supply of natural gas/LNG to improve the technical efficiency of the thermal power plants. Even though the power plants operating on RFO are technically more efficient than the plants running on natural gas without considering the environment factor, according to the results of the DEA, due to the fact that RFO has a higher emission factor than gas, both types of plants have an equal share in forming the metafrontier as exhibited by the meta-technology ratio (Qaiser and Grigoriadis, 2020).

The results obtained with the implementation of time series and panel data methodologies on the selected South Asian countries in essay three suggest that economic growth and a stable exchange rate are crucial factors for growth in the renewable energy sector in the region. Slow economic growth will curtail this growth. A depreciating exchange rate is also a critical factor behind poor growth of sustainable energy in the region, particularly in Pakistan and Sri Lanka, where the exchange rate has been volatile over the years. There are various factors that are impediments to the development of the sustainable energy sector in Pakistan and India. In the case of Pakistan these are, for example, a poor transmission and distribution network, over-dependence on the import of renewable energy equipment, lack of interest of the financial institutions in renewable energy projects, lack of knowledge and skills in relation to renewable energy technologies, and inadequate research into renewable energy technologies. The availability of loans only for the short term, high interest rates, and the deteriorating financial situation of the distribution companies are the major obstacles to growth of the renewable energy sector of India. There is a conflict of interest between the renewable energy developers and renewable energy equipment manufacturers, with the former wanting inexpensive and quality material for their projects and the latter wanting government protection in terms of the imposition of import duties. This conflict makes it difficult for the government to choose the right policy. These challenges can be overcome with green financing schemes, research into renewable energy technologies, and the provision of low-cost and good-quality renewable energy equipment in the market.

Appendix to Essay 1 (Figures)

Figure A.1: Map of the Durrani Empire



Elphinstone, M. (1842). *An Account of the Kingdom of Caubul, and its Dependencies in Persia, Tartary, and India.* Afghanistan Centre at Kabul University. https://doi.org/10.29171/azu_acku_ds352_e576_1815

Figure A.2. Ethnic Composition Map of Afghanistan

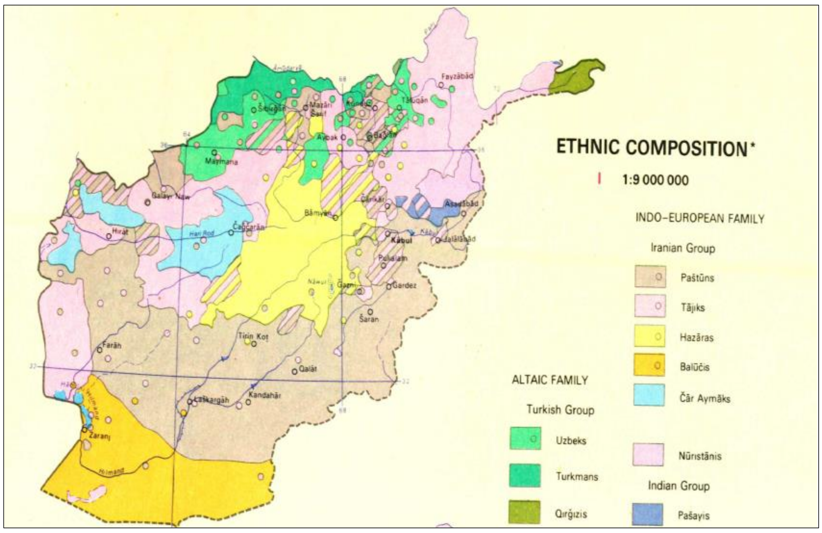
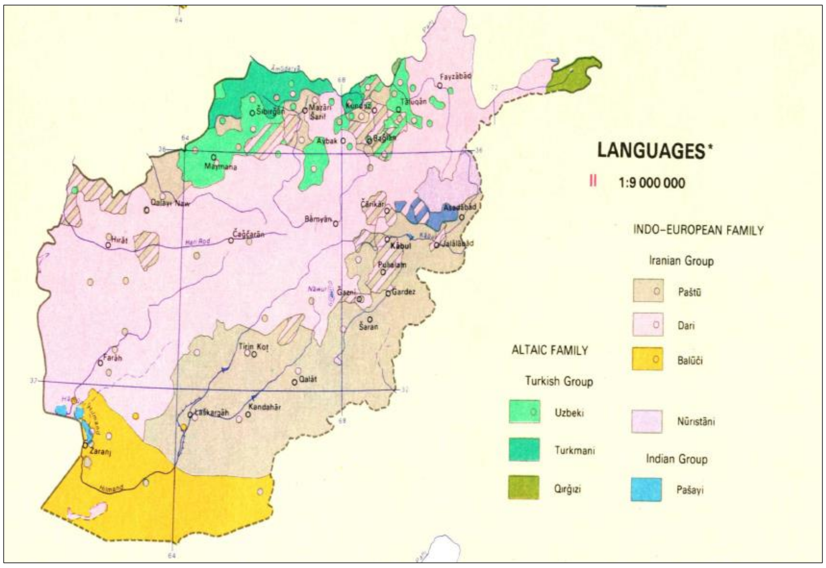
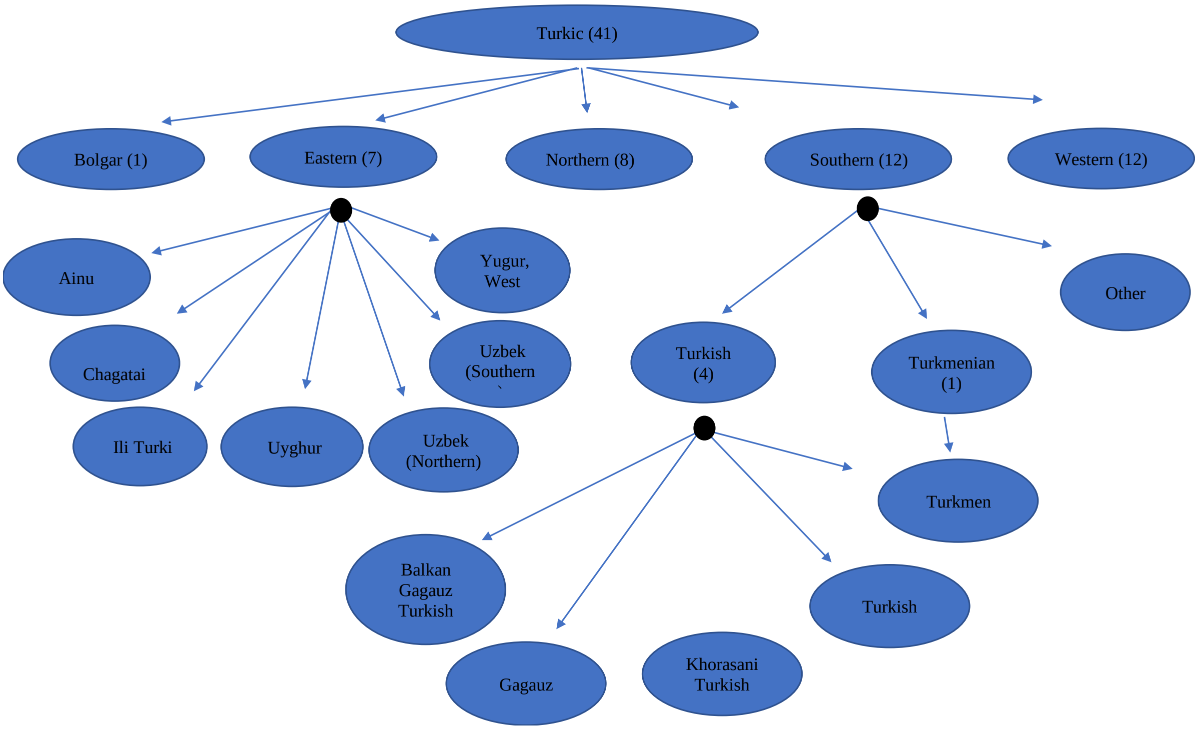


Figure A.3. Languages Map of Afghanistan



Source for Figures A.2 and A.3: National Atlas of the Democratic Republic of Afghanistan This map has been prepared according to the statistics in AGCHO (Afghan Geodesy and Cartography Head Office) - Kabul 1985.

Figure A.4. Language Trees of Afghanistan



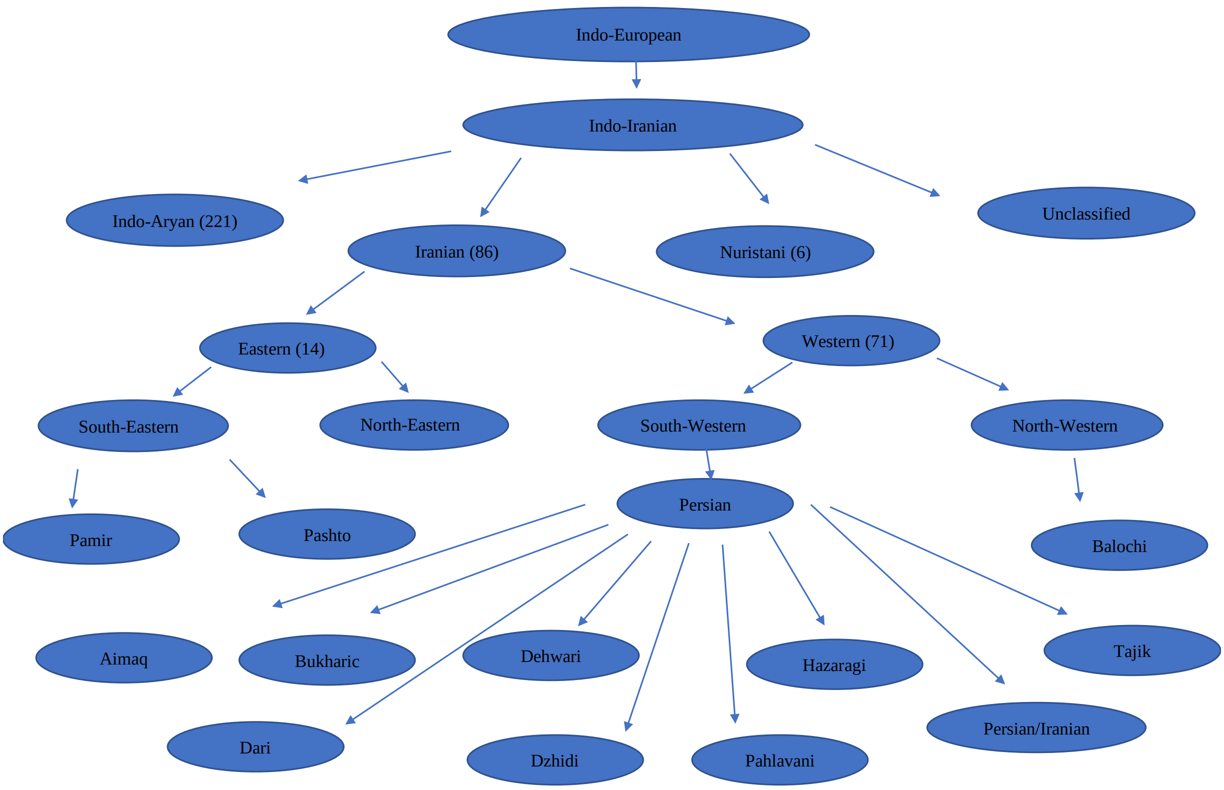
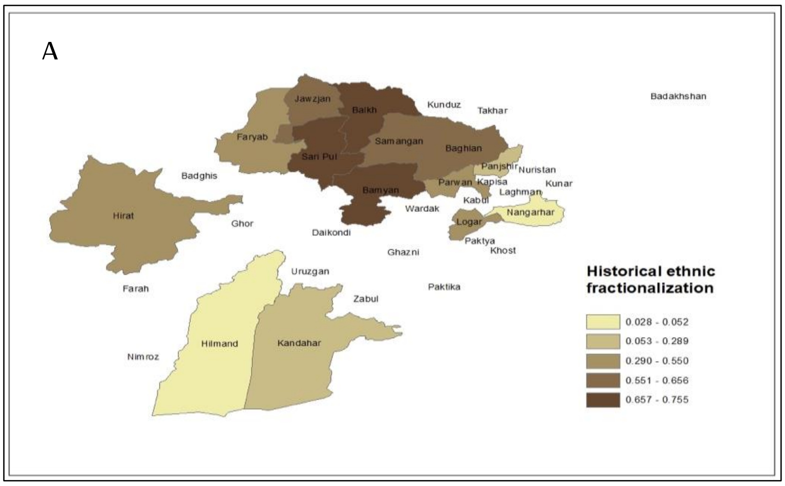
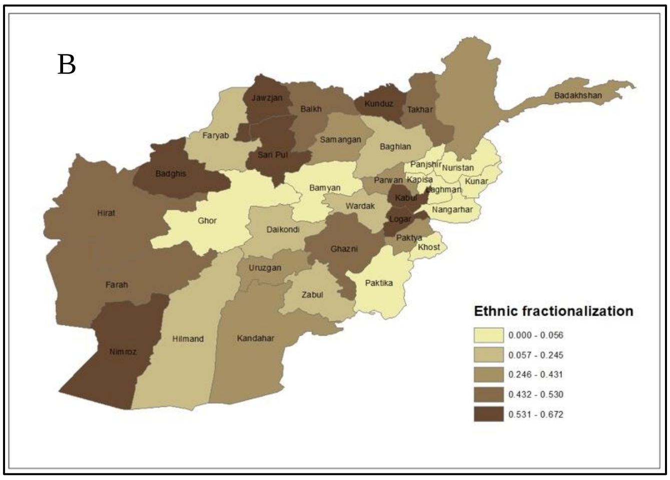


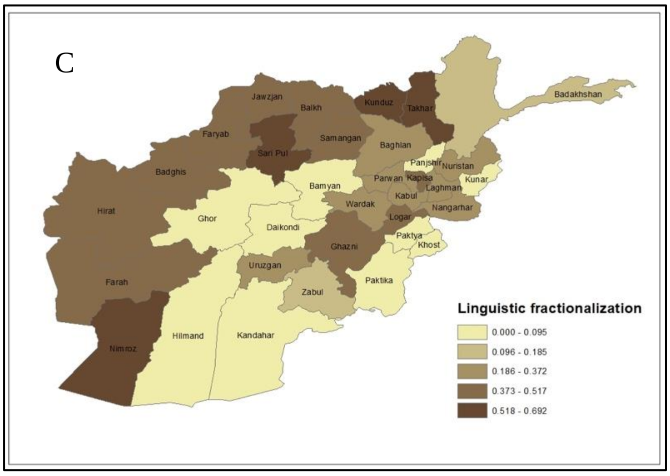
Figure A.5. Ethnolinguistic Fractionalization of Afghanistan. (A) Historical Ethnic Fractionalization, (B) Ethnic Fractionalization, (C) Linguistic Fractionalization.



Data Source: Historical and Political Gazetteer of Afghanistan 1914-1971.

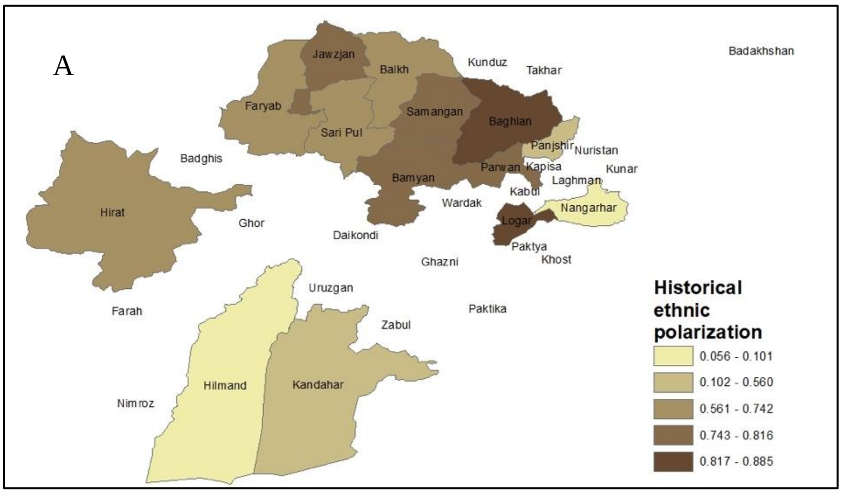


Data Source: Asia Foundation Survey 2017

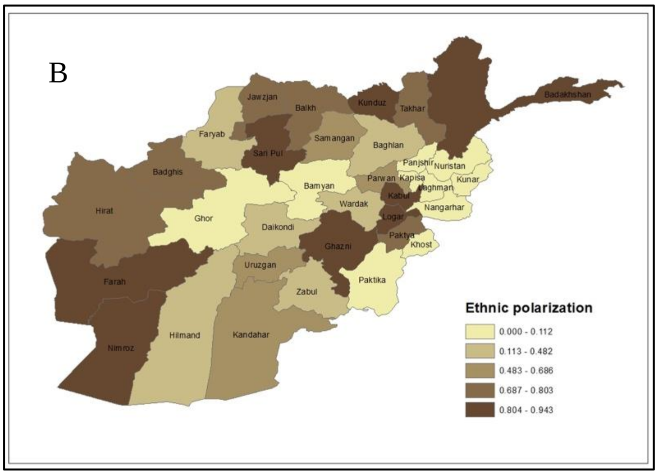


Data Source: Asia Foundation Survey 2006.

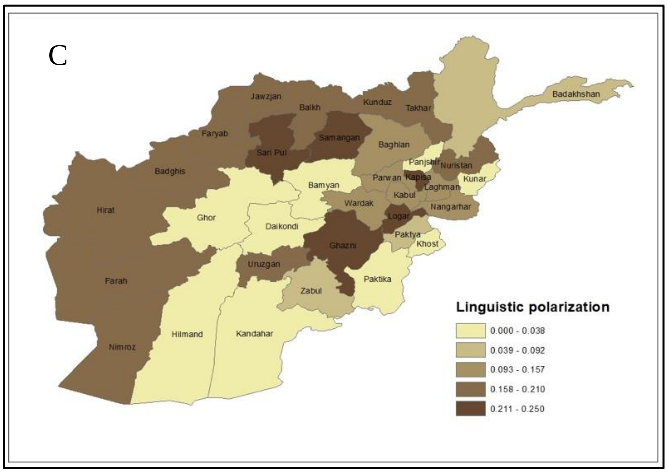
Figure A.6. Ethnolinguistic Polarization of Afghanistan, (A) Historical Ethnic Polarization, (B) Ethnic Polarization, (C) Linguistic Polarization.



Data Source: Historical and Political Gazetteer of Afghanistan 1914-1971.

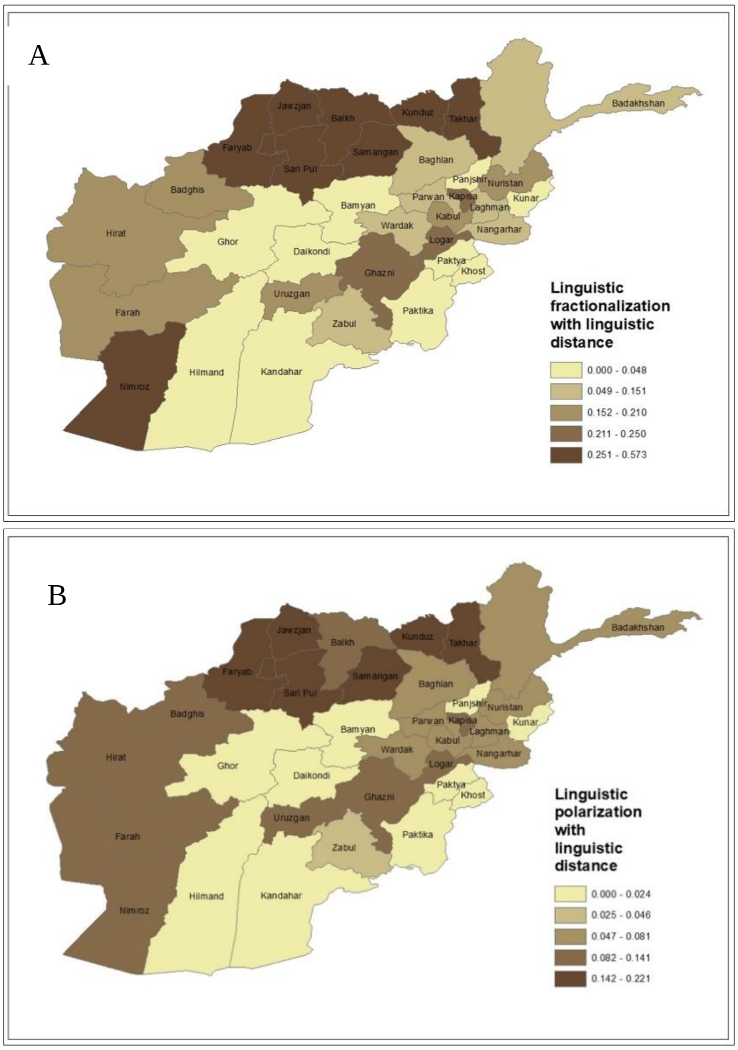


Data Source: Asia Foundation Survey 2017.



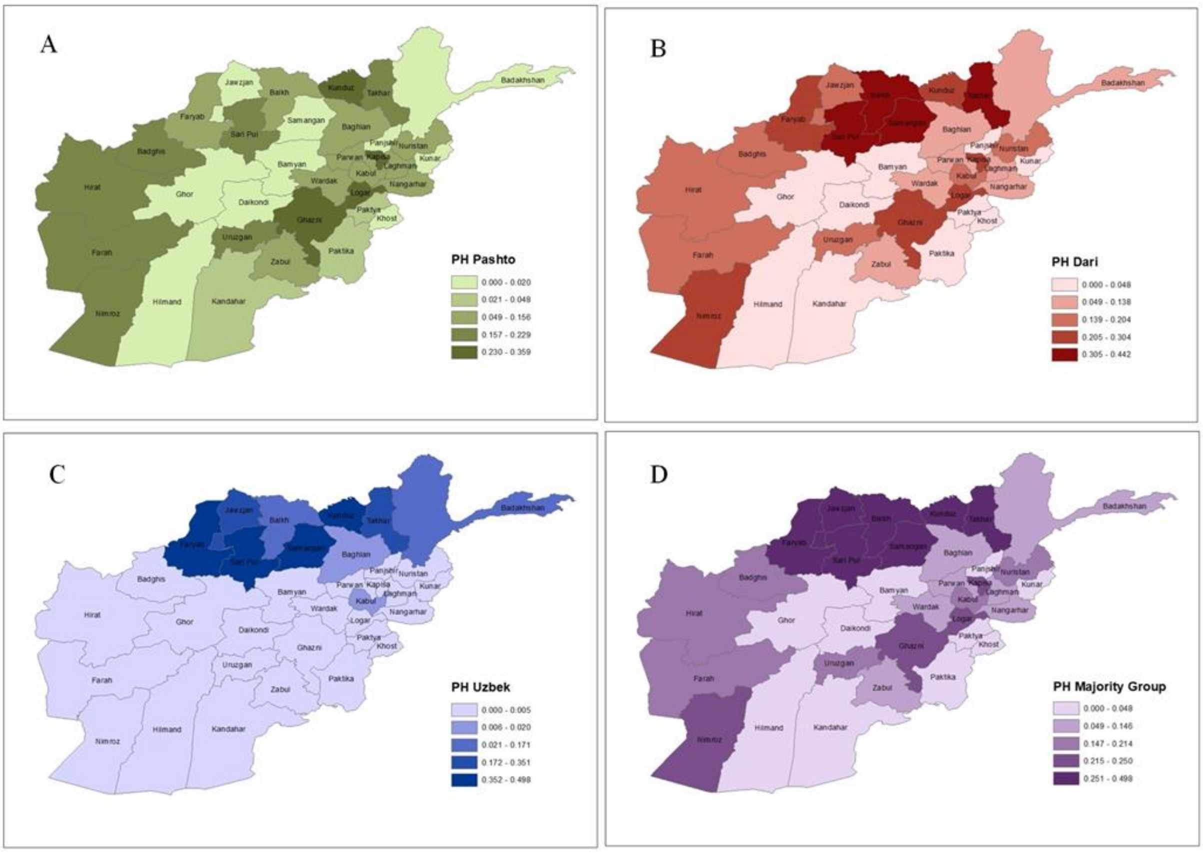
Data Source: Asia Foundation Survey 2006.

Figure A.7. Linguistic Fractionalization (A) and Polarization (B) with Linguistic Distance of Afghanistan



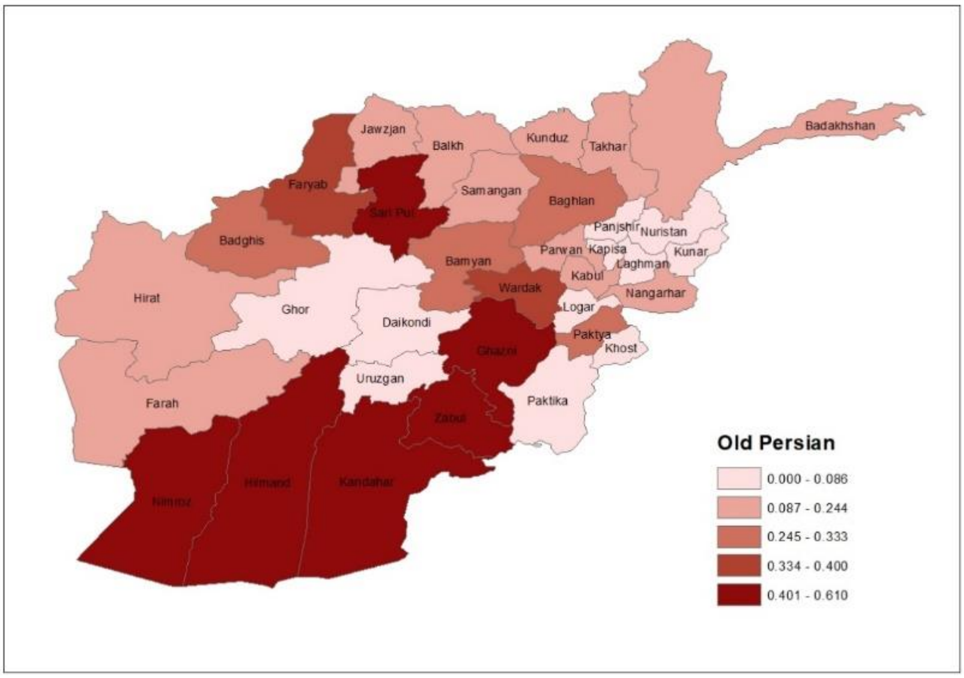
Data Source: Asia Foundation Survey 2006.

Figure A.8. Peripheral Heterogeneity Index of Afghanistan. (A) PH Pashto, (B) PH Dari, (C) PH Uzbek, (D) PH Majority Group.



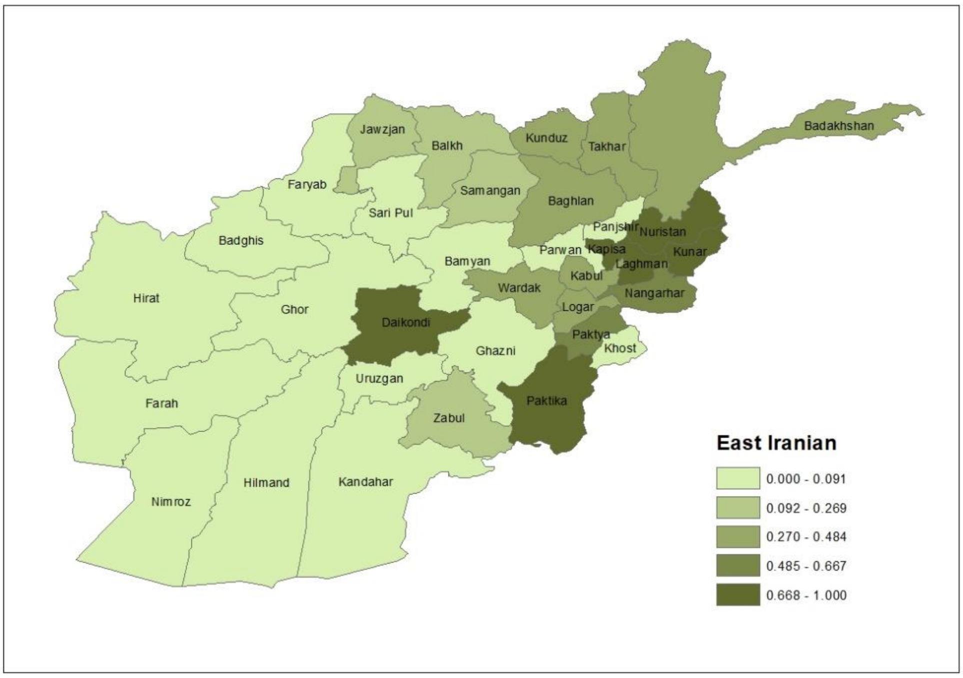
Data Source: Asia Foundation Survey 2017

Figure A.9. Map of the Number of Monuments Belonging to the Old Persian Civilization



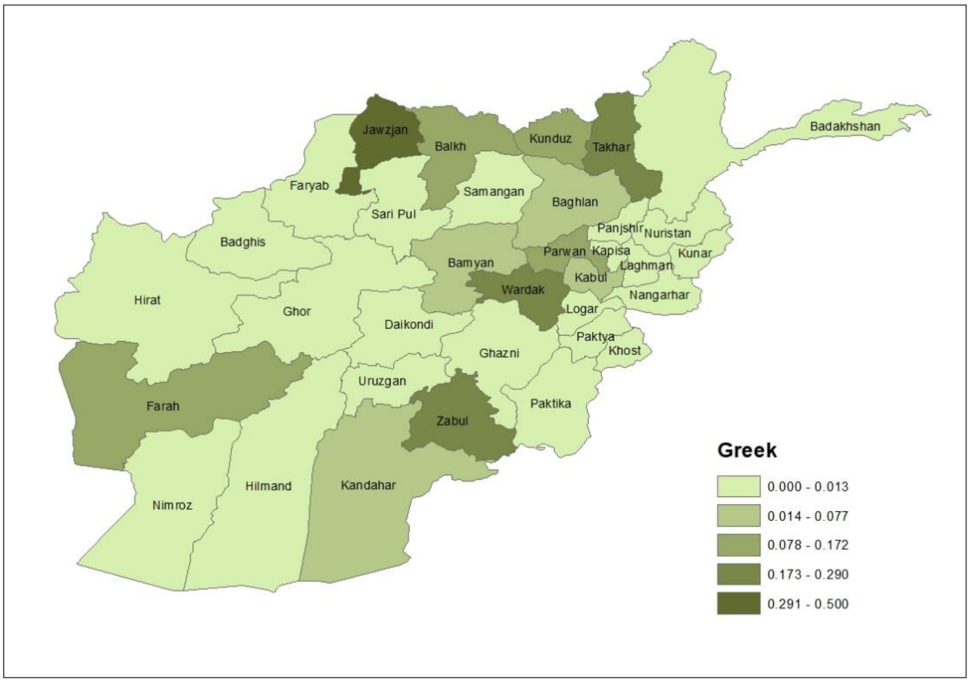
Data Source: Archaeological Gazetteer of Afghanistan 1982.
Note: Old Persian: Old Persian includes the empires of the Achaemenids, Parthians, and Sasanians with Persian as their official language.

Figure A.10. Map of the Number of Monuments Belonging to the East Iranian Civilization



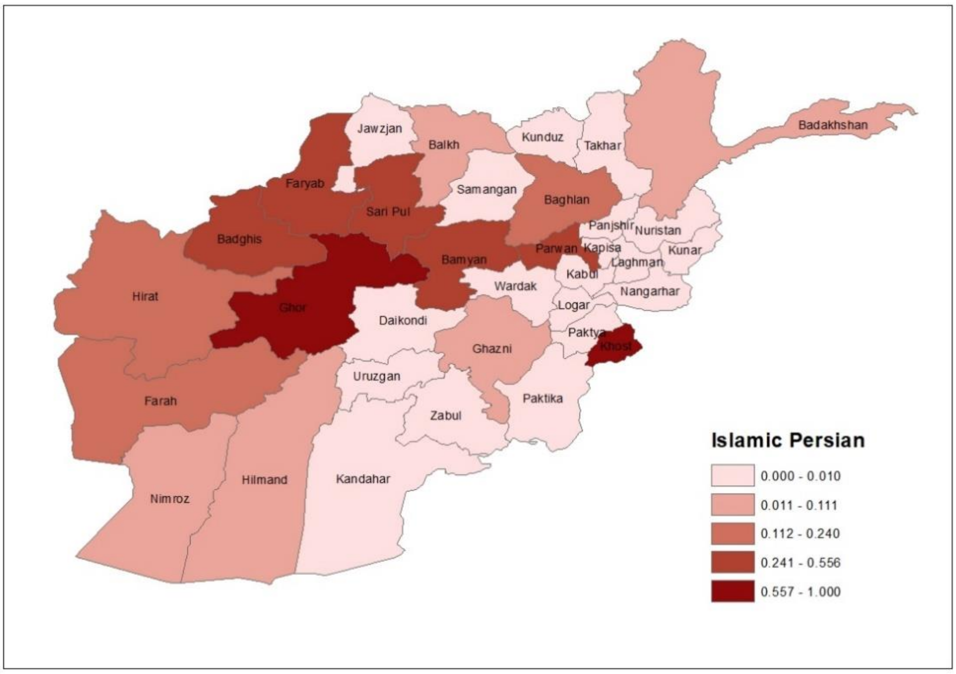
Data Source: Archaeological Gazetteer of Afghanistan 1982.
Note: East Iranian: The East Iranian category includes mainly Kushan, who used Bactrian language (a language of the East Iranian group of languages) as their official language.

Figure A.11. Map of the Number of Monuments Belonging to the Greek Civilization



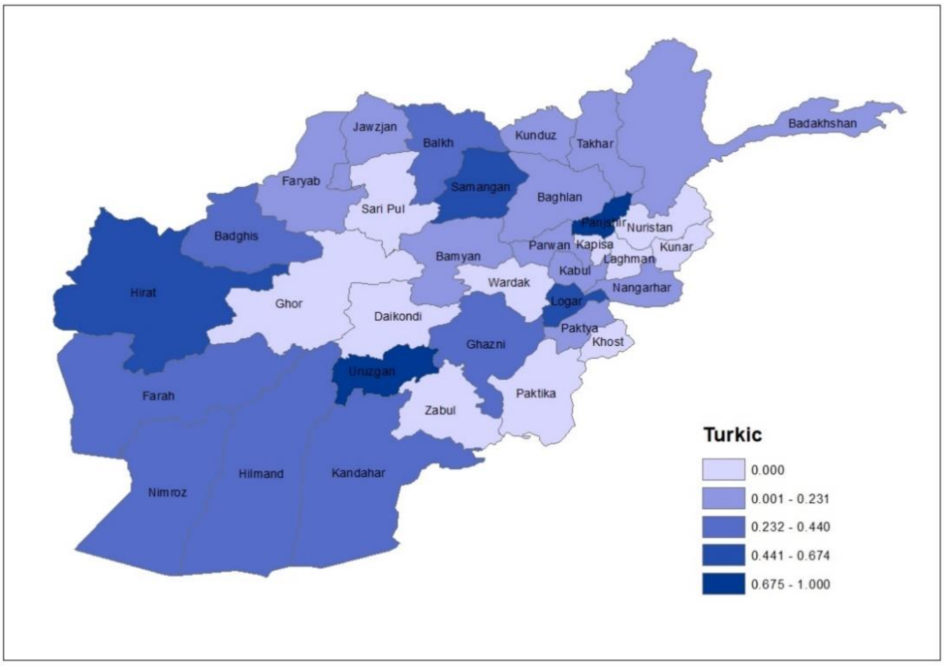
Data Source: Archaeological Gazetteer of Afghanistan 1982.
Note: Greek: Hellenistic era has been categorized as the Greek period.

Figure A.12. Map of the Number of Monuments Belonging to the Islamic Persian Civilization



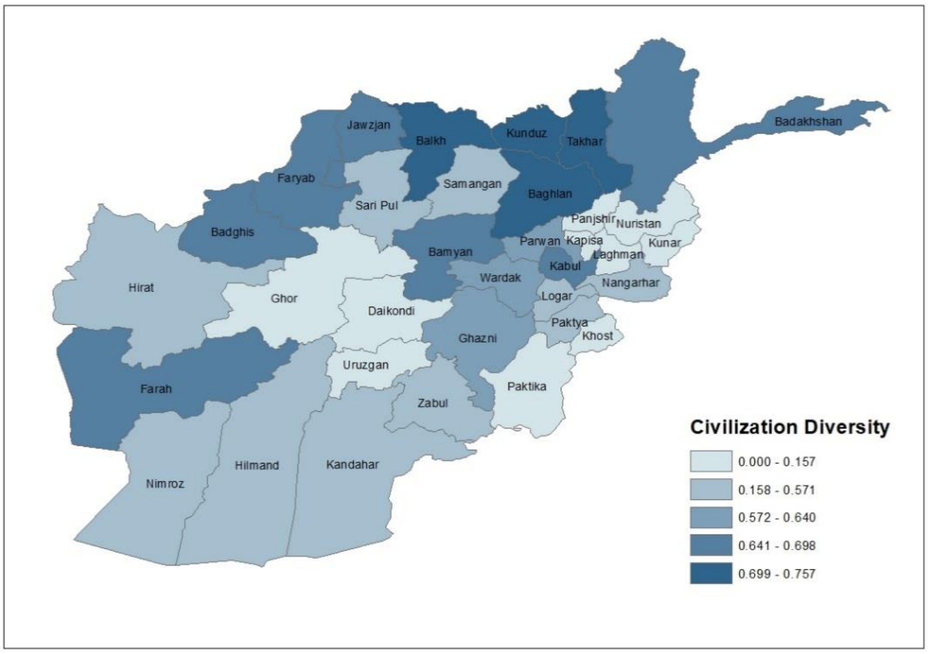
Data Source: Archaeological Gazetteer of Afghanistan 1982.
Note: Islamic Persian: Islamic Persian includes the Muslim empires of Samanids, Ghaznavids, Seljuks, and Ghurids

Figure A.13. Map of the Number of Monuments Belonging to the Turkic Civilization



Data Source: Archaeological Gazetteer of Afghanistan 1982.
Note: Turkic: The Timurid and Chugtai dynasties are classified as the empires of Turkic origin.

Figure A.14. Map of Civilization Diversity in Afghanistan



Data Source: Archaeological Gazetteer of Afghanistan 1982.

Figure A.15. RD Plots for Pashtun vs non-Pashtun

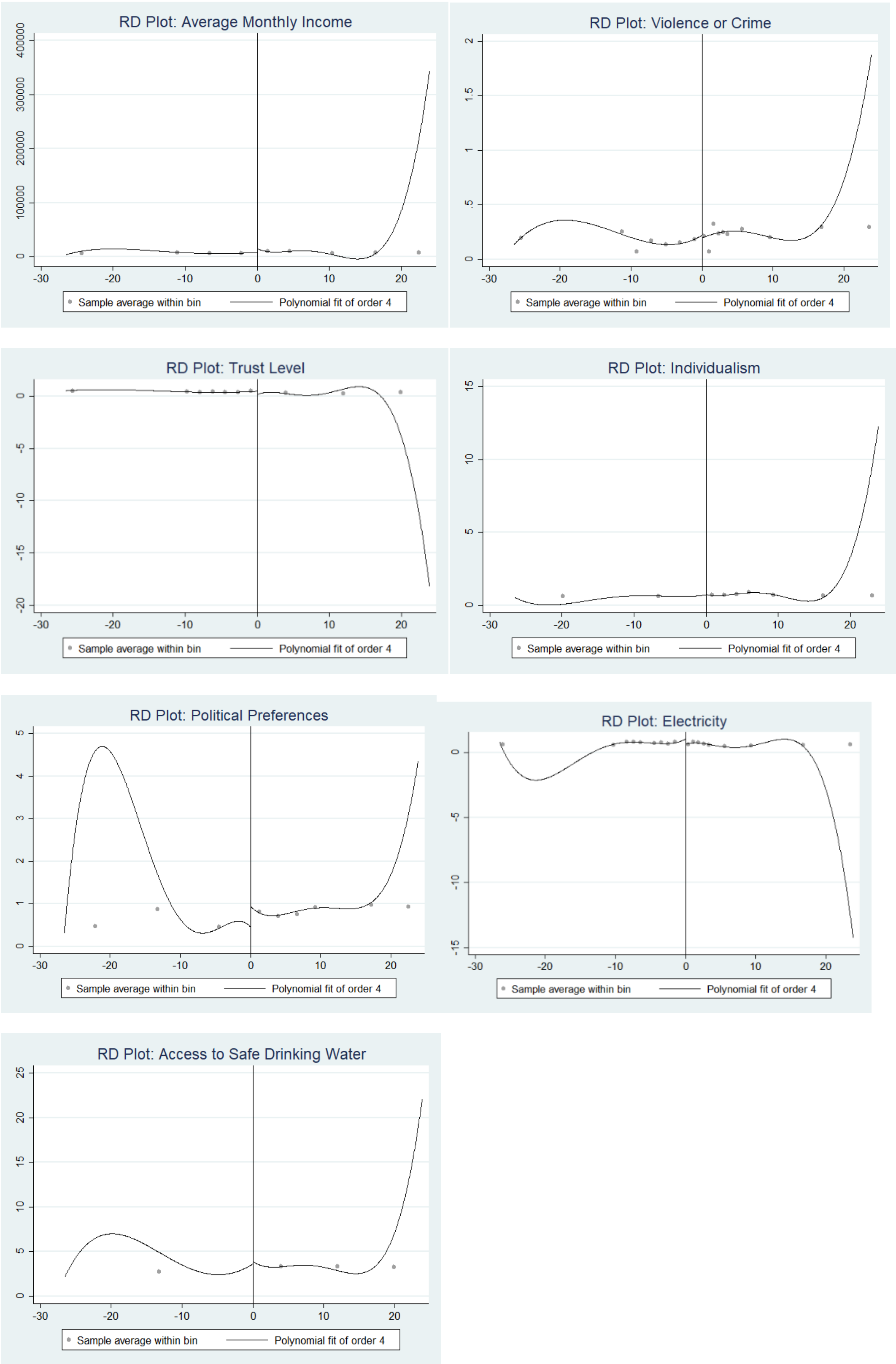


Figure A.16. RD Plots for Dari vs non-Dari

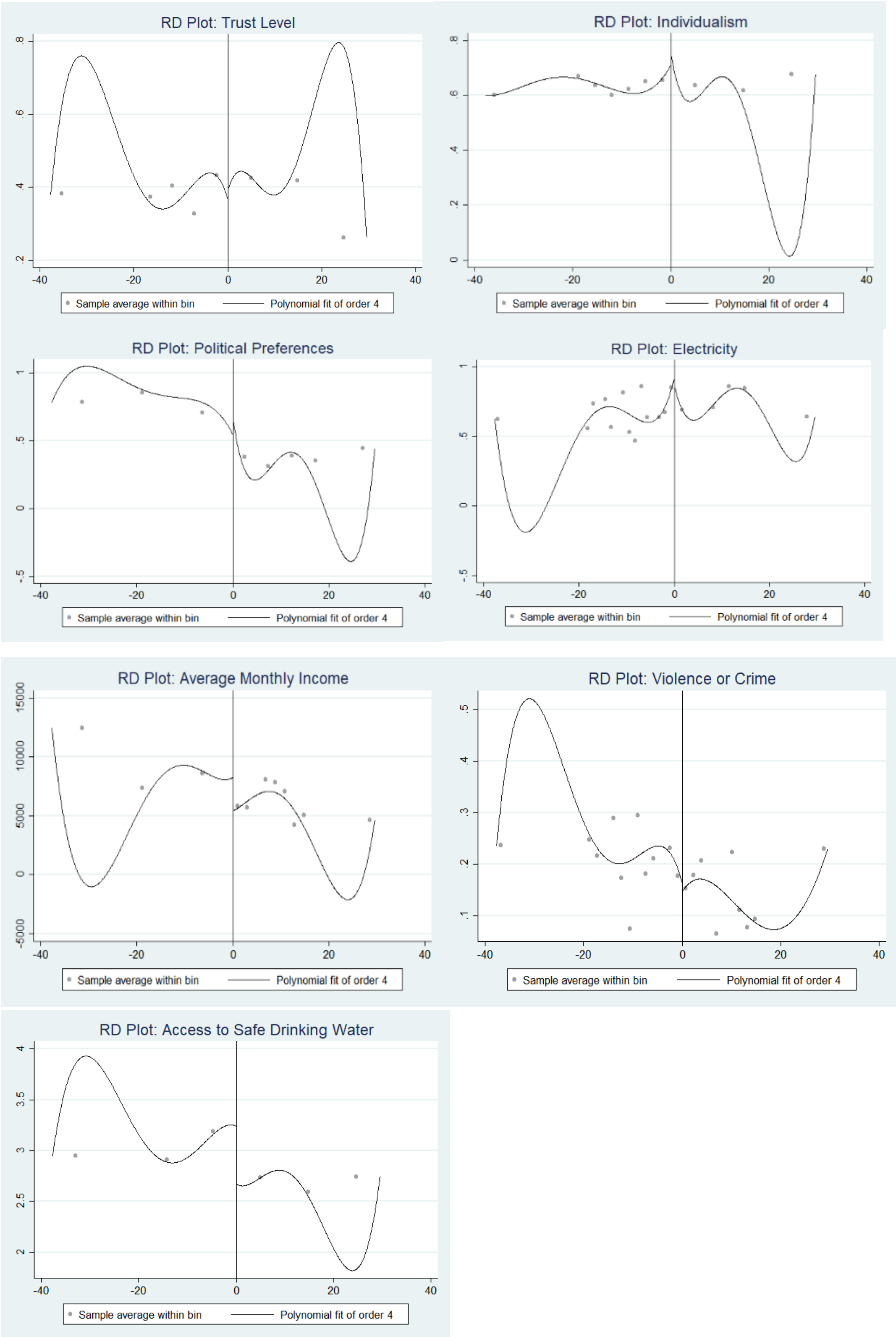


Figure A.17. RD Plots for Uzbek vs non-Uzbek

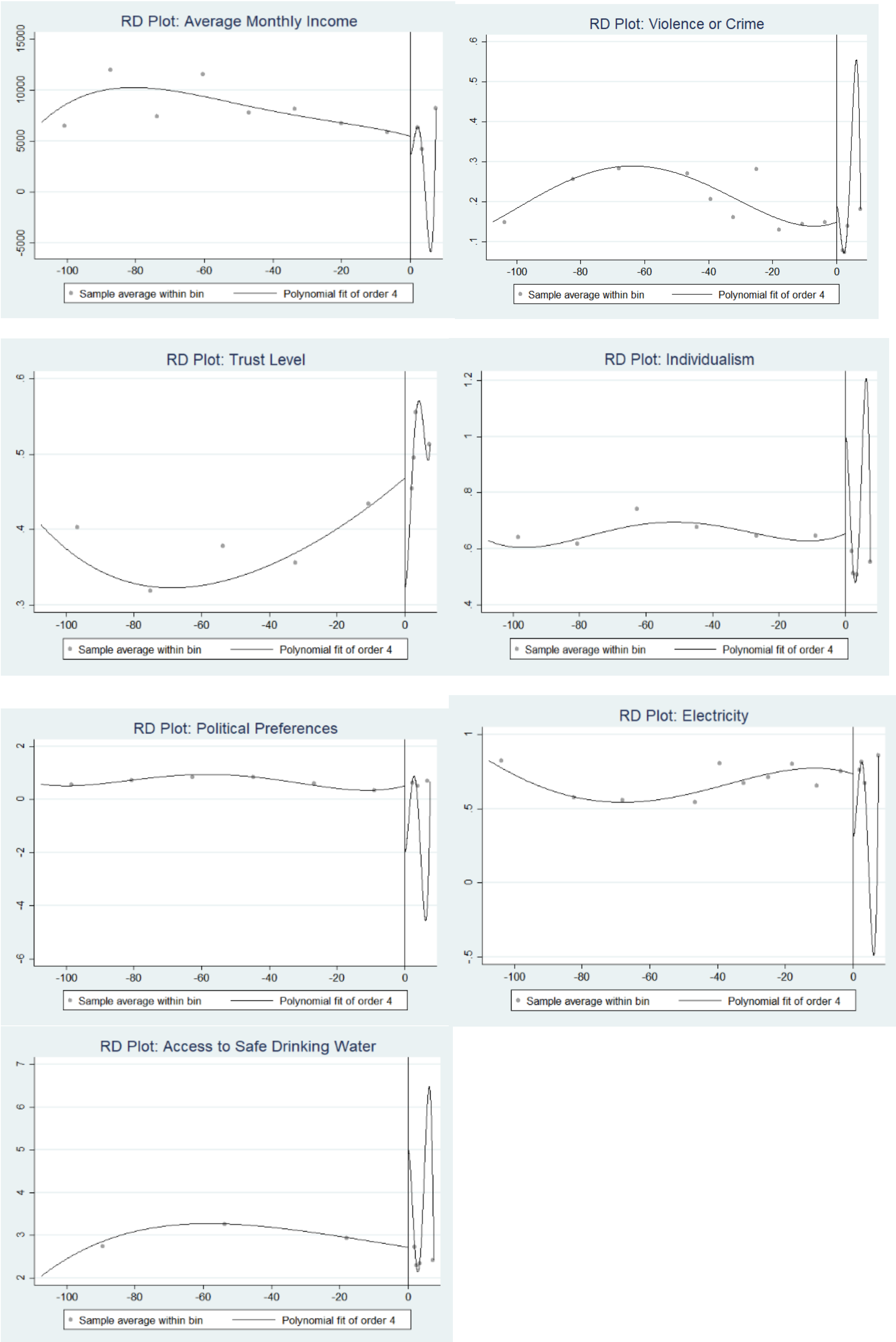
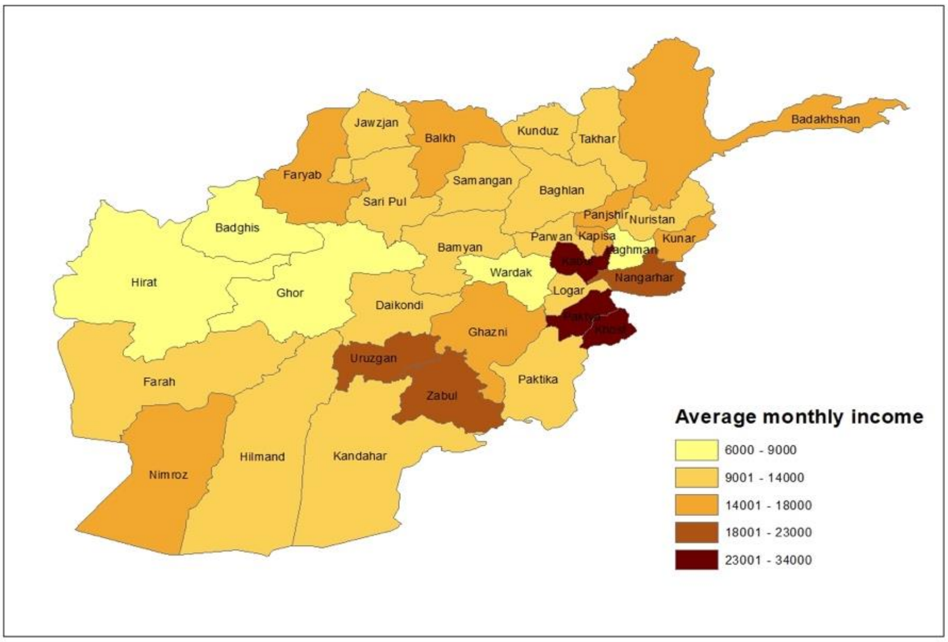
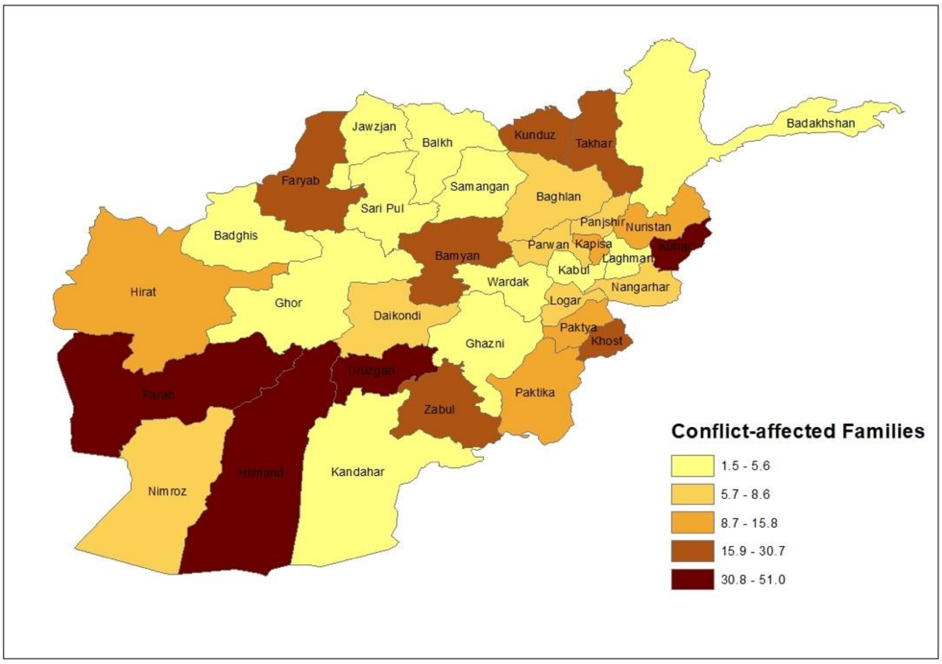


Figure A.18. Map of the Average Monthly Income in Afghanistan



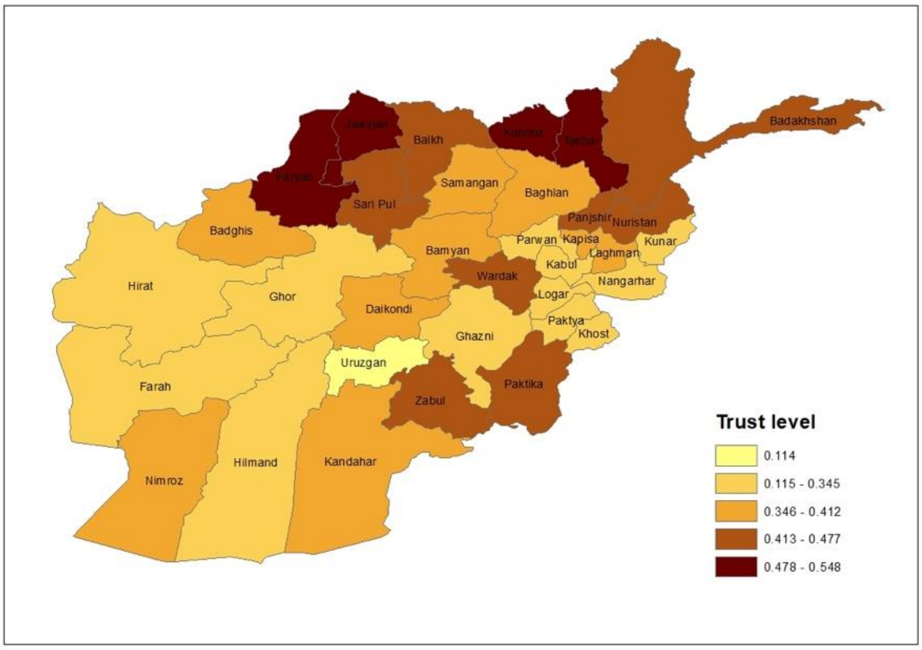
Data Source: Seasonal Food Security Assessment 2017.

Figure A.19. Map of Conflict in Afghanistan



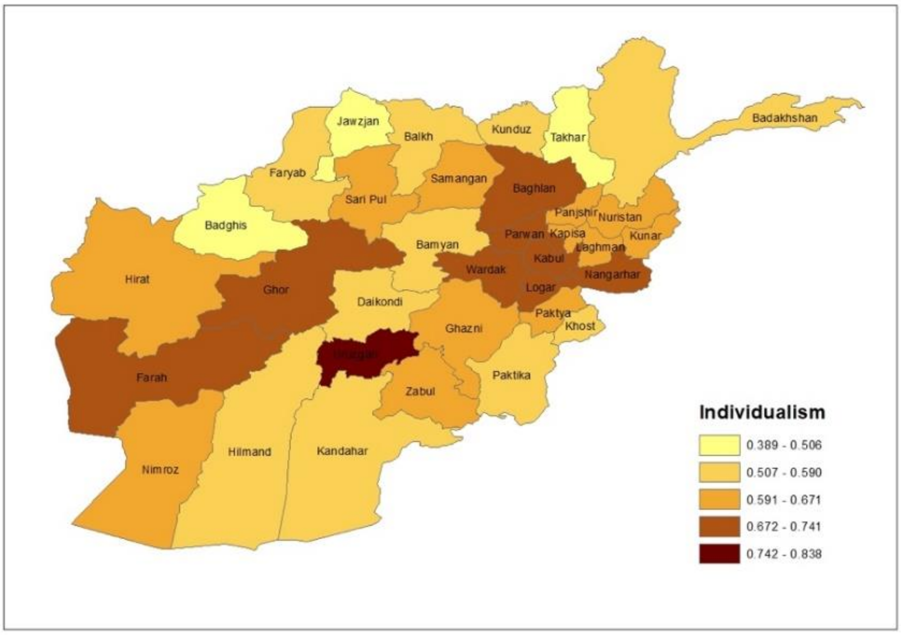
Data Source: Seasonal Food Security Assessment 2017.

Figure A.20. Map of Trust Level in Afghanistan



Data Source: Asia Foundation Survey (aggregated from 2006 & 2017).

Figure A.21. Map of Individualism in Afghanistan



Data Source: Asia Foundation Survey (aggregated from 2006 & 2017).

Appendix to Essay 1 (Tables)

Table A.1. Ethnic Share and Linguistic Distribution in Afghanistan.

Ethnicity		% share	Language		% share
Pashtun	20972	41.33	Pashto	2444	39.25
Tajik	19410	38.25	Dari	3092	49.66
Uzbek	3222	6.35	Uzbeki	511	8.21
Hazara	5043	9.94	Turkmeni	90	1.45
Turkmen	198	0.39	Urdu	5	0.08
Baloch	649	1.28	Arabic	14	0.22
Aymaq	327	0.64	Russian	1	0.02
Arab	229	0.45	Baloochi	14	0.22
Pashai	18	0.04	Pashaye	34	0.55
Sadat	465	0.92	Hazara	15	0.24
Qazelbash	96	0.19	Other	2	0.03
Gujar	22	0.04	Unknown	4	0.06
Bayat	60	0.12			
Taimani	36	0.07			
Total	**50747**	**100**	**Total**	**6226**	**100**

Source: Asia Foundation Survey (2012-2017) and Asia Foundation Survey (2009).

Table A.2. Correlation

	Access to Safe Drinking Water	Violence or Crime	Electricity Supply	Freedom of Expression	Trust Level	Individ-ualism	Average Monthly Income	Conflict Affected Families	Improved Water Source	Political Preferences	Educa-tion
historical elf	-0.479*	-0.507*	0.492*	0.236	0.536**	0.039	-0.468*	-0.416	-0.418	-0.378	0.056
	(0.083)	(0.064)	(0.074)	(0.417)	(0.048)	(0.894)	(0.092)	(0.139)	(0.137)	(0.183)	(0.850)
historical ethnic polarization	-0.424	-0.405	0.458	0.185	0.469*	0.165	-0.576**	-0.430	-0.352	-0.445	0.261
	(0.131)	(0.151)	(0.100)	(0.527)	(0.091)	(0.573)	(0.031)	(0.125)	(0.218)	(0.111)	(0.367)
Pashto speakers	0.539***	0.710***	-0.579***	-0.557***	-0.400**	0.172	0.339*	0.434**	0.171	0.694***	0.001
	(0.001)	(0.000)	(0.000)	(0.001)	(0.019)	(0.330)	(0.050)	(0.010)	(0.333)	(0.000)	(0.996)
Dari speakers	-0.269	-0.550***	0.401**	0.445***	0.149	0.012	-0.269	-0.427**	-0.070	-0.775***	0.246
	(0.124)	(0.001)	(0.019)	(0.008)	(0.402)	(0.947)	(0.124)	(0.012)	(0.694)	(0.000)	(0.161)
Pashtun proportion	0.630***	0.669***	-0.513***	-0.573***	-0.277	0.193	0.289*	0.382**	0.186	0.820***	-0.074
	(0.000)	(0.000)	(0.002)	(0.000)	(0.113)	(0.274)	(0.097)	(0.026)	(0.292)	(0.000)	(0.677)
Tajik proportion	-0.346**	-0.274	0.255	0.434**	0.068	0.066	-0.179	-0.297*	0.093	-0.728***	0.359**
	(0.045)	(0.117)	(0.146)	(0.010)	(0.704)	(0.713)	(0.310)	(0.088)	(0.600)	(0.000)	(0.037)
ethnic fraction-alization	-0.373**	-0.270	0.408**	-0.008	0.087	-0.179	-0.072	-0.162	-0.012	-0.128	-0.165
	(0.030)	(0.123)	(0.017)	(0.965)	(0.625)	(0.310)	(0.684)	(0.359)	(0.947)	(0.469)	(0.352)
ethnic polarization	-0.287	-0.209	0.379**	-0.075	0.038	-0.095	-0.024	-0.086	0.034	-0.103	-0.191
	(0.100)	(0.235)	(0.027)	(0.675)	(0.830)	(0.595)	(0.891)	(0.630)	(0.850)	(0.563)	(0.279)
linguistic fraction-alization	-0.378**	-0.142	0.357**	0.018	0.298*	-0.055	-0.180	-0.133	-0.190	-0.113	-0.063
	(0.027)	(0.422)	(0.038)	(0.918)	(0.087)	(0.757)	(0.308)	(0.454)	(0.282)	(0.524)	(0.723)
linguistic polarization	-0.294*	-0.083	0.311*	-0.038	0.169	0.052	-0.194	-0.183	-0.233	-0.155	0.048
	(0.091)	(0.640)	(0.074)	(0.833)	(0.340)	(0.771)	(0.271)	(0.300)	(0.186)	(0.381)	(0.786)
Pakistan former British-India border	0.199	0.343**	-0.423**	-0.415**	-0.050	-0.126	0.254	0.218	0.348**	0.531***	-0.292*
	(0.259)	(0.047)	(0.013)	(0.015)	(0.778)	(0.477)	(0.148)	(0.215)	(0.044)	(0.001)	(0.094)
Iranian border	-0.399**	0.038	0.174	-0.161	-0.168	0.146	-0.121	0.151	0.056	-0.102	-0.137
	(0.020)	(0.830)	(0.325)	(0.363)	(0.343)	(0.409)	(0.494)	(0.396)	(0.753)	(0.567)	(0.439)
former Soviet border	-0.441***	-0.352**	0.253	0.387**	0.571***	-0.662***	-0.199	-0.079	-0.026	-0.136	-0.214
	(0.009)	(0.042)	(0.149)	(0.024)	(0.000)	(0.000)	(0.260)	(0.659)	(0.886)	(0.444)	(0.224)

*Note: P-values within parentheses; * indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.*

Table A.3. RD Robust Results for Ethnic Pashtun vs non-Pashtun. BW: MSERD[1]

Outcome variable	**Method**	**Coefficient**	**Std. Err**	**z**	**95% Confidence Interval**		**N**
average monthly income	Conventional	4844.1**	2390.6	2.026	158.598	9529.65	406
	Bias-corrected	5528.4**	2390.6	2.313	842.863	10213.9	406
	Robust	5528.4*	2943.3	1.878	-240.33	11297.1	406
lny	Conventional	0.302	0.322	0.937	-0.330	0.934	406
	Bias-corrected	0.299	0.322	0.929	-0.332	0.931	406
	Robust	0.299	0.390	0.767	-0.466	1.065	406
violence or crime	Conventional	-0.026	0.060	-0.430	-0.143	0.092	406
	Bias-corrected	-0.053	0.060	-0.877	-0.170	0.065	406
	Robust	-0.053	0.066	-0.792	-0.183	0.078	406
individual-ism	Conventional	0.415**	0.174	2.381	0.073	0.756	100
	Bias-corrected	0.473***	0.174	2.715	0.131	0.815	100
	Robust	0.473**	0.215	2.199	0.051	0.895	100
political preferences	Conventional	0.122	0.221	0.549	-0.312	0.555	68
	Bias-corrected	0.236	0.221	1.067	-0.198	0.670	68
	Robust	0.236	0.285	0.829	-0.322	0.794	68
access to water	Conventional	0.834*	0.470	1.773	-0.088	1.756	34
	Bias-corrected	0.928**	0.470	1.973	0.006	1.849	34
	Robust	0.928	0.636	1.460	-0.318	2.173	34

[1] Mean Square Error Regression Discontinuity (MSERD) is a criterion used for the bandwidth selection in the regression discontinuity framework. The use of optimum bandwidth based on the MSERD criterion make the robust bias-corrected estimators valid (Calonico, 2020).

Table A.4. RD Robust Results for Ethnic Pashtun vs non-Pashtun. BW: 100 km

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
average monthly income	Conventional	3809.1***	568.070	6.705	2695.73	4922.53	406
	Bias-corrected	2781.6***	568.070	4.897	1668.2	3895	406
	Robust	2781.6***	975.410	2.852	869.83	4693.37	406
lny	Conventional	0.553***	0.072	7.634	0.411	0.695	406
	Bias-corrected	0.359***	0.072	4.962	0.217	0.501	406
	Robust	0.359***	0.130	2.772	0.105	0.613	406
violence or crime	Conventional	0.089***	0.017	5.299	0.056	0.122	406
	Bias-corrected	0.028	0.017	1.632	-0.006	0.061	406
	Robust	0.028	0.028	0.982	-0.027	0.082	406
trust level	Conventional	-0.050	0.040	-1.255	-0.129	0.028	100
	Bias-corrected	-0.069*	0.040	-1.713	-0.147	0.010	100
	Robust	-0.069	0.070	-0.978	-0.206	0.069	100
individualism	Conventional	0.096**	0.039	2.438	0.019	0.173	100
	Bias-corrected	0.036	0.039	0.907	-0.041	0.112	100
	Robust	0.036	0.077	0.459	-0.116	0.187	100
political preferences	Conventional	0.162*	0.087	1.860	-0.009	0.334	68
	Bias-corrected	-0.157*	0.087	-1.795	-0.328	0.014	68
	Robust	-0.157	0.166	-0.942	-0.483	0.170	68
electricity	Conventional	0.016	0.043	0.379	-0.067	0.100	238
	Bias-corrected	0.166***	0.043	3.904	0.083	0.250	238
	Robust	0.166**	0.074	2.250	0.021	0.311	238
access to water	Conventional	0.887***	0.208	4.272	0.480	1.293	34
	Bias-corrected	-0.046	0.208	-0.222	-0.453	0.361	34
	Robust	-0.046	0.322	-0.143	-0.678	0.586	34

Table A.5. RD Robust results for ethnic Pashtun vs non-Pashtun. BW: MSERD*Error! Bookmark not defined.* **with Covariates**[2]

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
violence or crime	Conventional	-0.026	0.101	-0.263	-0.224	0.171	134
	Bias-corrected	-0.045	0.101	-0.445	-0.242	0.153	134
	Robust	-0.045	0.123	-0.363	-0.287	0.197	134
political preferences	Conventional	0.145	0.106	1.366	-0.063	0.353	68
	Bias-corrected	0.192*	0.106	1.812	-0.016	0.400	68
	Robust	0.192	0.146	1.312	-0.095	0.479	68
access to water	Conventional	1.115***	0.399	2.795	0.333	1.897	34
	Bias-corrected	1.309***	0.399	3.281	0.527	2.091	34
	Robust	1.309***	0.488	2.683	0.353	2.265	34

[2] A different set of covariates was used for each outcome variable.
Income equation: education and violence or crime.
Violence or crime: education, income, freedom of expression.
Trust level, individualism, and political preferences: income level, education, violence, or crime.
Access to safe drinking water, electricity provision: income level, violence, or crime.

Table A.6. RD Robust results for Linguistic Uzbek vs non-Uzbek; BW: MSERD

Outcome variable	**Method**	**Coefficient**	**Std. Err**	**z**	**95% Confidence Interval**		**N**
average monthly income	Conventional	2321.6	3900.2	0.595	-5322.65	9965.83	406
	Bias-corrected	-3433.3	3900.2	-0.880	-11077.5	4210.95	406
	Robust	-3433.3	11004	-0.312	-25001.5	18135	406
lny	Conventional	0.794	0.601	1.322	-0.384	1.972	406
	Bias-corrected	-0.005	0.601	-0.009	-1.183	1.173	406
	Robust	-0.005	1.703	-0.003	-3.343	3.332	406
violence or crime	Conventional	0.018	0.110	0.168	-0.196	0.233	406
	Bias-corrected	0.311***	0.110	2.835	0.096	0.526	406
	Robust	0.311	0.362	0.859	-0.398	1.020	406

Table A.7. RD Robust results for Linguistic Uzbek vs non-Uzbek; BW: 100 km

Outcome variable	**Method**	**Coefficient**	**Std. Err**	**z**	**95% Confidence Interval**		**N**
average monthly income	Conventional	-899.02	866.8	-1.037	-2597.920	799.889	406
	Bias-corrected	6685***	866.8	7.712	4986.110	8383.92	406
	Robust	6685***	1690.1	3.955	3372.520	9997.51	406
lny	Conventional	-0.025	0.116	-0.213	-0.252	0.203	406
	Bias-corrected	1.339***	0.116	11.545	1.112	1.567	406
	Robust	1.339***	0.288	4.658	0.776	1.903	406
violence or crime	Conventional	-0.100***	0.020	-5.006	-0.140	-0.061	406
	Bias-corrected	-0.230***	0.020	-11.460	-0.269	-0.190	406
	Robust	-0.230***	0.057	-4.009	-0.342	-0.117	406
trust level	Conventional	0.010	0.060	0.159	-0.109	0.128	100
	Bias-corrected	-0.238***	0.060	-3.938	-0.356	-0.119	100
	Robust	-0.238	0.219	-1.083	-0.667	0.192	100
individualism	Conventional	-0.098*	0.059	-1.669	-0.214	0.017	100
	Bias-corrected	0.128**	0.059	2.177	0.013	0.244	100
	Robust	0.128	0.174	0.738	-0.212	0.469	100
electricity	Conventional	-0.034	0.066	-0.507	-0.164	0.096	306
	Bias-corrected	0.297***	0.066	4.477	0.167	0.427	306
	Robust	0.297	0.277	1.070	-0.247	0.840	306

Table A.8. RD Robust Results for Linguistic Uzbek vs non-Uzbek; BW: MSERD[1] with Covariates[2]

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
average monthly income	Conventional	1865.3	2083	0.895	-2217.36	5947.95	338
	Bias-corrected	4972.3**	2083	2.387	889.651	9054.96	338
	Robust	4972.3*	2925.9	1.699	-762.448	10707.1	338
lny	Conventional	0.701**	0.353	1.986	0.009	1.393	338
	Bias-corrected	1.23***	0.353	3.485	0.538	1.922	338
	Robust	1.23**	0.478	2.575	0.294	2.167	338
violence or crime	Conventional	-0.059	0.071	-0.835	-0.197	0.079	134
	Bias-corrected	-0.048	0.071	-0.680	-0.186	0.090	134
	Robust	-0.048	0.106	-0.452	-0.256	0.160	134
electricity	Conventional	0.072	0.211	0.340	-0.341	0.485	238
	Bias-corrected	0.097	0.211	0.459	-0.316	0.510	238
	Robust	0.097	0.337	0.287	-0.564	0.758	238

Note: The Uzbek language is a language of the majority of people only in six provinces. Therefore, most equations were not estimated due to too few observations, especially at the lower level bandwidths.

Table A.9. RD Robust results for Dari vs non-Dari; BW: MSERD Error! Bookmark not defined.

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
average monthly income	Conventional	-2803.1***	769.38	-3.643	-4311.02	-1295.11	406
	Bias-corrected	-2974.7***	769.38	-3.866	-4482.7	-1466.79	406
	Robust	-2974.7***	1049.2	-2.835	-5031.13	-918.363	406
lny	Conventional	-0.463***	0.109	-4.240	-0.677	-0.249	406
	Bias-corrected	-0.529***	0.109	-4.846	-0.743	-0.315	406
	Robust	-0.529***	0.142	-3.735	-0.807	-0.251	406
violence or crime	Conventional	-0.019	0.017	-1.160	-0.052	0.013	406
	Bias-corrected	-0.014	0.017	-0.833	-0.046	0.019	406
	Robust	-0.014	0.021	-0.650	-0.056	0.028	406
trust level	Conventional	0.114	0.085	1.345	-0.052	0.279	100
	Bias-corrected	0.123	0.085	1.451	-0.043	0.288	100
	Robust	0.123	0.096	1.272	-0.066	0.312	100
individualism	Conventional	0.003	0.086	0.041	-0.164	0.171	100
	Bias-corrected	0.025	0.086	0.292	-0.143	0.193	100
	Robust	0.025	0.101	0.246	-0.174	0.224	100
political preferences	Conventional	-0.039	0.131	-0.296	-0.296	0.218	68
	Bias-corrected	-0.012	0.131	-0.088	-0.269	0.246	68
	Robust	-0.012	0.153	-0.076	-0.312	0.289	68
electricity	Conventional	-0.049	0.077	-0.645	-0.200	0.101	306
	Bias-corrected	0.013	0.077	0.168	-0.137	0.163	306
	Robust	0.013	0.093	0.138	-0.170	0.196	306
access to water	Conventional	-0.380	0.360	-1.056	-1.085	0.325	34
	Bias-corrected	-0.440	0.360	-1.224	-1.145	0.265	34
	Robust	-0.440	0.680	-0.648	-1.773	0.892	34

Table A.10. RD Robust results for Dari vs non-Dari; BW: 100 km

Outcome variable	Method	Coefficient	Std. Err	z	95% Confidence Interval		N
average monthly income	Conventional	-2406.2***	482	-4.992	-3350.930	-1461.54	406
	Bias-corrected	-2607.7***	482	-5.410	-3552.390	-1663	406
	Robust	-2607.7***	692.04	-3.768	-3964.070	-1251.33	406
lny	Conventional	-0.348***	0.067	-5.234	-0.478	-0.218	406
	Bias-corrected	-0.441***	0.067	-6.632	-0.571	-0.311	406
	Robust	-0.441***	0.097	-4.547	-0.631	-0.251	406
violence or crime	Conventional	-0.031**	0.014	-2.193	-0.059	-0.003	406
	Bias-corrected	-0.039***	0.014	-2.715	-0.066	-0.011	406
	Robust	-0.039**	0.019	-2.053	-0.075	-0.002	406
trust level	Conventional	0.011	0.040	0.290	-0.066	0.089	100
	Bias-corrected	0.035	0.040	0.893	-0.042	0.113	100
	Robust	0.035	0.062	0.573	-0.085	0.156	100
individualis m	Conventional	-0.023	0.044	-0.529	-0.108	0.062	100
	Bias-corrected	-0.052	0.044	-1.189	-0.137	0.034	100
	Robust	-0.052	0.059	-0.881	-0.167	0.063	100
political preferences	Conventional	-0.250***	0.079	-3.165	-0.404	-0.095	68
	Bias-corrected	-0.122	0.079	-1.543	-0.276	0.033	68
	Robust	-0.122	0.114	-1.069	-0.345	0.102	68
electricity	Conventional	-0.062	0.041	-1.535	-0.142	0.017	306
	Bias-corrected	-0.066	0.041	-1.631	-0.145	0.013	306
	Robust	-0.066	0.056	-1.188	-0.175	0.043	306
access to water	Conventional	-0.591***	0.224	-2.642	-1.030	-0.153	34
	Bias-corrected	-0.744***	0.224	-3.324	-1.183	-0.305	34
	Robust	-0.744**	0.327	-2.277	-1.385	-0.103	34

Table A.11. RD Robust Results for Dari vs non-Dari; BW: MSERD[1] with Covariates[2]

Outcome variable	**Method**	**Coefficient**	**Std. Err**	**z**	**95% Confidence Interval**		**N**
average monthly income	Conventional	-3704.6*	2138.2	-1.733	-7895.36	486.1	338
	Bias-corrected	-4351.7**	2138.2	-2.035	-8542.39	-160.928	338
	Robust	-4351.7	3168.7	-1.373	-10562.2	1858.86	338
lny	Conventional	-0.867**	0.385	-2.254	-1.621	-0.113	338
	Bias-corrected	-1.164***	0.385	-3.026	-1.918	-0.41	338
	Robust	-1.164**	0.534	-2.178	-2.211	-0.116	338
violence or crime	Conventional	-0.020	0.037	-0.546	-0.094	0.053	134
	Bias-corrected	-0.013	0.037	-0.342	-0.086	0.061	134
	Robust	-0.013	0.043	-0.301	-0.096	0.071	134
trust level	Conventional	0.089	0.083	1.081	-0.073	0.252	100
	Bias-corrected	0.104	0.083	1.256	-0.058	0.266	100
	Robust	0.104	0.095	1.094	-0.082	0.290	100
individualism	Conventional	0.038	0.084	0.452	-0.126	0.202	100
	Bias-corrected	0.051	0.084	0.615	-0.113	0.216	100
	Robust	0.051	0.099	0.519	-0.143	0.246	100
political preferences	Conventional	0.227	0.151	1.498	-0.070	0.523	68
	Bias-corrected	0.406***	0.151	2.682	0.109	0.702	68
	Robust	0.406*	0.219	1.856	-0.023	0.835	68
electricity	Conventional	-0.140	0.094	-1.491	-0.324	0.044	238
	Bias-corrected	-0.099	0.094	-1.052	-0.283	0.085	238
	Robust	-0.099	0.117	-0.844	-0.328	0.131	238
access to water	Conventional	-0.286	0.281	-1.015	-0.837	0.266	34
	Bias-corrected	-0.089	0.281	-0.317	-0.641	0.462	34
	Robust	-0.089	0.363	-0.246	-0.800	0.621	34

Table A.12. IV Estimation for Political Preferences

	DV: Political Preferences					
	Ethnic Fractionalization	Ethnic Polarization	Linguistic Fractionalization	Linguistic Polarization	Elf Distance	Rq_Distance
Ethno-Linguistic Diversity	-0.456***	-0.309***	-0.670***	-1.672***	-0.839**	-2.533***
	(0.125)	(0.083)	(0.239)	(0.571)	(0.334)	(0.840)
Education	-1.108***	-1.161***	-0.862**	-0.697**	-1.079***	-0.969***
	(0.350)	(0.340)	(0.343)	(0.336)	(0.336)	(0.337)
LnY	0.283***	0.290***	0.234***	0.225**	0.233***	0.211***
	(0.066)	(0.068)	(0.068)	(0.067)	(0.070)	(0.074)
Violence or Crime	0.113	0.139	0.274	0.342	0.147	0.176
	(0.253)	(0.246)	(0.320)	(0.324)	(0.307)	(0.328)
Constant	-1.658***	-1.712***	-1.230**	-1.165*	-1.208*	-0.978
	(0.592)	(0.602)	(0.617)	(0.607)	(0.639)	(0.677)
Obs	68	68	68	68	68	68
R-squared	0.212	0.215	0.082	0.117	0.088	0.058
Wald stat	75.67	76.2	39.44	41.97	40.84	41.52
	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
1st stage F-stat	36.71	49.6	4.44	3.97	5.05	4.74
	0.000***	0.000***	0.000***	0.001***	0.000***	0.000***
Civilization Diversity	0.472***	0.787***	0.342**	0.143**	0.286**	0.114***
	(0.138)	(0.196)	(0.149)	(0.062)	(0.110)	(0.042)
Old Persian	-147.817***	-188.343***	-37.747	-25.973	-5.078	-7.369
	(50.280)	(65.703)	(56.477)	(22.558)	(46.661)	(17.134)
Greek	-147.482***	-188.202***	-37.359	-25.814	-4.725	-7.249
	(50.212)	(65.612)	(56.423)	(22.558)	(46.595)	(17.117)
East Iranian	-147.803***	-188.309***	-37.607	-25.880	-4.950	-7.303
	(50.231)	(65.648)	(56.412)	(22.543)	(46.621)	(17.125)
Islamic Persian	-147.815***	-188.433***	-37.733	-25.937	-5.009	-7.331
	(50.236)	(65.658)	(56.426)	(22.546)	(46.638)	(17.129)
Turkic	-147.559***	-187.953***	-37.477	-25.815	-4.887	-7.268
	(50.246)	(65.666)	(56.437)	(22.553)	(46.634)	(17.130)

*Note: Standard error in parentheses; * indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.*

Appendix to Essay 2

Table B1. Malmquist Index Summary for the Plant Means

Fuel Type	Firm	Efficiency Change	Techno-logical Change	Pure Efficiency Change	Scale Efficiency Change	TFP Change
Gas	5	1.109	1.023	1.000	1.109	1.135
Gas	6	1.096	1.195	1.106	0.991	1.311
Gas	8	1.126	1.144	1.066	1.056	1.288
Gas	9	1.145	1.103	1.090	1.050	1.263
Gas	10	1.180	1.129	1.102	1.071	1.331
Gas	11	1.001	1.024	1.000	1.001	1.025
Gas	12	1.053	1.074	1.041	1.012	1.131
Gas	16	1.028	1.079	1.036	0.992	1.110
Gas	17	1.082	1.137	1.080	1.002	1.230
Gas	19	1.081	1.081	1.070	1.010	1.169
Gas	23	0.860	1.067	0.861	0.999	0.918
Gas	27	0.995	1.091	0.996	1.000	1.086
Gas	30	1.014	0.952	1.000	1.014	0.965
Gas	32	1.002	0.941	0.992	1.011	0.943
	Mean	1.055	1.074	1.031	1.023	1.136
RFO	13	1.029	1.102	1.018	1.011	1.134
RFO	14	1.001	1.102	0.990	1.012	1.103
RFO	15	1.020	1.086	1.020	1.000	1.108
RFO	18	1.092	1.086	1.074	1.017	1.186
RFO	20	0.976	1.103	0.971	1.005	1.076
RFO	21	0.992	1.030	0.971	1.022	1.022
RFO	24	0.941	1.009	0.934	1.008	0.949
RFO	25	1.051	1.104	1.038	1.013	1.160
RFO	26	1.000	1.074	1.000	1.000	1.074
RFO	28	0.969	0.965	0.969	1.000	0.935
RFO	29	1.105	0.960	1.095	1.009	1.060
RFO	33	1.033	1.195	1.027	1.006	1.235
RFO	34	1.030	1.170	1.033	0.998	1.205
	Mean	1.018	1.076	1.011	1.008	1.096
Gas and RFO	1	1.171	1.104	1.000	1.171	1.293
Gas and RFO	2	1.035	1.173	1.000	1.035	1.215
Gas and RFO	3	1.094	1.208	1.039	1.053	1.321
Gas and RFO	4	1.096	1.128	1.030	1.064	1.236
Gas and RFO	7	1.070	1.157	1.006	1.064	1.239
Gas and RFO	22	0.921	1.067	0.911	1.011	0.983
Gas and RFO	31	1.000	0.901	1.000	1.000	0.901
	Mean	1.055	1.105	0.998	1.057	1.170
	Grand mean	1.039	1.079	1.015	1.023	1.121

DEA data envelopment analysis, RFO residual fuel oil, TFP total factor productivity.
Source: Authors' calculations.

Table B2.1. Cost and Carbon Efficiency with Variable Returns to Scale Assumption

Plant	Cost DEA with Price Specification			Efficiency Scores with Isocarbon Line			Fuel Type
	Technical Efficiency	Allocative Efficiency	Cost Efficiency	Technical Efficiency	Allocative Efficiency	Carbon Efficiency	
1	0.652	0.314	0.205	0.652	0.705	0.460	Gas and RFO
2	1.000	0.312	0.312	1.000	0.726	0.726	Gas and RFO
3	0.771	0.132	0.102	0.771	0.307	0.237	Gas and RFO
4	0.321	0.902	0.290	0.321	0.980	0.315	Gas and RFO
5	0.179	1.000	0.179	0.179	1.000	0.179	Gas
6	0.555	1.000	0.555	0.555	1.000	0.555	Gas
7	0.558	0.212	0.119	0.558	0.457	0.255	Gas and RFO
8	1.000	1.000	1.000	1.000	1.000	1.000	Gas
9	0.838	1.000	0.838	0.838	1.000	0.838	Gas
10	0.654	1.000	0.654	0.654	1.000	0.654	Gas
11	0.767	1.000	0.767	0.767	1.000	0.767	Gas
12	1.000	1.000	1.000	1.000	1.000	1.000	Gas
13	1.000	1.000	1.000	1.000	1.000	1.000	RFO
14	0.811	0.163	0.132	0.811	0.381	0.309	RFO
15	0.811	0.162	0.131	0.811	0.378	0.306	RFO
16	0.998	1.000	0.998	0.998	1.000	0.998	Gas
17	0.598	1.000	0.598	0.598	1.000	0.598	Gas
18	0.813	0.232	0.189	0.813	0.542	0.440	RFO
19	0.634	1.000	0.634	0.634	1.000	0.634	Gas
20	1.000	0.294	0.294	1.000	0.687	0.687	RFO
21	0.879	0.217	0.191	0.879	0.507	0.445	RFO
22	0.251	0.352	0.088	0.251	0.677	0.170	Gas and RFO
23	0.543	1.000	0.543	0.543	1.000	0.543	Gas
24	0.869	0.280	0.244	0.869	0.654	0.569	RFO
25	0.922	0.278	0.256	0.922	0.649	0.598	RFO
26	0.790	0.224	0.177	0.790	0.523	0.414	RFO
27	0.548	1.000	0.548	0.548	1.000	0.548	Gas
28	0.977	0.194	0.19	0.977	0.453	0.442	RFO
29	0.751	0.185	0.139	0.751	0.431	0.324	RFO
30	0.157	1.000	0.157	0.157	1.000	0.157	Gas
31	1.000	0.220	0.220	1.000	0.396	0.396	Gas and RFO
32	0.216	1.000	0.216	0.216	1.000	0.216	Gas
33	1.000	0.209	0.209	1.000	0.487	0.487	RFO
34	0.883	0.205	0.181	0.883	0.477	0.421	RFO
Mean	0.728	0.591	0.393	0.728	0.748	0.520	

DEA: data envelopment analysis, RFO: residual fuel oil, TFP: total factor productivity.
Source: Authors' calculations.

Table B2.2. Cost and Carbon Efficiency at Technically Efficient Inputs

Plant	Target Electricity Production (GWh)	Target Gas Consumption (MMBTU)	Target RFO Consumption (MMBTU)	Fuel Cost Reduction	CO2 Reduction	Cost Efficiency	Carbon Efficiency
1	160	155,034	1,527,600	34.762	34.803	0.314	0.705
2	76	6,763	1,364,908	0	0	0.312	0.726
3	4,515	236,187	40,571,308	22.871	22.878	0.132	0.307
4	1,832	7,818,473	362,475	67.863	67.863	0.902	0.980
5	4,386	18,085,622	0	82.113	82.113	1.000	1.000
6	353	2,456,765	0	44.539	44.539	1.000	1.000
7	2,577	3,244,823	14,121,228	44.175	44.171	0.212	0.457
8	100	1,476,328	0	0	0	1.000	1.000
9	196	1,848,351	0	16.193	16.022	1.000	1.000
10	504	3,041,926	0	34.556	34.504	1.000	1.000
11	356	2,468,390	0	23.264	23.307	1.000	1.000
12	6,222	25,200,569	0	0	0	1.000	1.000
13	7,796	0	73,767,491	0	0.003	1.000	1.000
14	1,754	0	13,934,887	18.890	18.899	0.163	0.381
15	1,797	0	14,360,707	18.919	18.910	0.162	0.378
16	182	1,794,098	0	0.184	0.404	1.000	1.000
17	1,149	5,541,458	0	40.157	40.147	1.000	1.000
18	564	0	4,070,854	18.747	18.776	0.232	0.542
19	755	4,014,613	0	36.608	36.624	1.000	1.000
20	210	0	1,865,036	0	0	0.294	0.687
21	826	0	5,703,409	12.072	12.072	0.217	0.507
22	1,160	2,516,996	3,856,725	74.851	74.856	0.352	0.677
23	2,865	12,191,376	0	45.717	45.720	1.000	1.000
24	252	0	2,126,743	13.073	13.004	0.280	0.654
25	260	0	2,176,592	7.811	7.953	0.278	0.649
26	679	0	4,787,433	20.951	20.974	0.224	0.523
27	4,146	17,155,563	0	45.208	45.213	1.000	1.000
28	1,221	0	8,656,705	2.306	2.338	0.194	0.453
29	1,333	0	9,765,816	24.873	24.873	0.185	0.431
30	1,390	6,475,392	0	84.330	84.332	1.000	1.000
31	6,304	3,749,075	47,799,321	0	0	0.220	0.396
32	773	4,084,367	0	78.429	78.424	1.000	1.000
33	1,087	0	7,329,732	0	0	0.209	0.487
34	1,121	0	7,666,427	11.745	11.761	0.205	0.477

CO_2: carbon dioxide, GWh: gigawatt hours, MMBTU: million British thermal unit, RF: residual fuel oil.

Source: Authors' calculations.

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Data Sources:

World Development Indicator

https://databank.worldbank.org/source/world-development-indicators

BP Statistical Review of World Energy 2019

http://www.bp.com/statisticalreview

The Global Economy

https://www.theglobaleconomy.com/download-data.php

Erklärung

Ort, Datum:…………………….…………..

<u>Erklärung gem. § 4 Abs. 2</u>

Hiermit erkläre ich, dass ich mich noch keinem Promotionsverfahren unterzogen oder um Zulassung zu einem solchen beworben habe, und die Dissertation in der Gleichen oder einer anderen Fassung bzw. Überarbeitung einer anderen Fakultät, einem Prüfungsausschuss oder einem Fachvertreter an einer anderen Hochschule nicht bereits zur Überprüfung vorgelegen hat.

Unterschrift: ……………………….……….………….…

Ort, Datum:…………………….…………..…..

<u>Erklärung gem. § 10 Abs. 3</u>

Hiermit erkläre ich, dass ich für die Dissertation folgende Hilfsmittel und Hilfen verwendet habe:

- Stata
- Microsoft Office
- ArcGIS
- R studio
- E-views
- DEAP

Auf dieser Grundlage habe ich die Arbeit selbstständig verfasst.

Unterschrift: ……………………….……….………….…