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TARIFF REFORMS AND INTERSECTORAL ALLOCATION NATURAL GAS: EVIDENCE FROM BANGLADESH

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APRIL 2010

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INTRODUCTION

1. Bangladesh can be said to be standing at an historical crossroads with respect to energy resource policy. Past decades of relatively abundant natural gas supported a set of policies that are unlikely to be sustainable in future decades. As of April 5, 2012, the country faced shortages of 400 million cubic feet of gas and 1400 mw of electricity per day, according to official estimates. The country still faces widespread poverty and the potential for conflict to arise as a result of energy and water shortages is not being ignored by the state, which has "tightened security across the country" (Karim: 2012). Energy shortages not only affect individual citizens, but have also antagonized business leaders, who fear that these problems could undermine the industrial and agricultural sectors as well. A better understanding of the topic is significant not only for long-term policy analysis, but also pressingly upon current public and private economic concerns. This report is intended to support evidence based dialog on the country's energy future.

2. Available evidence suggests that natural gas is very inefficiently allocated across the national economy. Moreover, this misallocation is reinforced by official pricing policies that encourage inappropriate technology choice and resource use in the electric power, fertilizer. The same policies also act to discourage both energy efficiency and development of gas reserves. With closer attention to both domestic and international economic realities, these policies could be reformed advance both livelihood and energy security objectives for Bangladesh.

OVERVIEW OF NATURAL GAS AND THE BANGLADESH ECONOMY

3. Domestically produced natural gas provides the vast majority of Bangladesh's energy. The country has limited alternatives and will continue to rely primarily on this energy source to fuel its development. Bangladesh imported 16% of its energy fuel in 2009 (mostly oil), and remains heavily dependent on biomass for energy production, particularly in rural areas. The country suffers from endemic energy poverty, and 96 million people remain without access to electricity (IEA, World Outlook 2011). The country's electrification rate of 41% is far below that of its neighbor India at 75%, and lack of access to electricity remains a challenge for development, and an essential criterion for success in Bangladesh's energy policy.

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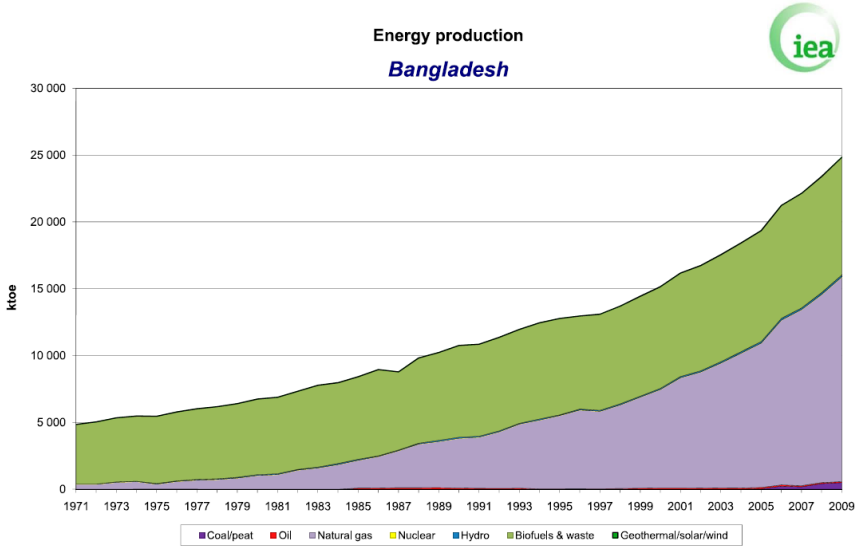
Figure 1:



Source: IEA: 2012

Table 1: National Power Consumption Comparison

COUNTRY	2009 ELECTRIC POWER CONSUMPTION (KWH PER CAPITA)
BANGLADESH	252
INDIA	597
PAKISTAN	449
CHINA	2631

Source: IEA: 2012

4. Per capita electric power consumption in Bangladesh is low even relative to income per capita (Figure 2), suggesting that the country's economic growth to date has occurred despite serious constraints on electrical infrastructure. Almost three quarters of Bangladesh's population live in rural areas, and about half are employed in agriculture (World Bank: 2004), and Bangladesh's electrical sector is more appropriate to that of an agrarian society. If the economy proceeds with energy-intensive industrialization and urbanization that has come to define developing countries, electrification and energy production will have to expand substantially.

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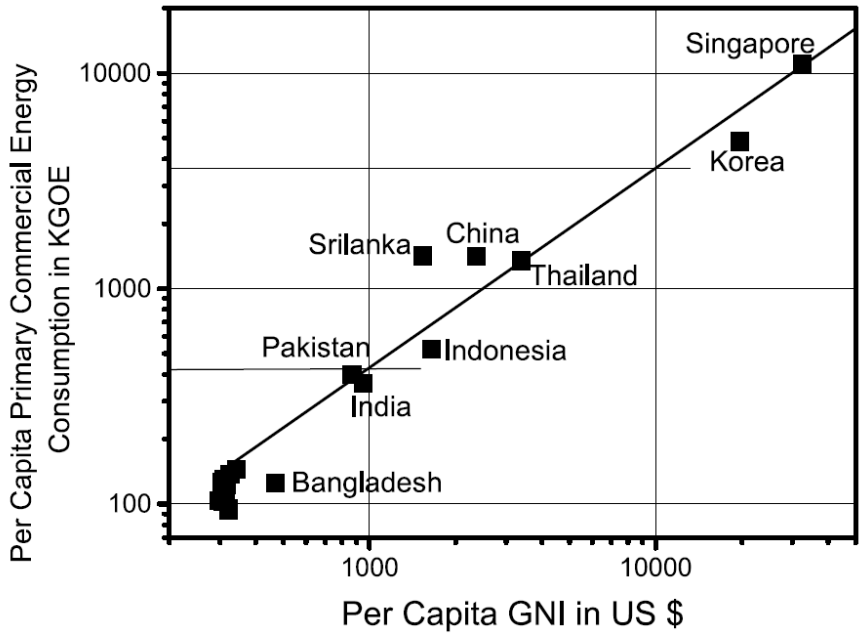
Figure 2: Per Capita Commercial Energy Consumption versus Per Capita GNI of Some Selected Asian Countries



Source: Per Capita Energy BP (2009) & Per Capita GNI (WB 2009)

5. Bangladesh's gas industry is primarily managed by State-Owned Enterprises (SOEs), grouped under the Bangladesh Oil, Gas and Mineral Corporation (Petrobangla), which are involved in all stages of onshore exploration, production and transmission. These companies have survived with government guarantees, and sustained a record of consistent losses. The energy industry has argued that tariff and price controls have prevented them from raising end-user prices while input prices have gone up. At the same time, however, widely publicized scandals have led to allegations of widespread mismanagement and corruption[1]. As with many state-owned enterprises, Bangladesh's gas companies may face conflicts of interest due to political interference, soft budget constraints, and lack of accountability to investors and capital market discipline.

[1] From gas worker to multi-millionaire. (2008, February 06). *Mumbai Mirror*. Retrieved from http://m.mumbaimirror.com/index.aspx?Page=article§name=News - World§id=4&contentid=20080206200802060208168878 84c25f4

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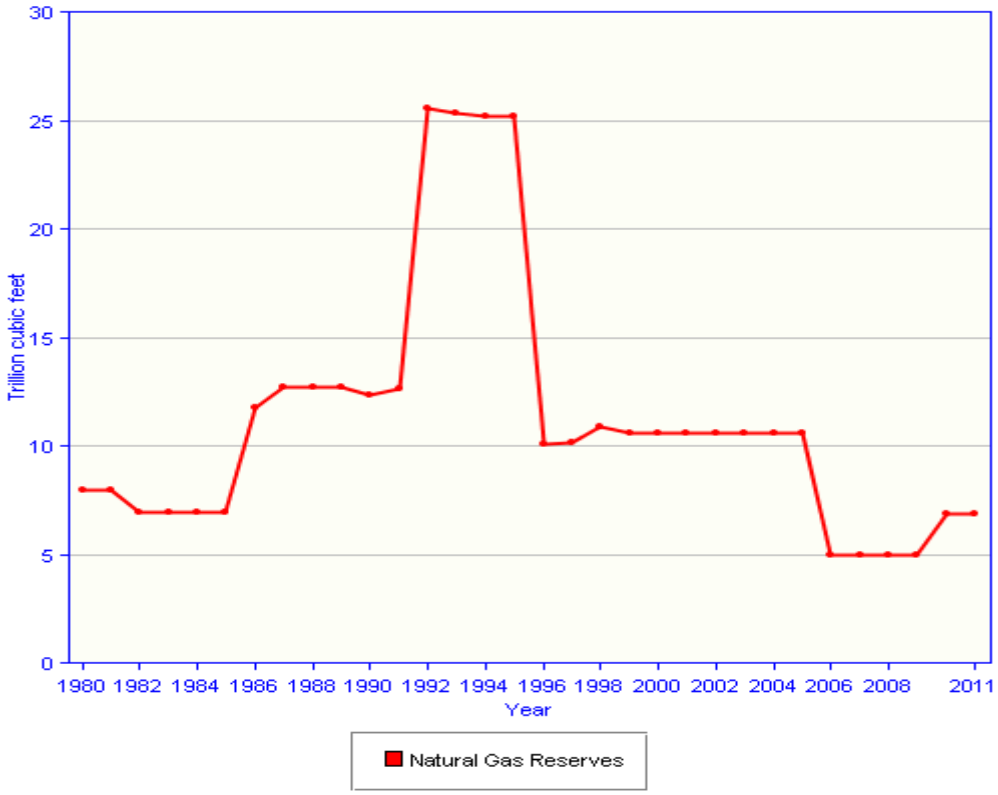
Figure 3: Proven Gas Reserves



Source: Petrobangla:2012.

6. Bangladesh faces a further challenge in that its proven reserves of natural gas are highly uncertain. In 2001 a joint research project with the United States Geological Survey estimated the country's total potential at 30 trillion cubic feet (TCF), but it remains unclear how much of this will every be recovered. As the following table makes clear, after discounting for recoverability and past production, available reserves may be as low as 13.53TCF.

7. As of 2011, BP estimated available reserves at 12.8TCF, with a reserve to production ratio of 18.3, meaning at existing capacity and domestic demand, reserves would be exhausted in less than 20 years (BP: 2011). In the same year, however, the domestic production consortium signed an agreement with foreign, while Bangladesh Petroleum Exploration and Production Co (Bapex) announced the discovery of a new reserves estimated to be at least 1TCF and perhaps as much as 2.4TCF. With reserved fluctuating annually by up to 15%, the supply side of the country's gas market remains plagued by uncertainty and risk.

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Table 2: Estimates of Proven Gas Reserves, 2009

Gas (Proven+Probable)	**28.62 TCF**
Recoverable	**20.63 TCF**
Cumulative Gas Production as June-07	**7.10 TCF**
Remaining Reserves	**13.53 TCF**
Gas Production in June-07	**0.04 TCF**

Note: TCF=trillion dry cubic feet.

Source: Petrobangla:2008.

8. Projected figures from Petrobangla, and the EIA graph of proven gas reserves above, reinforce the impression that Bangladesh could soon face a domestic supply problem. Financial constraints appear to limit the prospect for heavy investments required for nuclear energy, and Bangladesh lacks resource endowments to consider other forms of energy. As demand continues to grow, this may become the leading concern of energy policy, and will spill over into other areas as subsidizing energy imports places increasing strain on government finances.

9. In 2001, Unocal proposed to build a pipeline from Bangladesh to India, in order to export Bangladeshi gas to the HBJ pipeline, the backbone of India's gas infrastructure. Indian demand for gas would have built foreign exchange reserves, and the World Bank projected that Bangladesh would profit more from exporting gas than gas-intensive value-added products like electricity or fertilizer, which were then Bangladesh's major gas product exports. The suggestion met with enormous political resistance from opposition parties, motivated both by uncertainty about the extent of domestic gas reserves and by nationalist demands to fulfill demand at home before exporting. Bangladesh ultimately declined to export, a policy that continues to this day.

10. The recent discovery of large offshore reserves by French oil giant Total in 2009, who later renounced their exploration rights, citing "commercial unviability" in the area after a $30 million survey, may have helped improve prospects for the country's reserves (Quadir 2009). Bangladesh's national companies have restricted their operations to onshore gas fields, and the country appears to be completely dependent on international oil companies for the technology and investments to pursue offshore exploration. With the resolution of a maritime dispute with Myanmar in March 2012, outside energy firms have taken an interest in buying exploration rights in the blocks on sale. As of April 2012,

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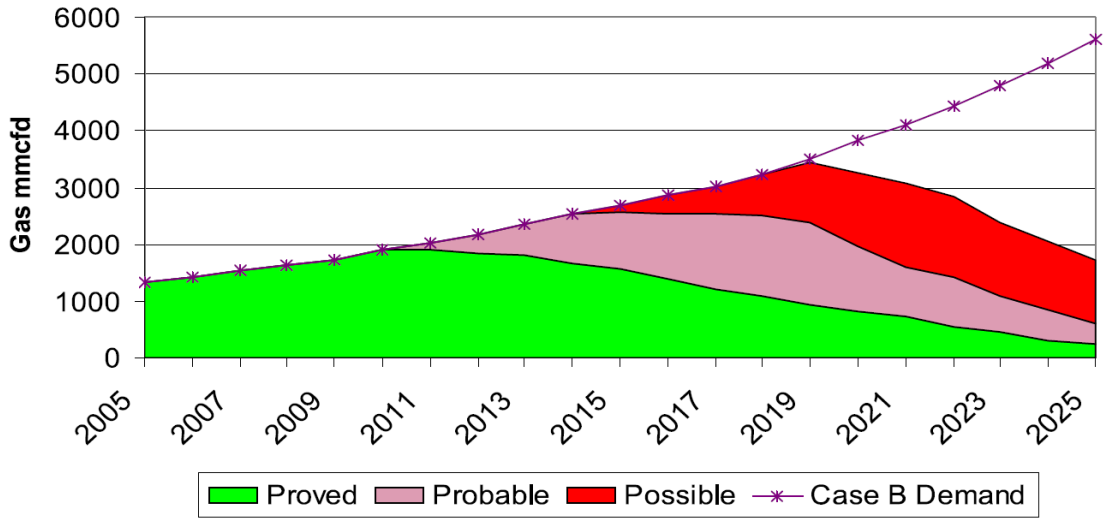
ConocoPhillips owns exploration rights to two deep-water blocks, and Santos is the only operator of an offshore gas field in the Sangu block of the Bay of Bengal. Due to long-standing maritime disputes between Bangladesh, Myanmar, and India, investors have repeatedly shied away from offshore exploration and development, and little geological data is available on the deep sea of Bangladesh, so the extent of the reserves in the Bay of Bengal remains unknown. So far, only two commercially viable gas finds have been discovered in offshore Bangladesh, one in 1996 and one in February of 2012.

Figure 4: Projected Supply and Demand



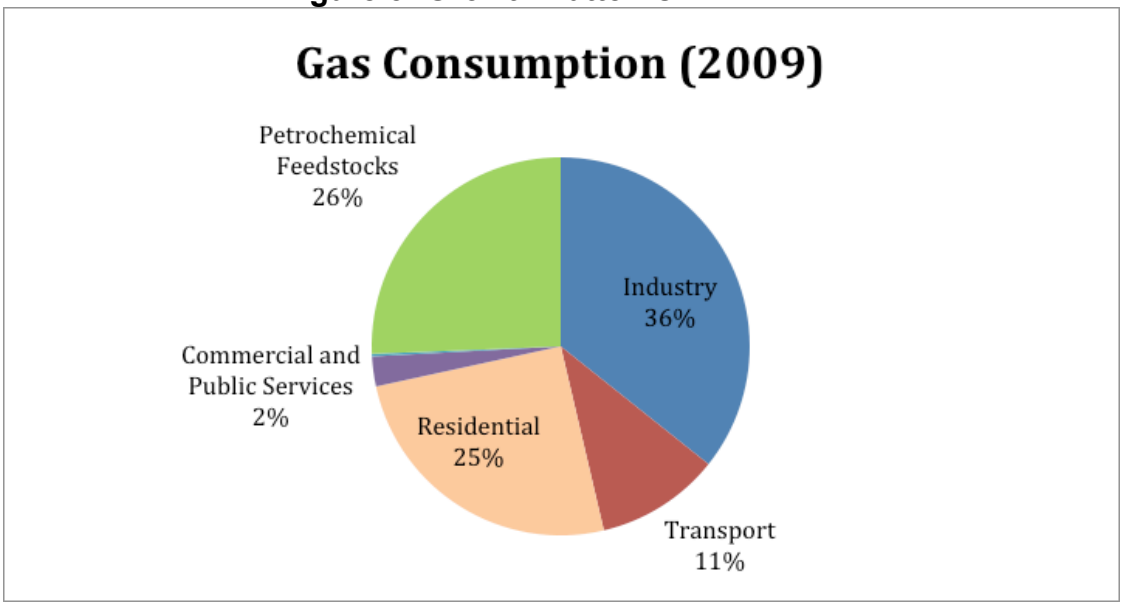
Sarwar, M. (2008)

11. The debate around exports hinges on the extent to which new discoveries in the Bay of Bengal can increase Bangladesh's proven reserves, creating excess capacity above expected domestic demand growth. The prospect of exhausting reserves has been the strongest argument leveled against a gas export policy, one that has resonated across Bangladeshi society. Current energy shortages have reinforced a political environment hostile to exporting in the short term. As the finance minister, Abul Maal Abdul Muhith, has commented, "We do not have proven reserves of several trillion of gas, and the LNG system does not exist in the country. So, the question of exporting gas is nonsense" ("Muhith rubbishes talk of gas export" 2011). Bangladesh does not currently import natural gas.

12. The role for International Oil Companies (IOCs) has been controversial in Bangladesh. Their presence is a logical result of financial and technical capacity constraints among the SOEs, but they have also been accused of pilfering Bangladesh's natural resources to sell on global markets (effectively circumventing Bangladesh's policy on exports). Current conditions for export on the part of IOCs (namely that local

demand is not being met, and that the gas must be converted to LNG, though no such facilities exist in Bangladesh) would appear to render these accusations meaningless, but the opposition to IOCs contends that enforcement mechanisms may not be strong enough to ensure that gas originating in Bangladeshi reserves actually comes to the domestic market (Bergman 2011). An alternative argument against exporting gas can be made - that enriching state coffers might not increase quality of life for citizens as much as would redistribution of gas resources directly to consumers and businesses. Transparency International gave Bangladesh a relatively low score (2.7) on their Corruption Perception Index, suggesting potential distrust of the state in dealing with export revenue accruing to SOEs ("Corruption Perceptions Index 2011").

Figure 5: Growth Patterns



Source: IEA, 2010

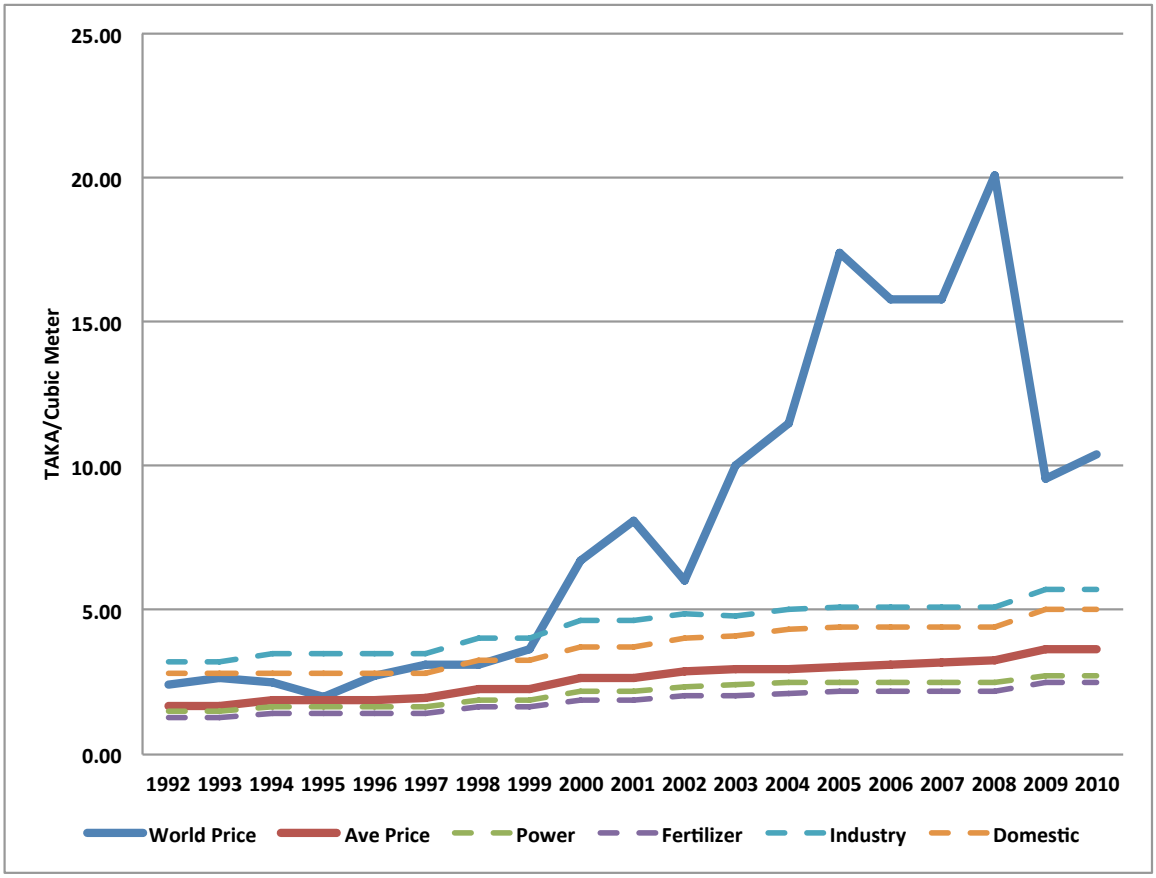
Table 3: Retail Gas Prices by Use (Taka/CM)

Retail	**2.82**
Fertilizer	**2.58**
Industry	**5.86**
Commercial	**9.47**
Tea-Estate	**5.86**
Domestic	**5.16**
Captive Power	**4.18**
CNG Feedstock	**9.97**

Source: PetroBangla, 2010.

13. Economic development in Bangladesh has been shaped by energy policy in a number of ways. The urban centers of Dhaka and Chittagong have clearly benefited from growing industrial sectors due to the placement of gas infrastructure, and urban residents in general benefit from much higher electrification rates than their rural counterparts, a common feature in developing countries. Eastern Bangladesh, the source of all of the onshore gas fields, has benefited from an energy source that has not been distributed as widely in Western Bangladesh, where the transaction costs of building gas-transporting infrastructure have constrained energy supplies.

Figure 6: Annual Dry Gas Prices (Taka/CM)



Source: Author estimates from IEA, World Bank, and Petrobangla sources.

14. At least as important as reserves is the issue of gas tariffs, which in Bangladesh are highly differentiated as a matter of government policy. The degree of price stratification is apparent in the next figure, which compares average and domestic world prices with prices administered to different demand categories. A few salient features of these trends have important policy implications. Firstly, world wholesale gas prices, even accounting for the steep fall over the last few years, have remained above domestic retail prices for at least a decade. This divergence promotes overuse of gas domestically

and increases the opportunity cost of export restrictions. Secondly, the degree of price discrimination between domestic activities is dramatic, with strong bias in favor of electric power and fertilizer, and against households and energy. The recent premium of the latter two trends over world wholesale prices may not reflect profits, but merely domestic inefficiency in processing and distribution.

15. A differentiated energy tariff regime has encouraged different sectors. The fertilizer sector enjoys the lowest tariff for gas, as well as important cash subsidies. Power and agriculture have both been favored by gas policy because they are assumed to benefit the largest proportion of people, and shortfalls or tariff increases in either could be costly from a political perspective. The argument has been raised that this is inefficient as electricity access in Bangladesh is so low to begin with that it is doubtful power subsidies really benefit the poor ("Natural Gas Pricing in Bangladesh: A Preliminary Assessment" 2010). With an electrification rate of 41%, it is possible that lower tariffs disproportionately benefit urban dwellers with an already higher standard of living than the majority of Bangladeshis. We shall return to this issue in our section “Impact on Households”.

Table 4: Costs and Contributions to Power Sector by Fuel Type (2006)

FUEL	AVERAGE COST (TK./KWH)	% OF CURRENT SOURCES
NATURAL GAS	1.69	86.25%
PETROLEUM FUELS	13.04	5.57%
COAL	3.14	4.27%
HYDRO	.65	3.91%
WEIGHTED AVERAGE	2.36	

Source: ("Natural Gas Pricing in Bangladesh: A Preliminary Assessment": 2010.

16. The importance of natural gas for power is made clear in Table 4. Gas is by far the leading fuel for electric power generation and, due to the limited hydropower generation capacity, natural gas is the most cost competitive option. The Bangladesh Chamber of Commerce has released a paper calling for increased use of coal, which might become competitive with gas were subsidies to be removed, but the government has hesitated to move towards this option due to opposition from citizens’ groups. The current method of

importing petroleum fuels to make up some of the gas shortage seems an extremely expensive solution for the government, and one that is almost certainly unsustainable without subsidies or tariff raises. Nuclear power requires investments of time and capital that the government does not have, and renewable energy is far too expensive. Traditional biomass is still used as an alternate fuel.

17. The approved tariff in 2008 was 2.37 Tk./kWh, for a net profit of about .01 Tk./kWh. Low tariffs have historically contributed to weak financial positions and reinvestment opportunities for public utilities, which have caused growth in this sector to lag behind the general economy.

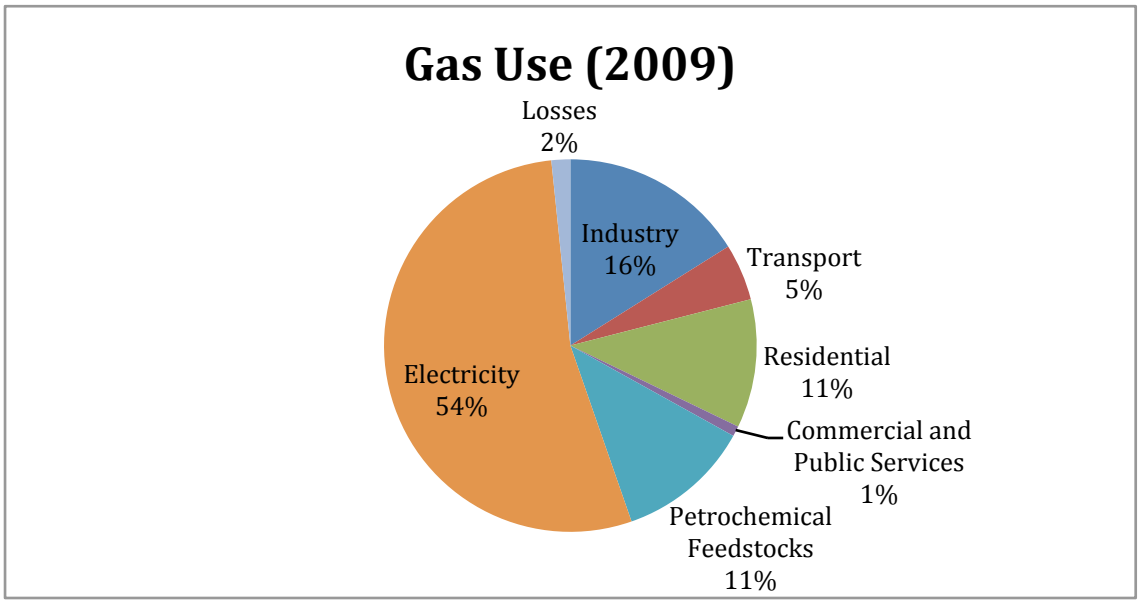
Table 5: Average Cost, Average Price and Marginal Cost of Electricity Production

	AC/KWh*	MC*	Price /KWh**	Weighted AC**
Hydro	0.81	-	3.27	5.09
Natural Gas	3.68	2.26	3.27	5.09
Coal	3.21	4.03	3.27	5.09
Furnace Oil	9.85	7.02	3.27	5.09
HS Diesel	18.33	10.34	3.27	5.09
Average	3.89	2.51	3.27	5.09

Sources: * Haque, A.K. (2012), ** PDB (15 Dec 2011, Info by PDB).

18. According to Haque (2012), natural gas is economically inefficient in the production of electricity because it has failed to achieve economies of scale, as have all other forms of fuel with the exception of coal. The differences between the two tables on this page highlight the difficulty of trying to analyze true costs without the distorting effects of subsidies.

Figure 7:



Source: Petrobangla:2010.

19. Natural gas has become an integral part of the Bangladeshi economy. Bangladesh has developed gas-intensive industries such as fertilizer, and has highly subsidized gas, leading to relatively inefficient industrial and power plants. The need for captive power was recognized as early as 1996 in order to answer the problem of emergency shortages. The median firm owns a power generator, relying on it to produce 28% of its energy (Islam December 2008), a pattern of proliferation of small generators that fail to achieve economic scale and inflate energy demand. System loss in power generation has fallen from 28.5% in 2001 to 20% in 2008, but nevertheless suggests a chronically inefficient distribution system.

20. The government has dealt with energy shortages in a number of ways. Gas rationing is now common for both businesses and households, and several industrial plants have been taken off of the gas grid until capacity has risen to meet demand. There has been some redirection of resources from urban centers to agriculture, in order to ensure energy availability for irrigation purposes.

21. The fertilizer industry appears to be the largest beneficiary of the current gas tariff schedule. According to Haque, this is unwarranted, as the Willingness-To-Pay (WTP) is quite high. Haque also argues that this is because the fertilizer industry has the highest marginal benefits from the use of gas, while current gas-based electricity producers (the other main beneficiary of current gas tariffs) have the lowest.

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Table 6: Marginal Benefits from use of natural gas in different sectors

GAS PRICE CHARGED IN PRODUCDTION OF	(৳ / mcf)	Fertilizer Producers	Electricity Producers			Household users	
			HSD based	Furnace Oil Based	Gas Based	Cooking gas	Vehicle (CNG)
Power	79.82	3,514.18	566.59	438.53	93.14	791.33	1,046.74
Fertilizer	72.92	3,210.39	517.61	400.62	85.09	791.33	1,046.74
Industrial	165.91	7,304.40	1,177.69	911.50	193.59	791.33	1,046.74
Commercial	268.09	11,803.00	1,903.00	1,472.87	312.82	791.33	1,046.74
Tea Garden	165.91	7,304.40	1,177.69	911.50	193.59	791.33	1,046.74
Brick Field	233	10,258.12	1,653.92	1,280.09	271.88	791.33	1,046.74
Domestic (metred)	146.25	6,438.84	1,038.14	803.49	170.65	791.33	1,046.74
		P =======➔	16.06	12.43	2.64		
				Electricity Price			
			HSD	F.Oil	Gas		

Source: Haque, A.K. (2012)

Table 7: WTP for prices of gas per cubic meter

	Fertilizer Producers	Electricity Producers			Household users	
Basis of Gas price		Diesel based	Furnace Oil based	Gas based	Cooking gas	Vehicle (CNG)
Low	124.09	20.01	15.48	3.29	27.94	36.96
High	416.77	67.20	52.01	11.05	27.94	36.96

Source: Haque, A.K. (2012)

22. Haque's policy inference is to turn away from electricity production and focus on other gas use in fertilizer production and household consumption. The current low prices produce a shortage and the discriminatory pricing distorts demand to an economically inefficient allocation.

23. Industry pays slightly above average tariffs, with export-oriented industry gaining preferential treatment in the form of an 80% refund of the national Value-Added Tax on their gas use. Tariffs for transportation-oriented gas (CNG for vehicles), jumped 300% in 2008 after the government realized the willingness of consumers to pay, and both this and commercial demand appear to be heavily discouraged by the current tariff schedule. The government has justified this one the grounds that both sectors have the ability to pay, and that these high tariffs do not affect the majority of Bangladesh's poor.

Table 8: Contribution to Domestic Natural Gas Demand and Revenue

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Sector	Percent Gas Use	Percent Revenue
Power	40.07	30.64
Fertilizer	13.46	8.8
Industry	15.77	24.07
Commercial	1.13	2.71
Tea Estate	0.14	0.21
Domestic	11.81	15.82
CNG	3.9	2.81
Captive Power	13.72	14.94

Source : ("Natural Gas Pricing in Bangladesh: A Preliminary Assessment" 2010)

24. Table 8 illustrates a different point of view on the topic. According to the source, both fertilizer and electricity production are being overrepresented, and from a revenue perspective, industry, commercial and domestic uses of gas have been unreasonably constrained by the current policy mix. A report by the Bangladesh Chamber of Commerce agrees with the assessment that prices should be liberalized and that priority should be shifted away from power, where opportunities exist for coal or for electricity imports from India, Bhutan or Nepal exist (Islam, November 2008).

25. Both the ADB report and Islam stress that the complicated nature of gas tariffs, combined with the lack of transparency and vulnerable financial situation of Petrobangla, are not conducive to economic growth and equitable distribution of the income from Bangladesh's national resources. Islam adds that government agencies have difficulty coordinating projects together, and alleges that governments did not display sufficient initiative in seeking out new fields prior to the power crisis.

26. The general conclusion is that tariff rates are significantly below WTP in all sectors, and that government pricing policy has focused on electricity and fertilizer production, while discouraging other sectors. Across all studies examined, the need for alignment with market prices is emphasized, as is the need for a reevaluation of government priorities. It is clear that low tariff rates have created a shortage due to excess demand and underinvestment, that the benefits of these low rates are very unequally distributed, and that lack of growth and efficiency in both energy and utility infrastructure has constrained economic progress. The question of whether exporting fertilizer, guaranteeing energy access to industry, or allowing domestic consumers and vehicle owners to take an increased share of the gas resources lacks a clear consensus, however.

A. Impact on Households

27. Natural gas serves an important purpose as a household cooking fuel. According to an Asian Development Bank Study ("Natural Gas Pricing in Bangladesh: A Preliminary

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Assessment" 2010), natural gas is by far the cheapest fuel option for domestic households with access to it. Since this criterion is only applicable to the 8% of total households with pipeline connections to gas, this energy use option is primarily of interest to urban dwellers in major cities. Unfortunately, the price is far below the reservation cost for many households, creating a strong incentive for overuse of individual gas connections, ranging from resale of gas through renting out burners to other households to uses of burners for alternative purposes including home heating and commercial enterprises. Households without access to gas are willing to pay far above market price in order to obtain natural gas. The study concludes that it would encourage efficiency and reduce market distortions to allow gas tariffs for domestic use to appreciate.

Table 9: Monthly Cost of Cooking by Fuel Type

Fuel Type	Taka/Month
Natural Gas (Single Burner)	400
Natural Gas (Double Burner)	450
Natural Gas Metered (Taka 4.16/CM, 0.85 CM/hrx8hr/dayx30day/mo)	849
Kerosene (Taka 47/litre x 30 litre/mo)	1410
LPG (Taka 700/cylinder x 2 cyl/mo)	1400
Fuelwood (Taka 4.86/kg x 200kg/mo)	972
Electricity (Taka 5.25/kWh x 1kWh/day x 20 day/mo)	1260

Source: ("Natural Gas Pricing in Bangladesh: A Preliminary Assessment" 2010)

28. Haque's results, given in the table below, appear to substantiate the prior study. The WTP is significantly higher than market rates, and if, according to the information used to create the table above, gas burners are often used for heating purposes as well, it is difficult to imagine that current gas bills are anywhere near WTP, an inference supported by the residential supply shortage. Since there is a substantial social and economic premium on gas, it is unlikely that raising prices would hurt consumers any more than the current shortage. At worst, there would be some redistribution of gas resources from the urban poor to more wealthy potential customers, but the table below indicates that all levels of income are willing to pay in excess of the current market price.

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Table 10: Mean WTP for Households by Monthly Income

			Mean WTP**
Income per month	All households	Connected	Not-Connected
5000	1441	1057	1508
10000	1487	1098	1556
15000	1535	1139	1604
22468*	1606	1203	1677
25000	1631	1225	1701
35000	1729	1313	1801
45000	1829	1404	1902
65000	2033	1592	2108
75000	2137	1690	2213
85000	2242	1789	2319

*Note: * mean income, ** WTP at mean values of variable. Source: Haque, A. K. (2011)*

29. The same assessment applies to electricity, which is priced at production cost rather than demand value, leading to excess demand and shortages (and exacerbating the gas shortage). The major effect on the urban poor, as in the case of gas, may be that many switch from sporadic access to gas to being priced out of consumption as higher income households increase their share of consumption. On the other hand, public receipts from increased gas and electric revenue may benefit the urban poor through increased government expenditures or increased investment in energy and utility infrastructure, which will ultimately expand access to both gas and electricity.

30. The case is more extreme for the rural poor. Since rural electrification rates are far below urban rates, the majority of the rural poor are not affected by tariffs in electricity or gas, other than indirectly through consumption of products such as fertilizer. An increase in price which would strengthen the energy and utility sectors' balance sheets, allowing for greater reinvestment, which in turn could alleviate energy poverty and decrease prices through expansion of supply through economies of scale.

31. The impacts on Bangladeshi public health are varied. Power outages have created a demand for alternate fuel sources: diesel-run generators use expensive imported petroleum products to generate electricity, but also impose significant public health burdens by releasing hazardous gases and smokes. Similarly, substitution with biomass, particularly dung, is an obstacle to development as smoke release, particularly indoors, is the most important source of Indoor Air Pollution. Bangladesh has also suffered from extensive deforestation in the past, and retains 5.9% of its historical forest cover according to FAO estimates, far less than the officially suggested 25%. This would appear to preclude substitution with firewood as environmentally unsustainable for the

country (Ahmed 2008). Power shortages also increase costs for almost all goods and services, including health services.

32. Adverse economic impacts of the current power crisis act mainly through the mechanism of shortages, which builds uncertainty and unneeded transactions costs into commercial, industrial and domestic activities. Gas shortages affect households both directly, through intermittent disruptions of gas consumption, and indirectly, through disruption of gas-requiring resources like water and electricity and by reducing access to those same resources for producers of private or public goods which households consume. In other words, gas shortages have significant short-term consequences and also impoverish households through negatively impacting economic growth by limiting a critical input for production of most goods and services.

33. Haque has outlined the limits at which various income levels will likely be unable to afford gas, and a similar survey would be helpful in establishing boundaries for electricity tariff appreciation. The current premium indicates that there is still a layer of price increases that would reduce real incomes of customers, but reduce consumption mush less so. Increases past the various levels in Table 6 above would redistribute gas resources to wealthier households.

34. Increased tariffs would raise revenues for gas producers and allow for economic realignment among economic sectors. The potential for reinvestment and capacity-building would help households in both urban and rural areas (though with preferences that might be dictated by political economy), but the threat of the value being captured by IOCs or corruption in SOEs appears publically credible. Riots over power outages have erupted with alarming frequency in the last few years, and potential political turmoil adversely affects the investment climate. The tariff situation is at its root a political issue, and a political conflict resolution may be costly for Bangladeshis.

35. Agreement among independent researchers and outside observers is nearly unanimous, that Bangladesh's energy sector has serious problems of institutional weakness and inefficiency, and prices reflect neither resource cost nor willingness to pay. While a few recent finds have raised optimism in Bangladesh about increasing reserves, the current status of proven reserves still suggest the need a long term solution to declining non-renewable resources.

POLICY SCENARIOS

36. To assess the long term implications of Bangladesh's energy situation generally, its natural gas sector in particular, and options for policy reform, we use a dynamic economic forecasting model. This inter-temporal decision tool is designed to trace detailed interactions between demand, supply, and resource use within economies and in their trade with the global economy. In today's world, economic linkages are so

complex that it is unlikely that policy makers relying on intuition alone will achieve anything approaching optimality. Indeed, much evidence now suggests that indirect effects of many policies outweigh direct effects and, if not adequately understood, can substantially offset or even reverse them. Because of their abilities to capture exactly such linkages, computable general equilibrium (CGE) models have become preferred tools for tracing supply and demand linkages across extended chains of price-directed exchange. Because of their detailed behavioural specification, these models are particularly good at elucidating adjustments in income distribution and economic structure.

37. The model we use here was calibrated to a new Social Accounting Matrix, estimated for Bangladesh as of the year 2010. The general structure of the Bangladesh CGE and SAM are summarized below, but suffice for the present to describe the combination of these as a dynamic economic forecasting model that permits assessment of alternative policy scenarios for the country. In the present study, we used it to evaluate several leading issues related to the country's natural gas policy, although these comprise only a few of the issues that can be addressed with this framework. The following table presents seven scenarios considered in the context of natural gas issues raised in the preceding sections.

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Table 11: Policy Scenarios

	Scenario	Description
1	**Baseline**	Business-as-usual reference trends. No policy changes.
2	**MKT**	Equalize natural gas prices across all uses, using a reference market price from India and Pakistan (Taka 5/CM)
3	**MKTEE**	Scenario 2, combined with 1% annual increases in average energy use efficiency.
4	**Fert**	Scenario 3, but Fertilizer is exempt from price reform.
5	**Coal50**	Imported coal is used to meet 50% of domestic electric power production.
6	**GasExp**	Natural gas marketing at world prices is permitted up to 10% of domestic use.
7	**GasCoal**	Scenario 6 combined with domestic coal for 50% of domestic electric power.
8	**InfDev**	Infrastructure investment increased with half of new natural gas marketing revenues.

38. Firstly, we evaluate a Baseline or Business-as-Usual scenario across the forecast period (2010-2030). This assumes no change in current policies and stable trends in global prices, and we use it as a dynamic reference case for the policy alternatives considered. In the second scenario (MKT), we assume the government removes administered price interventions in domestic natural gas markets, eliminating the price dispersion seen in Figure 6 above and achieving something approaching the economywide average gas price in that figure for all uses. Because Bangladesh both subsidizes and taxes gas, depending on the use, removing price distortions will increase prices for some economic actors and lower them for others. The net result for the economy as a whole is an empirical question (indeed an interesting one in itself) that is of great relevance to the country's overall economic performance.

39. Generally speaking, the patterns of price adjustment that emerge from the MKT scenario suggest that energy costs will rise for the economy as a whole, conferring small welfare costs under existing patterns of technology use. If however, the economy were to react to higher energy prices by increasing efficiency, these costs could be averted. Historically, energy subsidies in most countries have been associated with low efficiency levels, while higher energy prices appear to induce conservation behavior and technology adoption that can substantially improve energy efficiency, saving money while stimulating innovation and growth. To assess the potential of such responses to offset the welfare costs removing of Bangladeshi subsidies, as well as contribute to sustainable growth objectives, we examine a third scenario (MKTEE) that implements the same gas pricing policies but assumes the economy responds with very modest but sustained, 1% annual improvements in overall electrical use efficiency. In many industrial economies, these rates of improvement have been exceeded for decades, and

given the relatively low initial energy efficiency levels in Bangladesh today, we believe this is a modest expectation for induced conservation and new technology adoption.

40. A fourth scenario is intended to represent another important dimension of the country's natural gas policy dialog, price policies for the fertilizer industry. As mentioned in previous sections, because natural gas is a primary input to another primary input (fertilizer) that is believed to contribute to food security, many believe that existing subsidies for natural gas in this use should be retained. The fourth (Fert) scenario is the same as MKTEE, except that Fertilizer gas subsidies are retained at Baseline levels.

41. Scenario five (Coal50) represents another leading natural gas policy issue, the argument that less expensive coal should be used as a substitute for natural gas to generate the country's electric power. Although this would increase Bangladesh's import bill, it would also holds the potential reduce costs across the economy, improving export competitiveness and raising real incomes. For this scenario, we assume that electric power investments shift at comparable fixed cost from gas to coal over the 20 period under consideration, achieving 50% replacement of gas-fired capacity by 2030.

42. The sixth scenario (GasExp) represents the obverse of the coal import story. Even though global natural has prices have fallen substantially in recent years, they remain well above domestic prices and significantly so on a trended basis. For this reason, domestic gas use in Bangladesh has a high opportunity cost, in terms of foreign exchange and government revenues that might be earned by taxing these exports to foreign markets. As we have already explained, the current political situation in Bangladesh is less than congenial to gas exports, but this argument is difficult to make on economic grounds. This scenario is intended to support dialog on this important choice facing the country with better evidence. For the sake of illustration, we assume Bangladesh limits its exports to 10% of annual total supply.

43. The seventh scenario combines all the components of a new energy agenda for the country, uniform domestic market prices for gas (except to the fertilizer sector), modest energy efficiency, natural gas exports of up to 10% of domestic supply, and partial coal substitution for gas in electric power generation, but this time with domestic coal. Because this substitution would require a very substantial increase in domestic coal production, we estimate it can only be competitive to about a 25% fuel share, with the rest imported.

AGGREGATE RESULTS

Applying the Bangladesh dynamic forecasting model to the eight scenarios described above, we obtained the results summarized in the following table:

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Table 12: Macroeconomic Results
(percent change from Baseline in 2030)

	MKT	MKTEE	Fert	Coal50	GasExp	GasCoal	InfDev
Real GDP	0.5%	1.5%	4.0%	4.5%	7.7%	24.6%	81.9%
HH Real Income	-0.5%	1.1%	3.7%	3.7%	6.5%	20.2%	63.0%
Real Consumption	-0.5%	1.1%	3.8%	3.8%	6.8%	21.6%	71.9%
Exports	1.4%	1.0%	3.3%	4.7%	10.6%	27.9%	80.5%
Imports	0.5%	0.6%	2.2%	1.9%	9.4%	22.1%	59.3%
CPI	-0.3%	-0.1%	-1.0%	-1.3%	2.1%	0.1%	-6.7%
Real Wage	-0.3%	0.5%	1.5%	1.1%	5.6%	10.2%	21.7%
Rental	-3.5%	-1.3%	-1.3%	-2.7%	0.6%	0.5%	2.9%
Revenue	12.5%	13.2%	6.5%	14.1%	17.2%	24.2%	62.9%
CO2 Emissions	-3.1%	-5.8%	-3.5%	19.5%	23.1%	34.1%	121.3%

Notes: "Revenue" measures the change in government revenue collection, assuming a constant real government budget balance across scenarios. Source: Authors' estimates.

44. A number of salient findings emerge from these results, one's that would likely be robust against reasonable uncertainty regarding external events and the degree of behavior response. Firstly, removing Bangladesh's long established price supports for domestic natural gas, while politically difficult, would not significantly undermine the country's long-term economic growth. Even without the kind of private efficiency responses and complementary policies considered here, the economy's overall GDP would only be one percent smaller two decades from now. Of course there can be many dramatic structural adjustments beneath the smooth veneer of macroeconomic advocates, but clearly energy price subsidies are not essential to the country's overall progress. Indeed, the Baseline assumes stable resource costs, while we know that the country's gas reserves are threatened by continued subsidies and trend usage patterns. These two facts, combined with fiscal sustainability questions, suggest that the Baseline itself may be too optimistic. The revenue impact of this scenario suggests that the government could reduce tax collections over 12% by 2030 if gas subsidies were abolished, while gas price increases would naturally promote conservation.

45. The second scenario reminds us that raising average resource costs has an adverse aggregate welfare effect on the economy as a whole, but what level of conservation and new energy efficiency would be needed to offset this? The answer might be surprising to subsidy advocates, but in fact only very modest EE improvement, 1% per year for electricity use, would convert unsustainable price supports and resource depletion into a more sustainable, growth oriented story. Again, these kinds of improvements are well within reach of even the most advanced economies (e.g. California averaged 1.4% EE

improvement over 1972-2006). For a developing country like Bangladesh, where inefficiency is a widespread and chronic legacy of underinvestment and adverse incentives, the potential for improvement is far greater. So too would be the attendant growth benefits.

46. With our without EE improvements, exempting the Fertilizer sector would more than offset the aggregate welfare costs of natural gas price reform. The reason for this is simple, fertilizer is not merely an input to agriculture but something that increases its productivity. It is important that this indirect (gas input) subsidy not promote unsustainable patterns of fertilizer application, but making this productivity tool less expensive has pervasive cost of living benefits, especially for lower income groups for whom food is a dominant budgetary category (note the relatively large CPI decline).

47. Many have observed that coal would be a more cost effective fuel for Bangladesh's electric power sector. Even though it may take time to transition the country's stock of gas-fired generators, the energy density per Taka of coal is far greater, and gas can then be used for higher value activities such as transport and domestic heating/cooking.

48. Our results (Coal50) strongly support this reasoning, suggesting that gas has a high domestic as well as international cost, and that using coal in the electric power would free the government from subsidies without as much attendant energy cost escalation. Indeed, making coal a primary electric power fuel would reduce domestic gas costs and allow it to fuel higher real consumption, savings, and investment among households and enterprises. Switching to more cost-effective electric power, while reforming gas prices to respond to market forces would take real Bangladeshi GDP 5-25% higher by 2030, depending on the source of coal, with lower costs for enterprises and households, stimulating domestic demand and export competitiveness.

49. It may also be observed that, despite its negative environmental reputation, electric power would be a good place to introduce coal, as its emissions would be more concentrated and thereby easier to monitor and manage. In distributed use, e.g. transport, household heating and cooking, gas would be more appropriate for converse reasons.

50. The sixth scenario asks the energy trade question from the opposite perspective, what is the growth opportunity cost of restricting export sales for Bangladesh natural gas. Our results are unambiguous on this point, even modest sales concessions (10% of domestic supply) would significantly increase the country's aggregate income, employment, and trade. By realizing market prices for at least a fraction of the nation's mineral resources, Bangladesh increases national wealth while promoting more sustainable domestic resource use.

51. The seventh scenario deploys in concert all the gas policy reform measures considered, and the long-term benefits for real growth and incomes, when combined with domestic coal sourcing, are more than additive. This finding makes it clear that

energy policy reform, to be most effective, should be a multi-faceted exercise. This will more effectively distribute adjustment burdens and animate new economic potential, allowing the country to rise to a higher long-term trajectory of livelihood and mutually beneficial engagement with the global economy.

52. Finally, the investment public scenario reminds us of the productivity and growth dividends from infrastructure investment. Reducing trade and transport margins (CPI drops nearly 7%, and real incomes rise accordingly) improves private profitability across the economy, resulting in substantially higher GDP. This strategy also appears to be very beneficial to the public sectors whose fiscal revenues increase over 60% by 2030.

53. Environmental impacts of the policies considered would vary, with atmospheric emissions depending on fuel switching, efficiency measures, and aggregate growth. In the event, both gas market reforms and energy efficiency reduce CO2 and other greenhouse gas (GHG) emissions, while coal substation increases emissions intensity and growth (ceteris paribus) does too. These tradeoffs represent a dilemma for all developing countries, but there are now a wide range of technology choices to address this. The growth and revenue dividends in some of these scenarios suggest that there could be substantial opportunities for complementary mitigation and clean-up policies.

HOUSEHOLD RESULTS

54. Even though Bangladesh's population is predominately rural and predominately low income, there are important sources of economic diversity in the country. Measured in Table 13 by a basic aggregate welfare metric, real consumption, we can see that the eight scenarios will affect different households according to where they are in income distribution, in supply chains, labor markets, and where they live. Note that these results are cumulative, measuring the change in total household real consumption over the whole period considered (2012-2030). This can be contrasted with the macroeconomic results in

55. Results are difficult to generalize, but driven by two main factors – household energy dependence in absolute and relative terms. Some regions have relatively high electrification and other fuel use rates compared to the national average, and particularly some poor households are spending more on energy as a percent of total income. The latter condition, apparent for ChitRur, BariRur, and SlyhetRur, suggests the basic welfare argument for energy subsidies. Unfortunately, these groups can also least afford efficiency technologies, which reinforces the tendency of subsidies to promote excessive consumption.

56. A more important message from the first two scenarios is that energy efficiency can produce savings that offset higher energy price costs for every household category. This does not mean that households can accomplish this alone, because part of the benefit is

lower energy price trends from aggregate conservation. It does mean, however, that conservation and energy efficiency promotion should be an integral part of any policies intended to achieve effective gas price reform.

57. Meanwhile, a food oriented policy (Fert) falls somewhat more uniformly. Of course rural dwellers are poorer, but monetized food costs are a larger proportion of Rural household budgets, and most so for the poor, so all households benefit relatively equally from the indirect food subsidy coming from cheap gas for fertilizer production.

Table 13: Household Real Consumption (cumulative percent change, 2012-2030)

	MKT	MKTEE	Fert	Coal50	GasExp	GasCoal	InfDev
BariRur	-0.5%	0.7%	2.2%	2.2%	4.1%	12.0%	37.1%
BariUrb	-0.6%	0.5%	1.9%	1.8%	4.0%	11.6%	36.3%
ChitRur	-0.5%	0.7%	2.3%	2.3%	4.2%	12.6%	38.7%
ChitSMA	-0.6%	0.5%	1.7%	1.6%	3.8%	11.5%	36.5%
ChitUrb	-0.5%	0.6%	2.0%	2.0%	4.1%	12.2%	38.0%
DhakaRur	-0.5%	0.7%	2.2%	2.3%	4.3%	12.1%	36.9%
DhakaSMA	-0.5%	0.5%	1.9%	1.9%	3.8%	11.6%	37.4%
DhakaUrb	-0.6%	0.5%	1.8%	1.7%	3.8%	11.4%	36.0%
KhulnaSMA	-0.5%	0.6%	2.1%	2.1%	4.2%	12.4%	38.6%
KhulnaUrb	-0.6%	0.5%	1.8%	1.7%	3.9%	11.6%	36.4%
KulnaRur	-0.5%	0.7%	2.4%	2.5%	4.5%	12.7%	38.4%
RajRur	-0.5%	0.8%	2.5%	2.5%	4.9%	14.3%	42.8%
RajSMA	-0.7%	0.6%	1.9%	1.8%	4.1%	11.8%	36.6%
RajUrb	-0.6%	0.5%	1.9%	1.9%	4.5%	13.4%	41.0%
SylhetRur	-0.6%	0.7%	2.1%	2.2%	4.2%	12.1%	37.5%
SylhetUrb	-0.6%	0.3%	1.4%	1.2%	3.4%	10.3%	33.2%
Wgt Average	-0.5%	0.7%	2.2%	2.2%	4.3%	12.6%	38.8%

Source: Authors' estimates.

58. Energy fuel substitution (Coal50) affects households quite diversely because of large differences in baseline household electricity use. As was mentioned in the introductory sections of this report, electrification remains a work in progress across the country, and until it is complete the benefits of more affordable electricity policies will fall quite unequally across Bangladesh. For the gas export policy, we are seeing essentially a macroeconomic impact on average domestic energy prices and aggregate foreign savings. Both of these have positive, but distributionally fairly neutral, impacts on households. Combining the two energy trade policies higher benefits for all households, which are less than additive but about average in terms of distributional incidence. In other words, the electricity component has highly diverse impacts, gas exports is fairly

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neutral, and the combination is somewhere in between. The biggest gains, as can be imagined, are among the most electric power dependent (SMA) populations.

59. The most uniform benefits accrue when the growth dividends of energy policy reform are reinvested in infrastructure (InfDev scenario). Here we see that infrastructure can improve market access, the main gateway out of poverty for both rural and urban poor, and increase the profitability of investment for higher income groups.

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CONCLUSIONS

60. Most independent observers see Bangladesh at a crossroads in terms of its natural gas policies. The country has a long history of using ample natural endowments to address extensive development challenges. While these policies can be said to have been appropriate in the sense of targeting a social agenda with national resource wealth, many have expressed concern about the efficiency of individual policies and the capacity of individual institutions to effectively execute those policies. Regardless of debates about past intentions, policy designs, and implementation, Bangladesh today faces a different future than it did decades ago when relatively abundant natural gas seemed to be the key to prosperity. Known reserves are not expected to last a decade on current use trends, energy price policies appear to seriously undermine economic efficiency, and the fiscal costs of those policies is being seriously questioned.

61. To support more evidence-based dialog on energy development, allocation, and pricing reform, this study uses a detailed economic forecasting model to evaluate leading issues facing Bangladesh. After an overview of natural gas sector experience and policy, we use this model evaluate a variety of policy options that are under active discussion and consideration by public and private stakeholders. In particular, we consider reforms that would make gas prices more market determined and uniform across private uses, as well as energy efficiency potential, the special nature of the fertilizer sector, coal substitution for electric power generation, and the prospect of exporting part of the country's natural gas reserves at more competitive international prices.

62. These polices are quite diverse, but all have important implications for the country's energy sector, particularly in terms of economywide efficiency, equity, and sustainability. Our results suggest that, although its energy future is more challenging that in the early days of gas abundance, Bangladesh has many options for energy policy reform than could facilitate higher, more equitable, and more sustainable levels of economic growth in the economy. To realize the vast human and economic potential of this country, more balanced consideration of political and economic criteria will be essential. This study offers support for a more objective, evidence-based approach to sustained prosperity for Bangladesh.

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REFERENCES

Ahmed, A. I. Mahbub Uddin. Global Forest Coalition, "Underlying Causes of Deforestation and Forest Degradation in Bangladesh." Last modified August 2008. Accessed April 12, 2012.

Asian Development Bank, "Natural Gas Pricing in Bangladesh: A Preliminary Assessment." Last modified November 25, 2010. Accessed April 12, 2012.

Bergman, David. Asia Calling, "Bangladesh opens its gas fields to US company." Last modified December 31, 2011. Accessed April 12, 2012.

BP (2010). "Statistical Review of Global Energy," http://www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf

Chowdhury, Syed Tashfin (2011). "Bangladesh gas find boosts supply hopes," Asia Times, 10/4/2011.

CIA World Factbook, "Bangladesh." Last modified 2009. Accessed April 12, 2012.

Haque, A. K. (2012). "Tariff reform and intersectoral allocation of natural gas – draft final report. " Accessed April.

Guntilake, H., S. Riahan, and D. Roland-Holst (2012) "A Dynamic CGE Model for Bangladesh: Technical Documentation," Working Paper, Department of Agricultural and Resource Economics, University of California, Berkeley.

Imam, Badrul. Banglapedia, "Gas, Natural." Last modified 2002. Accessed April 12, 2012. **http://www.banglapedia.org/httpdocs/HT/G_0045.HTM**.

Islam, Ifty. Asian Tigers Capital Partners, "Can Bangladesh be the Next Asian Tiger?", Powerpoint Presentation in Dhaka. Last modified November 1, 2008. Accessed April 12, 2012.

Islam, Ifty. The Federation of Bangladesh Chambers of Commerce and Industry, "Maximizing Growth for Bangladesh: A Private Sector Vision." Last modified December 6, 2008. Accessed April 12, 2012.

Jaccard, Mark, Mujibur Khan, and John Richards. "Natural Gas Options for Bangladesh." ***IUBAT-CPR Commentary 1***. (2000). Accessed April 12, 2012.

Karim, Naium-UI. Xinhua News Agency, "Bangladeshis boil over power, water, gas shortage amid rising temperature." Last modified April 5, 2012. Accessed April 12, 2012.

Petrobangla, "Annual Report 2010." Accessed April 12, 2012.

Pokharel, Bipin. McGill University, "Power Shortage, its impacts and the Hydropower Sustainability Assessment Protocol: in the context of South Asia." Last modified December 8, 2010. Accessed April 12, 2012.

Rashid, M. M. (2007). "The exploration of natural gas and its export potential in Bangladesh. " *Science Technology Society*, *12.* (245). Accessed April 12, 2012.

Rahman, Azizur. The Financial Express, "Offshore gas-blocks to be re-demarcated." Last modified March 24, 2012. Accessed April 12, 2012.

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Quadir, Serajul. Reuters, "Total abandons Bangladesh oil exploration rights." Last modified March 17, 2009. Accessed April 12, 2012.

The Daily Star, "Muhith rubbishes talk of gas export." Last modified June 19, 2011. Accessed April 12, 2012.

Sarwar, M. (2008, February 27). Petrobangla, "Gas Infrastructure in Bangladesh", Powerpoint Presentation in Delhi. Last modified February 27, 2008. Accessed April 12, 2012.

Transparency International, "Corruption Perceptions Index 2011." Accessed April 12, 2012. http://cpi.transparency.org/cpi2011/results/

U.S. Energy Information Administration, (2011). Accessed April 12, 2012.

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ANNEX 1: SUMMARY OF THE BANGLADESH CGE MODEL

The Bakgladesh CGE model is in reality a constellation of research tools designed to elucidate economy-environment linkages in Bangladesh. This section provides a brief summary of the formal structure of the Bangladesh model. For the purposes of this report, the 2010 Bangladesh Social Accounting Matrix (SAM), was aggregated along certain dimensions. The detailed equations of the model are completely documented elsewhere (Guntilake, Raihan, and Roland-Holst: 2012), and for the present we only discuss its salient structural components.

A. Structure of the CGE Model

Technically, a CGE model is a system of simultaneous equations that simulate price-directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economywide resource allocation, production, and income determination.

The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed-form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, where linkages to other domestic markets and agents are deliberately

excluded from consideration. A large and growing body of evidence suggests that indirect effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi-country model like the one used in this study, indirect effects include the trade linkages between countries and regions which themselves can have policy implications.

The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language, and calibrated to the new Bangladesh SAM estimated for the year 2010.[2] The result is a single economy model calibrated over the twenty year time path from 2010 to 2030.[3]

B. Production

All sectors are assumed to operate under constant returns to scale and cost optimization. Production technology is modeled by a nesting of constant-elasticity-of-substitution (CES) function.

In each period, the supply of primary factors — capital, land, and labor — is usually predetermined.[4] The model includes adjustment rigidities. An important feature is the distinction between old and new capital goods. In addition, capital is assumed to be partially mobile, reflecting differences in the marketability of capital goods across sectors.[5] Once the optimal combination of inputs is determined, sector output prices are calculated assuming competitive supply conditions in all markets.

1.1.1 Consumption and Closure Rule

All income generated by economic activity is assumed to be distributed to consumers. Each representative consumer allocates optimally his/her disposable income among the different commodities and saving. The consumption/saving decision is completely static: saving is treated as a “good” and its amount is

[2] See e.g. Meeraus et al (1992) for GAMS.
[3] The present specification is one of the most advanced examples of this empirical method, already applied to over 50 individual countries and/or regions.
[4] Capital supply is to some extent influenced by the current period’s level of investment.
[5] For simplicity, it is assumed that old capital goods supplied in second-hand markets and new capital goods are homogeneous. This formulation makes it possible to introduce downward rigidities in the adjustment of capital without increasing excessively the number of equilibrium prices to be determined by the model.

determined simultaneously with the demand for the other commodities, the price of saving being set arbitrarily equal to the average price of consumer goods.

The government collects income taxes, indirect taxes on intermediate inputs, outputs and consumer expenditures. The default closure of the model assumes that the government deficit/saving is exogenously specified.[6] The indirect tax schedule will shift to accommodate any changes in the balance between government revenues and government expenditures.

The current account surplus (deficit) is fixed in nominal terms. The counterpart of this imbalance is a net outflow (inflow) of capital, which is subtracted (added to) the domestic flow of saving. In each period, the model equates gross investment to net saving (equal to the sum of saving by households, the net budget position of the government and foreign capital inflows). This particular closure rule implies that investment is driven by saving.

C. Trade

Goods are assumed to be differentiated by region of origin. In other words, goods classified in the same sector are different according to whether they are produced domestically or imported. This assumption is frequently known as the *Armington* assumption. The degree of substitutability, as well as the import penetration shares are allowed to vary across commodities. The model assumes a single Armington agent. This strong assumption implies that the propensity to import and the degree of substitutability between domestic and imported goods is uniform across economic agents. This assumption reduces tremendously the dimensionality of the model. In many cases this assumption is imposed by the data. A symmetric assumption is made on the export side where domestic producers are assumed to differentiate the domestic market and the export market. This is modeled using a *Constant-Elasticity-of-Transformation* (CET) function.

D. Dynamic Features and Calibration

The current version of the model has a simple recursive dynamic structure as agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. Dynamics in the model originate in three sources: i) accumulation of productive capital and labor growth; ii) shifts in production technology; and iii) the putty/semi-putty specification of technology.

[6] In the reference simulation, the real government fiscal balance converges (linearly) towards 0 by the final period of the simulation.

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E. Capital accumulation

In the aggregate, the basic capital accumulation function equates the current capital stock to the depreciated stock inherited from the previous period plus gross investment. However, at the sector level, the specific accumulation functions may differ because the demand for (old and new) capital can be less than the depreciated stock of old capital. In this case, the sector contracts over time by releasing old capital goods. Consequently, in each period, the new capital vintage available to expanding industries is equal to the sum of disinvested capital in contracting industries plus total saving generated by the economy, consistent with the closure rule of the model.

F. The putty/semi-putty specification

The substitution possibilities among production factors are assumed to be higher with the new than the old capital vintages — technology has a putty/semi-putty specification. Hence, when a shock to relative prices occurs (e.g. the imposition of an emissions fee), the demands for production factors adjust gradually to the long-run optimum because the substitution effects are delayed over time. The adjustment path depends on the values of the short-run elasticities of substitution and the replacement rate of capital. As the latter determines the pace at which new vintages are installed, the larger is the volume of new investment, the greater the possibility to achieve the long-run total amount of substitution among production factors.

	Label	Household
1	BariRur	Barishal Rural
2	BariUrb	Barishal Urban
3	ChitRur	Chittagong Rural
4	ChitUrb	Chittagong Urban
5	ChitSMA	Chittagong SMA
6	DhakaRur	Dhaka Rural
7	DhakaUrb	Dhaka Urban
8	DhakaSMA	Dhaka SMA
9	KulnaRur	Kulna Rural
10	KhulnaUrb	Khulna Urban
11	KhulnaSMA	Khulna SMA
12	RajRur	Rajshahi Rural
13	RajUrb	Rajshahi Urban
14	RajSMA	Rajshahi SMA
15	SylhetRur	Sylhet Rural
16	SylhetUrb	Sylhet Urban

G. Dynamic calibration

The model is calibrated on exogenous growth rates of population, labor force, and GDP. In the so-called Baseline scenario, the dynamics are calibrated in each region by imposing the assumption of a balanced growth path. This implies that the ratio between labor and capital (in efficiency units) is held constant over time.[7] When alternative scenarios around the baseline are simulated, the technical efficiency parameter is held constant, and the growth of capital is endogenously determined by the saving/investment relation.

H. Emissions

The Bangladesh dynamic CGE model model captures emissions from production activities in agriculture, industry, and services, as well as in final demand and use of final goods (e.g. appliances and autos). This is done by calibrating emission functions to each of these activities that vary depending upon the emission intensity of the inputs used for the activity in question. We model both CO2 and the other primary greenhouse gases, which are converted to CO2 equivalent. Following standards set in the research literature, emissions in production are modeled as factors inputs. The base version of the model does not have a full representation of emission reduction or abatement. Emissions abatement occurs by substituting additional labor or capital for emissions when an emissions tax is applied. This is an accepted modeling practice, although in specific instances it may either understate or overstate actual emissions reduction potential.[8] In this framework, emission levels have an underlying monotone relationship with production levels, but can be reduced by increasing use of other, productive factors such as capital and labor. The latter represent investments in lower intensity technologies, process cleaning activities, etc. An overall calibration procedure fits observed intensity levels to baseline activity and other factor/resource use levels..

[7] This involves computing in each period a measure of Harrod-neutral technical progress in the capital-labor bundle as a residual. This is a standard calibration procedure in dynamic CGE modeling.

[8] See e.g. Babiker et al (2001) for details on a standard implementation of this approach.

Table A1.1 Emission Categories

Air Pollutants		
1.	Suspended particulates	PART
2.	Sulfur dioxide (SO_2)	SO2
3.	Nitrogen dioxide (NO_2)	NO2
4.	Volatile organic compounds	VOC
5.	Carbon monoxide (CO)	CO
6.	Toxic air index	TOXAIR
7.	Biological air index	BIOAIR
8.	Carbon Dioxide (CO_2)	
Water Pollutants		
8.	Biochemical oxygen demand	BOD
9.	Total suspended solids	TSS
10.	Toxic water index	TOXWAT
11.	Biological water index	BIOWAT
Land Pollutants		
12.	Toxic land index	TOXSOL
13.	Biological land index	BIOSOL

The model has the capacity to track 13 categories of individual pollutants and consolidated emission indexes, each of which is listed in Table A1.1. Our focus in the current study is the emission of CO2 and other greenhouse gases, but the other effluents are of relevance to a variety of environmental policy issues.

An essential characteristic of the Bangladesh dynamic model's approach to emissions modeling is endogeneity, i.e. emission rates vary with bevioral decisions about fuel mix and efficiency (technology adoption and use). This feature is essential to capture structural adjustments arising from market based climate policies such as Pigouvian taxes or cap and trade, as well as the effects of technological change.

ANNEX 2: SUMMARY OF THE BANGLADESH SOCIAL ACCOUNTING MATRIX

Table A2.1: Institutions in the 2010 Bangladesh Social Accounting Matrix

Institution	Definition	
aCereal	Activity	Wheat, Rice, Millet, and other Grains
aCrops	Activity	Other Crops
aLvstk	Activity	Livestock
aOthAg	Activity	Other Agricultural Goods and Services
aCoal	Activity	Coal Extraction and Trade
aOil	Activity	Petroelum Extraction and Trade
aGas	Activity	Natural Gas Extraction and Trade
aMinrl	Activity	Mineral Mining
aMeatD	Activity	Meat and Dairy
aFoodPr	Activity	Other Food Processing
aTxtApp	Activity	Textile and Apparel
aManuf	Activity	Other Manufacturing
aChem	Activity	Chemicals
aMetal	Activity	Metal Products
aElect	Activity	Electricity
aGasDist	Activity	Natural Gas Distribution
aWater	Activity	Water
aConst	Activity	Construction
aTrade	Activity	Wholesale and Retail Trade
aTransp	Activity	Transportation Services
aComm	Activity	Communications
aBusServ	Activity	Private Services
aPubServ	Activity	Public Administration
kCereal	Commodity	Wheat, Rice, Millet, and other Grains
kCrops	Commodity	Other Crops
kLvstk	Commodity	Livestock
kOthAg	Commodity	Other Agricultural Goods and Services
kCoal	Commodity	Coal Extraction and Trade
kOil	Commodity	Petroelum Extraction and Trade
kGas	Commodity	Natural Gas Extraction and Trade
kMinrl	Commodity	Mineral Mining
kMeatD	Commodity	Meat and Dairy
kFoodPr	Commodity	Other Food Processing
kTxtApp	Commodity	Textile and Apparel

kManuf	Commodity	Other Manufacturing
kChem	Commodity	Chemicals
kMetal	Commodity	Metal Products
kElect	Commodity	Electricity
kGasDist	Commodity	Natural Gas Distribution
kWater	Commodity	Water
kConst	Commodity	Construction
kTrade	Commodity	Wholesale and Retail Trade
kTransp	Commodity	Transportation Services
kComm	Commodity	Communications
kBusServ	Commodity	Private Services
kPubServ	Commodity	Public Administration
Land	Factor	Land
UnSkil	Factor	Unskilled Labor
Skill	Factor	Skilled Labor
Captl	Factor	Capital
natrs	Factor	Natural Resources
indtx	Fiscal	Indirect Taxes
fctts	Fiscal	Factor Taxes
dirtx	Fiscal	Income Taxes
imptx	Fiscal	Import Tariffs
exptx	Fiscal	Export Taxes
ent	Institution	Enterprises
BariRur	Household	Barishal Rural
BariUrb	Household	Barishal Urban
ChitRur	Household	Chittagong Rural
ChitUrb	Household	Chittagong Urban
ChitSMA	Household	Chittagong SMA
DhakaRur	Household	Dhaka Rural
DhakaUrb	Household	Dhaka Urban
DhakaSMA	Household	Dhaka SMA
KulnaRur	Household	Kulna Rural
KhulnaUrb	Household	Khulna Urban
KhulnaSMA	Household	Khulna SMA
RajRur	Household	Rajshahi Rural
RajUrb	Household	Rajshahi Urban
RajSMA	Household	Rajshahi SMA
SylhetRur	Household	Sylhet Rural
SylhetUrb	Household	Sylhet Urban
inv	Institution	Capital Account
gov	Institution	Government
row	Institution	Rest of World