OPPORTUNITY COST OF NATURAL GAS SUBSIDIES IN BANGLADESH

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ABSTRACT

Natural gas is heavily subsidized in Bangladesh, resulting in waste, low government revenues, and gas and power shortages. This paper examines the impact of optimal gas pricing policy—aligning the price with the international market price—together with better gas revenue management regime, in which augmented gas revenue is used to invest in physical and social infrastructure. General equilibrium model assessment results show that Bangladesh is losing a significant development opportunity due to its gas subsidy. By 2030, if these changes were made, Bangladesh could reach $4,070 gross domestic product per capita in comparison to the business-as-usual per capita projected gross domestic product of $1,580. Inflationary pressures from higher energy prices would be completely offset by the positive impacts of infrastructure constraint removal. The optimal gas pricing and investment in infrastructure would benefit all sectors of the economy without any adverse effects on the poor.

ABBREVIATIONS

CGE	–	computable general equilibrium
CNG	–	compressed natural gas
CPI	–	consumer price index
GDP	–	gross domestic product
GJ	–	gigajoule
IOC	–	international oil company
IPP	–	independent power producers
MW	–	megawatt
SAM	–	social accounting matrix
TCF	–	trillion cubic feet

Currency unit – Taka
Tk1.00 = $0.013
$1.00 = Tk 77.75

I. INTRODUCTION

A. Pricing of Exhaustible Natural Resources

1. Bangladesh is a natural resource-scarce country with a growing population. Its population density is 920 people per square kilometer, arable land availability is 0.05 hectare per person, and it is ranked 70th in fresh water availability among 169 countries. Natural gas may be the most valuable natural resource it is endowed with. Within the context of a growing energy demand in Bangladesh, this paper focuses on the opportunity cost of subsidizing gas resources. The country has been suffering from a gas shortage that has affected industrial production, power generation, and the overall quality of life. Sustainable development of the gas sector has been constrained due to multi-dimensional problems, all of which have direct and/or indirect linkages with the power sector due to the fact that about 85% of the installed generation capacity is gas fired. The subsidized gas supply in many sectors is a root cause of the problems of the gas and power sectors. In the past, relatively abundant natural gas supported energy prices far below the true value of energy consumed. These prices are now unsustainable, resulting in dwindling exploration and production alongside rapidly rising demands. Unless Bangladesh's gas pricing policy is revised, the current pricing methods will result in monumental economic crises when the gas fields are completely depleted.

2. The Government of Bangladesh is maintaining lower gas prices possibly taking into account the potential public opposition to gas price increase as the main reason. Energy price increases are politically a highly sensitive issue in Bangladesh. Table 1 shows the current retail gas prices as applied for different sectors. In comparison to the gas prices in the region, Bangladesh prices are very low. Within the political establishment, bureaucracy and society at large there is a belief that lower prices help economy's competitiveness and poor are benefitted from the lower energy prices. While these beliefs should be subjected to proper scientific investigation, the focus of this paper is on possible costs of subsidized gas in terms of foregone development opportunities.

Table 1: Gas Prices in Bangladesh and Selected Neighboring Countries
$/m^3

Country and Effective Rate of Tariff	Bangladesh	Pakistan	India	Malaysia	Thailand	Indonesia	Singapore
	19 Sep 2011	7 Aug 2011	1 Dec 2011	1 Jun 2011	1 Jun 2011	1 Jun 2011	1 Jun 2011
Consumer Category							
Power	1.05	5.14	5.06	4.36	5.81	6.7	13.79
Independent Power Producers	1.05	4.34		...	...	...	...
Fertilizer							
Feedstock	0.96	1.17	5.06	...	...	...	...
Power	1.56	4.99					
Industry	2.19	4.99	18.19	5.12	6.20	5.97	35.21
Captive power	1.56	4.99		...	...	...	...
Compressed natural gas	8.60	6.57	16.17	...	...	...	...
Large commercial	3.54	6.05	18.19	5.12	...	...	...
Small commercial	3.54	6.05	23.51	5.12	...	...	...
Domestic	1.93	1.24	12.27	...	...	...	...

... = data not available.
Source: Estimates by the authors.

3. Because natural gas is an exhaustible natural resource, its use for sustainable development requires systematic inquiry. In a seminal paper, Herold Hotelling showed that the price of an exhaustible resource should increase at the rate of interest to account for dwindling resource stock (Hotelling 1931). His theory states that if exhaustible resource prices do not rise at the prevailing interest rate, there will be no restrictions on supply. If, conversely, the resource prices are expected to increase faster than interest rates, a country would be better off not bringing the resource out of the ground. The practical implication of this theory is that the price of an exhaustible resource is higher than the marginal cost of extraction, and the price should increase over time.

4. Since introduction of Hotelling's theory, a number of studies have re-examined its validity by relaxing his original assumptions about constant production costs, technological changes, supply limitations, new discoveries, etc. Amongst these studies, Barnet and Morse (1963), Smith (1979), Slade (1982), Farrow (1985), Halvorsen and Smith (1991), Young (1992), and Young and Ryan (1996) do not find evidence supporting Hotelling's theory. Studies by Miller and Upton (1985a, 1985b) and Cairns and Davis (1998) find mixed results. Work by Stollery (1983), Slade and Thille (1997), Berck and Bentley (1997), and Chermak and Patrick (2001) provides evidence in support of Hotelling's results. Despite this mixed supportive evidence, Hotelling's theory provides a useful way of looking at exhaustible resources pricing as leading to a situation where increasing prices drive a gradual reduction in demand and production levels, therefore supporting the search for alternative energy sources.

5. When an economy is heavily supported by an exhaustible resource, sustaining its economic performance is an important issue because the resource will be depleted at some point in time. Hartwick (1977) showed that the level of consumption (a proxy for the overall welfare) can be sustained if the rent from the exhaustible resource is invested in physical and social capital. Hartwick's rule defines the amount of investment in produced capital (buildings, roads, power plants, knowledge stocks, health, etc.) that is needed to accurately offset declining stocks of the exhaustible resource. Solow (1986) referred to this as Hartwick's rule (or rule of thumb) for sustainability in exhaustible resource economies. Hartwick's rule points out the importance of pricing exhaustible resource optimally to collect adequate resource rents that can be invested in manmade capital to ensure sustainable development.[1] Hamilton and Hartwick (2005), using time series data from 70 countries, show that application of Hartwick's rule in resource-rich countries would have placed these countries at much higher income levels than they currently have. For example, they show that Venezuela, Trinidad and Tobago, and Gabon would be as wealthy as the Republic of Korea, and Nigeria would be five times as well off as is it was in 2005 if these countries had collected an optimal amount of rent and invested it in their economies.

6. Motivated by Hamilton and Hartwick (2005), this paper investigates the opportunity cost of gas subsidies in Bangladesh. Official statistics from Petrobangla,[2] show that current gas revenue is $300 million per year. If gas prices are increased to the average gas price in India and Pakistan, $2.9 billion in annual gas revenue can be generated. Similarly, if gas prices are increased to match the landing price of liquefied natural gas in India, gas revenue can be increased to about $6.7 billion per year. This paper assesses the developmental impacts of the investment of that $6.7 billion and $2.9 billion in physical and social capital using two separate techniques. The first technique involves the use of a SAM (social accounting matrix) multiplier model to assess the economy-wide impacts of such infrastructural investment in Bangladesh. The second technique involves the application of a dynamic

[1] Sustainable development here is defined as a constant level of consumption over time.
[2] Bangladesh Oil, Gas & Mineral Corporation.

computable general equilibrium (CGE) model to assess the macro, sectoral, and welfare impacts of infrastructure investments.

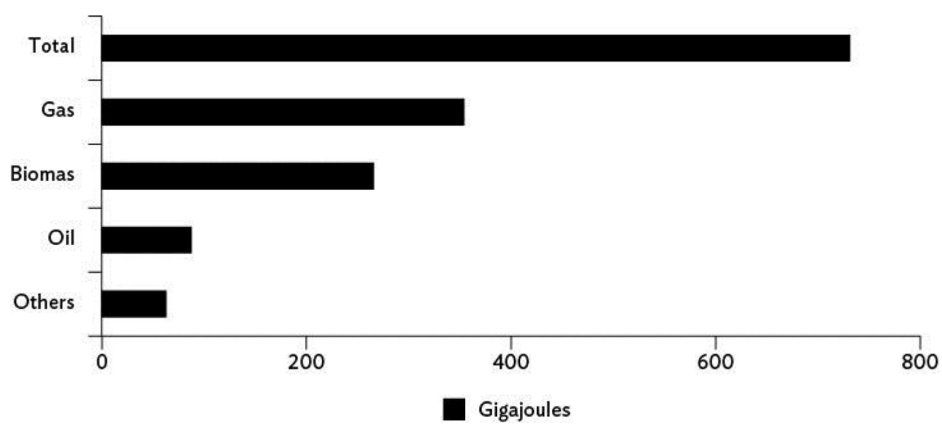
B. The Gas Sector in Bangladesh: An Overview

7. As of April 2012, according to official estimates, Bangladesh faced shortages of 500 million cubic feet of gas and 1400 megawatts (MW) of electricity per day. This power shortage is directly linked to the gas shortage due to the fact that about 85% of the installed generation capacity is gas fired. The country's electrification rate is about 50%, which is far below that of neighboring countries including India (75%) and Sri Lanka (95%). Providing universal access to electricity remains a major development challenge in Bangladesh. Even areas with access to electricity face severe power shortages. In the summer of 2012, urban areas experienced about 5 hours of power cuts daily while rural areas facing much more severe power shortages.

8. Bangladesh is taking part in the worldwide trend away from centrally planned nationalized economies, but much of the nation's commercial energy infrastructure remains government owned, organized, and regulated. The introduction of international oil companies (IOC) to the oil and gas sector has been a success, with 52% of gas currently supplied by international companies. Similarly, the introduction of independent power producers to the electricity sector provided modest improvements in the power sector. Despite the progressive introduction of private sector skills, energy shortages impose major costs on the whole economy, including interrupted and poor-quality supplies of gas and electricity.

9. Bangladesh has energy supplies from both renewable and nonrenewable sources. Bangladesh's sixth five-year plan (2011–2015) quotes an annual energy requirement of 36 million metric tons of coal equivalent (720 million gigajoules). Figure 1 shows that natural gas accounted for about 48% of primary energy use in 2009. Thus, about half of all energy used is from natural gas. In addition to natural gas and crude oil a small quantity of coal is used as fuel, mainly in the brick fields and at the Barapukuria Thermal Power Plant, the sole coal-fired power station in the country. Biomass accounts for just under half of Bangladesh's annual primary energy supply, mostly in areas where there is no gas reticulation.

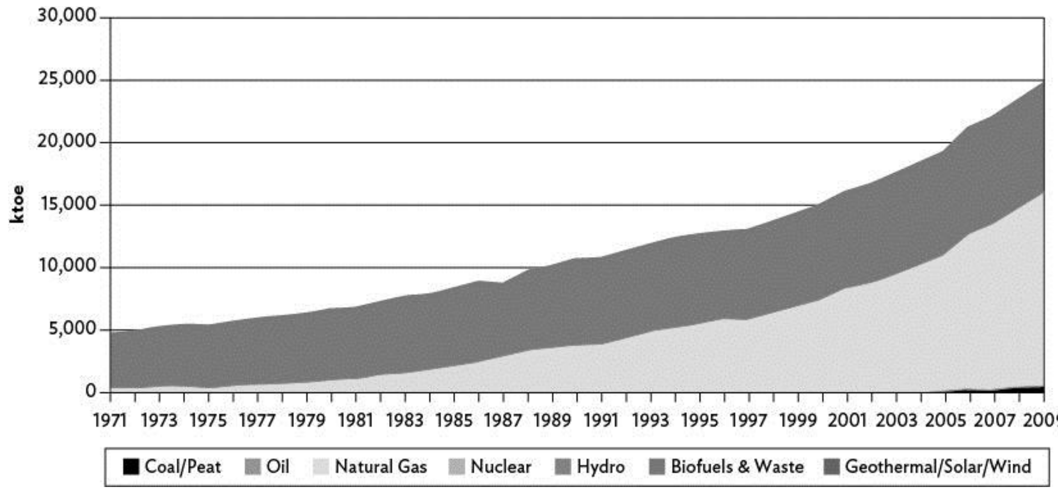
Figure 1: Sources of Annual Primary Energy Supply in Bangladesh, 2009



Source: Energy and Mineral Resources Division, Ministry of Power Energy and Mineral Resources.

10. Figure 2 illustrates the growing importance of gas in Bangladesh's energy production. Currently about 75% of commercial energy is provided by natural gas. This includes the gas feedstock for the electricity sector.[3] The country has few alternatives and will continue to rely on this energy source to fuel much of its development. Bangladesh imported 16% of its energy in 2009 (mostly fuel oil) and remains heavily dependent on biomass for energy production in rural areas.

Figure 2: Energy Production in Bangladesh, 1971–2009



Source: International Energy Agency. 2011.

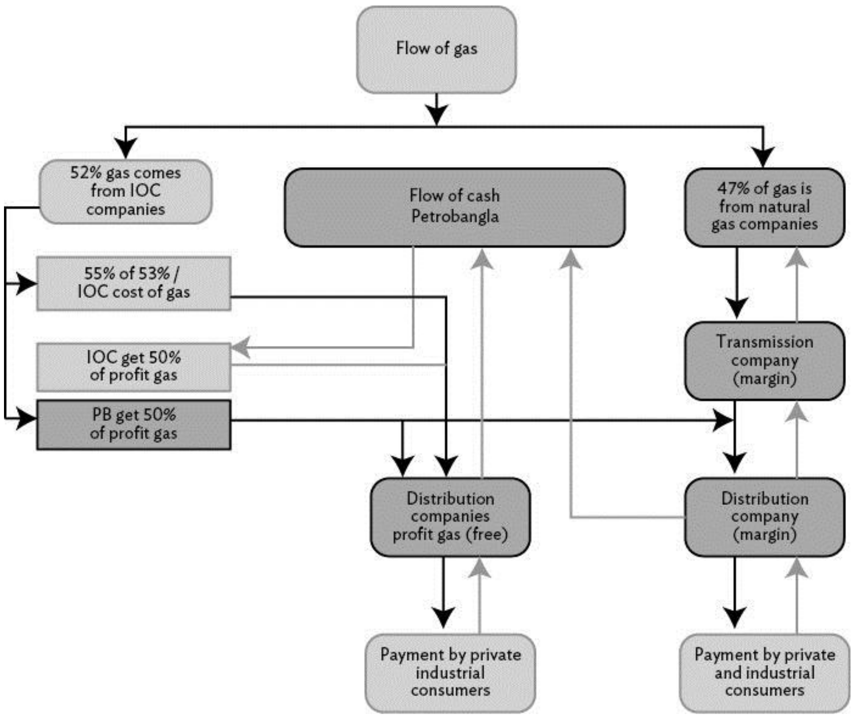
11. The gas market is composed mainly of flows of gas and money. Its principal features are:

(i) Production sharing contracts between the Government of Bangladesh and international oil companies (IOCs) are the principal documents governing the Bangladesh gas market.
(ii) Of total gas produced, 53% is produced by IOCs and 47% is produced by the national gas companies;
(iii) Of IOC gas production:
  (a) 55% is cost gas produced to cover the costs of the IOCs; and
  (b) 45% is profit gas, which is shared on a 50-50 basis with Petrobangla.
(iv) IOCs can, in theory, sell their gas to the highest bidder. However, in practice Petrobangla exercises its "first refusal" option and purchases all profit gas to meet the growing demand.
(v) Petrobangla supplies its 50% share of profit gas directly to its distribution companies free of charge, and they sell to consumers at prevailing retail prices (which include transmission and distribution charges).
(vi) The 47% of gas produced by the national gas companies is sold to final consumers at retail prices that include a transmission and distribution margin.
  - In the event that production by IOCs increases, the oil companies are guaranteed a profit margin after tax, supplementary duty, and value-added tax. If the margin is eroded by tax or duty increases, Petrobangla indemnifies the companies.

3 Petrobangla. 2010. *Annual Report 2010*. 9.

12. Figure 3 illustrates the flow of gas and money in the Bangladesh gas market. As a private company would, it collects value-added tax on retail sales and forwards that, along with supplementary duty and income tax liabilities, to the National Board of Revenue.

Figure 3: Bangladesh Gas Market: Flows of Gas and Money

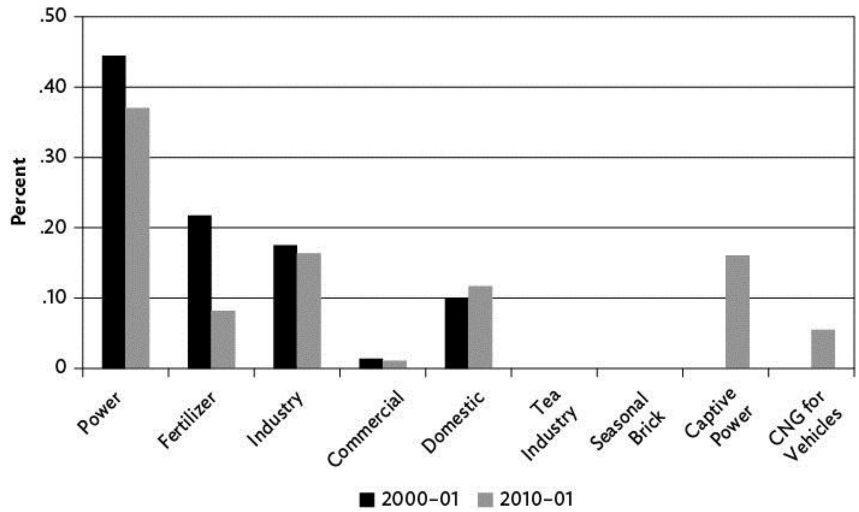


Source: Petrobangla and the authors.

13. Natural gas in Bangladesh is mainly used to generate electricity, manufacture urea fertilizer, sustain industry, power transport (particularly buses and small taxis), and for domestic food preparation. Figure 4 shows the allocation of gas among the sectors in 2000 and 2011. Power generation (grid and captive) in 2001 accounted for approximately 45% of all gas used in Bangladesh, but in 2011 these two uses accounted for about 59% of total gas used. The captive generation sector, which did not exist in 2001, accounted for 17% of the total in 2011. Captive generation is less energy efficient than grid generation, reflecting a deterioration in the efficiency of the sector. The fertilizer industry accounted for 23% of consumption in 2001 but halved in importance by 2011, and the seasonal brick industry no longer uses gas. Condensed natural gas (CNG) in vehicles did not register in 2001, but in 2011 accounted for 5.8% of the total available gas. Both industrial and commercial uses of gas declined in importance from 2001 to 2011, and the allocations to these sectors are unlikely to increase given the ban on new gas connections that was introduced in 2009.

14. 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 industrial growth that relied on 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 location of all of the country's onshore gas fields, has benefited from availability of gas. Western Bangladesh has not been benefited much from this natural resource due to its shortage and, high costs of building gas-transporting infrastructure.

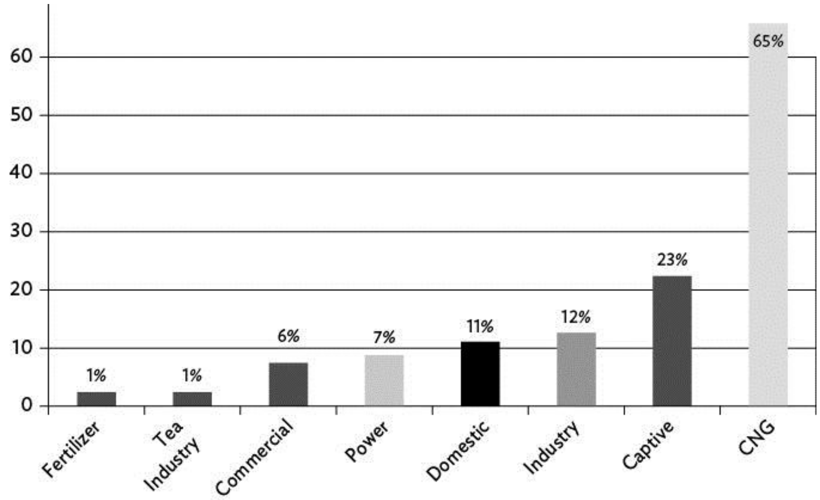
Figure 4: Sectoral Use of Gas, 2000–2001 and 2010–2011
(% of total gas)



Source: Estimates by the authors.

15. Figure 5 shows the annual average growth rate in the use of gas by different sectors from 1991 to 2010. The average increase in the consumption of gas for power production between 1991 and 2010 was 7%. The amount of gas used for domestic, industrial, and captive power generation grew faster, with growth rates for CNG being the highest. The lowest rate of increase (1%) was for fertilizer and the highest growth rate (65%) was for CNG, with captive power production coming close behind.

Figure 5: Annual Average Growth Rate of Use of Gas by Sector, 1991–2010



Source: Petrobangla (2012).

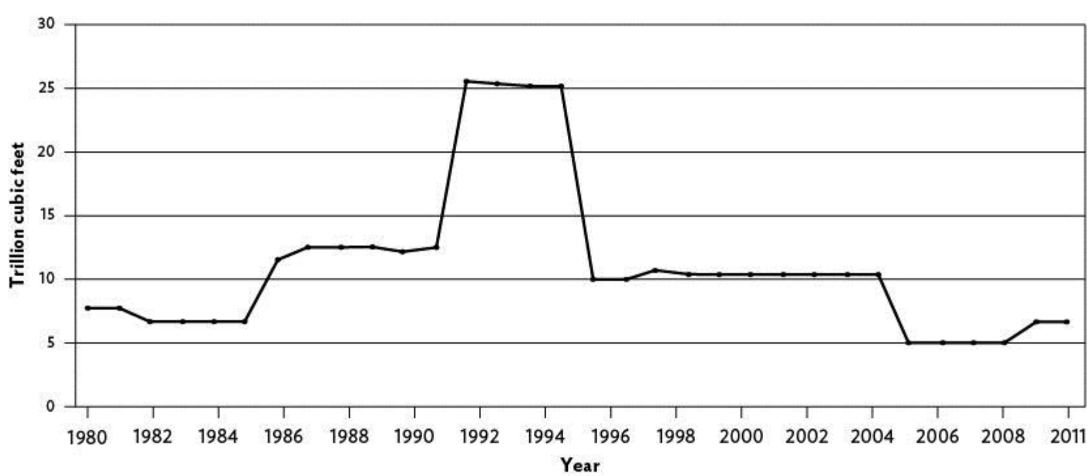
16. Imported oil accounts for 12% of the country's energy requirements, and it has increased in significance due to the widespread use of diesel generators since 2009. However, at present and in the foreseeable future, 75% of the commercial energy in Bangladesh (more than 300 million gigajoules [GJ]) is and will be provided by natural gas. Daily gas production by Petrobangla in 2009–10 was

reported as 903 MMCF (955 GJ)[4]; production by international oil companies (IOC) was approximately 1,022 million mcf[5] (MMCF) daily (1080 GJ). Despite this additional production, as of April 2012 there is a daily shortage of about 500 MMCF despite a 284 MMCF increase in gas supplied to the grid between January 2009 and January 2010.[6] Indications are that in the immediate future, without significant policy changes, disparity between demand and supply will continue to widen. The shortfall identified by Petrobangla in 2009 has become worse in 2012.

17. There have been complaints from industrial groups and domestic consumers of gas failing at critical times. In terms of thermal efficiency, direct use of gas in final use applications is usually considered the best use of the finite resource. Uses such as CNG and domestic gas for cooking therefore rate highly. The electricity sector is unable to keep up with demand and rolling power cuts are a daily occurrence. Factories, hospitals, hotels, shops, and even domestic residences now have standby electricity generators. As many of these are gas-fired captive generators, which are less efficient than combined-cycle or even single-cycle generators, they have also become a factor in the shortage. Those without reliable access to gas are forced to use heavy fuel oil or diesel to generate their own electricity. Captive generation, diesel stand-by sets, and power shedding are very expensive stopgap measures that fail to address the underlying problem. Every successive stopgap measure adds further layers of costs to the sector and contributes nothing to sector revenues.

18. 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 ever be recovered. The remaining recoverable reserve of 16.63 TCF, as of December 2011, if fully exploited, can meet gas demand at best until 2026, assuming a modest demand growth rate of 5% per year. Therefore large-scale exploration in onshore and offshore areas for further discovery, along with systematic appraisal and development of known and producing gas fields, is necessary to sustain gas demand beyond 2026. Figure 6 shows, after discounting for recoverability and past production, that available reserves may be as high as 25 TCF or lower than 10 TCF.

Figure 6: Variations in Proven Gas Reserves



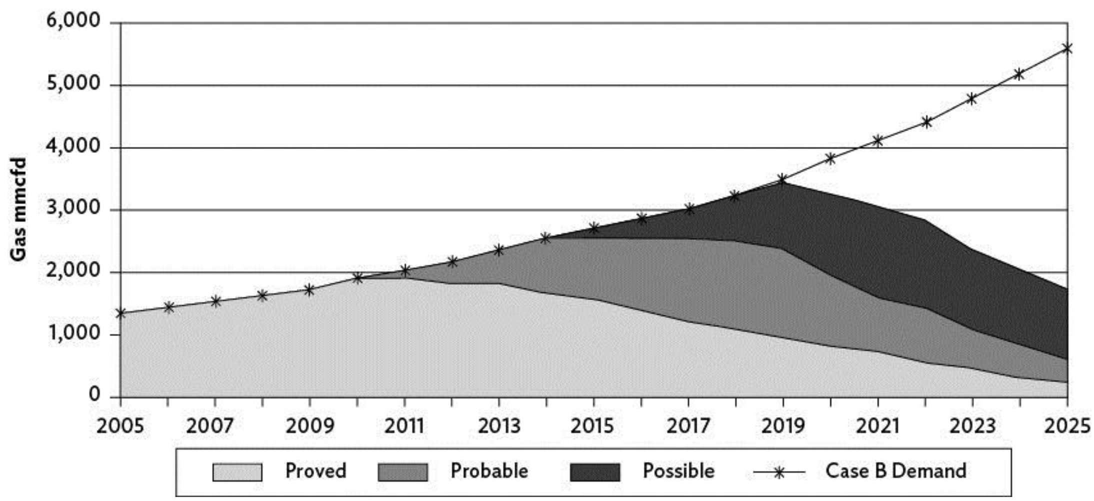
Source: I US Energy Information Administration (2011).

[4] Petrobangla. 2010. *Annual Report 2010.* 16 (converted).
[5] mcf = 1000 cubic feet.
[6] Petrobangla. 2010. *Annual Report 2010.* 16.

19. 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. With the resolution of a maritime dispute with Myanmar in March 2012, outside energy firms have shown interest in buying exploration rights in the blocks on sale. As of April 2012, ConocoPhillips owns exploration rights to two deep-water blocks, and Santos is the only operator of an offshore gas field in the Sangu block in the Bay of Bengal. So far, in Bangladesh only two commercially viable gas finds have been discovered offshore, one in 1996 and one in February 2012.

20. The daily shortfall between the demand and supply indicates a market where signals to producers and consumers are distorted. This is resulting in overdependence on natural gas to meet the needs of electricity generation at a time when the demand for commercial energy of all kinds is expanding rapidly and gas supplies are constrained. Figure 7 shows projections that indicate the position will get worse.

Figure 7: Natural Gas Projected Supply and Demand, 2005–2025



mmcfd = million cubic feet per day.

Source: Sarwar, M. 2008.

21. Bangladesh Power Development Board reports that substantial losses have left them with insufficient funds to purchase the feedstocks required to generate electricity. Petrobangla suffers a chronic gas supply shortage caused by the combination of a shortage of cash to pay for exploration, few new discoveries, and rapidly increasing demand. Even with large subsidies, utilities in deficit cannot maintain and service their capital assets or improve their capacity for investment in their business. As a result the development of facilities is minimal and they cannot pay taxes. Financial un-sustainability of gas utilities, gas shortages, and consequent power shortages are all rooted in gas pricing policy. In order to understand the degree of under pricing we estimated the costs of alternative energy sources, as shown in Table 2. Table 3 shows the potential energy price increase if alternatives were used in place of gas. These numbers indicate that the economy of Bangladesh will face huge crisis if the current prices are not gradually changed to make them equal to international market prices.

Table 2: Costs of Alternative Fuels for Various Categories of Consumers

Consumer Category	Cost of gas, Tk/mcf	Alternative Product	HSFO	Gasoline	Diesel	Kerosene	LPG[a]	Fuelwood
		Equivalent Amount	26.28 liter	30.12 liter	26.77 liter	27.14 liter	20.5 kg	110 kg
		Unit Price	60	89	61	61	56	8
Power	79.85		1,577	–	1,633	–		–
Industrial	165.94		1,577	–	1,633	–	1,148	–
Commercial	268.16		–	–	–	1,656	1,148	880
Captive Power	118.36		–	–	1,633	–	1,148	–
CNG	849.50		–	2,681	1,633	–	1,148	–
Domestic	146.11		–	–	–	1,656	1,148	880

CNG = Compressed natural gas; HSFO = high sulfur fuel oil; LPG = liquefied petroleum gas. mcf = 1000 cubic feet.

[a] Though the government fixed price for 12.5 kilogram LPG cylinders is Tk700, due to high demand the market selling price is over Tk1,500.

[b] Includes refueling stations' margin of Tk7/cm.

Source: Estimates by authors.

Table 3: Possible Price Increases When Gas Resources are Completely Depleted

Category	Cost Tk/mcf	Hugh Sulfur Fuel Oil	Gasoline	High Speed Diesel	Kerosene Oil	Liquid Petroleum Gas	Fuelwood
Electricity	79.85	1875%		1945%			
Industrial	165.94	850%		884%		592%	
Commercial	268.16				518%	328%	228%
Captive power	118.36			1280%		870%	
CNG for NGV	849.50		216%	92%		35%	
Domestic	146.11				1033%	686%	502%

CNG = compressed natural gas; mcf = 1000 cubic feet.

Source: Estimates by the authors.

II. ECONOMY-WIDE EFFECTS OF INVESTING REVENUE FROM NATURAL GAS

A. Social Accounting Matrix Model

22. This section uses a social accounting matrix (SAM) multiplier model to understand the potential impacts of an increase in investment on social and physical infrastructure in the Bangladesh economy. The advantage of using the SAM multiplier model is that it shows linkages among different sectors and actors in the economy, and thus it is able to capture the economy-wide effects of any exogenous shock. Therefore, *ex ante* assessment of various infrastructural investments can be conducted using this model.

1. Bangladesh Social Accounting Matrix 2007

23. In a narrower sense, a SAM is a systematic database and an organized, consistent classification system. As a data framework, the SAM is a snapshot that explicitly incorporates various crucial transaction links among variables, such as the mapping of factorial income distribution from the structure of production and the mapping of the household income distribution from the factorial income distribution, among others. In a broader sense, in addition to providing a consistent classification scheme, it can be conceived as a modular analytical framework for a set of interconnected subsystems that specifies the major relationships among variables within and among these systems (see Pyatt and Round, 1977).

24. For the purpose of this exercise, a SAM for 2007 for Bangladesh has been constructed. The 2007 SAM identifies the economic relations through *four types of accounts*: (i) production activity and commodity accounts for 41 sectors; (ii) four factors of productions with two different types of labor and two types of capital; (iii) current account transactions between four main institutional agents: household-members and unincorporated capital, corporations, government, and the rest of the world; and (iv) two consolidated capital accounts distinguished by public and private origins to capture the flows of savings and investment. The disaggregation of activities, commodities, factors, and institutions in the SAM is given in Table 4.

Table 4: Disaggregation and Description of Bangladesh Social Accounting Matrix Accounts

Accounts	Description of Elements
Activities (41)	
Agriculture (12)	Paddy cultivation, grains, jute cultivation, sugarcane cultivation, vegetables, commercial crops, other crop cultivation, livestock rearing, poultry rearing, shrimp farming, fishing, and forestry
Manufacturing (20)	Rice milling, grain milling, fish process, oil industry, sweetener industry, food, leather, jute, clothing, rmg, tobacco, wood, chemical, fertilizer, petroleum, clay products, cement, steel, machinery, and miscellaneous
Construction (1)	Construction
Services (8)	Utility, trade, transport, social services, financial services, public administration and defense, professional services, and other services
Commodities (41)	
Agriculture (12)	Paddy cultivation, grains, jute cultivation, sugarcane cultivation, vegetables, commercial crops, other crop cultivation, livestock rearing, poultry rearing, shrimp farming, fishing, and forestry
Manufacturing (20)	Rice milling, grain milling, fish process, oil industry, sweetener industry, food, leather, jute, clothing, rmg, tobacco, wood, chemical, fertilizer, petroleum, clay products, cement, steel, machinery, and miscellaneous
Construction (1)	Construction
Services (8)	Utility, trade, transport, social services, financial services, public administration and defense, professional services, and other services
Factors of Production (4)	
Labor (2)	Labor unskilled, and labor skilled
Capital (2)	Capital and land
Current Institutions (11)	
Households (8)	Rural: landless, agricultural marginal, agricultural small, agricultural large, nonfarm poor and nonfarm non poor Urban: households with low educated heads, and households with high educated heads
Others (3)	Government, corporation, and rest of the world

continued on next page

Table 4 *continued*

Accounts	Description of Elements
Capital Institutions (2)	
Public Capital	Public capital
Private Capital	Private Capital

Source: 2007 social accounting matrix of Bangladesh.

2. Derivation of the SAM Multiplier

25. The move from a SAM data framework to a SAM model or multiplier framework requires decomposing the SAM accounts into "exogenous" and "endogenous," as well as introducing a set of assumptions pertaining to the Generalized Leontief Model (Alarcon, 2002). Generally, accounts intended to be used as policy instruments (e.g., government expenditure, investment, exports) are made exogenous and accounts *a priori* specified as objectives or targets must be made endogenous (e.g., activity, commodity demand, factor return, and household income).

26. For any given injection into the exogenous accounts (i.e., instruments) of the SAM, influence is transmitted through the interdependent SAM system among the endogenous accounts. The interwoven nature of the system implies that the incomes of factors, households, and production are all derived from exogenous injections into the economy via a multiplier process. The multiplier process is developed here on the assumption that when an endogenous income account receives an exogenous expenditure injection, it spends it in the same proportions as shown in the matrix of average propensities to spend. The elements of the average propensities to spend matrix is calculated by dividing each cell by its corresponding column sum totals.

27. The multiplier analysis using the SAM framework helps us understand the linkages between the different sectors and the institutional agents at work within the economy. Accounting multipliers have been calculated according to the standard formula for accounting (impact) multipliers, as follows:

$$Y = A\,Y + X = (I - A)^{-1}\,X = M_a\,X$$

where:

Y is a vector of incomes of endogenous variables
X is a vector of expenditures of exogenous variables
A is the matrix of average expenditure propensities for endogenous accounts
$M_a = (I - A)^{-1}$ is a matrix of aggregate accounting multipliers (generalized Leontief inverse).

28. Variations in any one of the exogenous accounts (in this case ΔX) will produce total impacts (ΔY) of endogenous entries via the multipliers. More specifically, this are expressed as:

$$\Delta Y = M_a \times \Delta X.$$

29. The economy-wide effect is thus equal to $\Delta Y = M_a \times \Delta X$. Thus ΔY captures the economy-wide impacts on the four endogenous accounts, namely (i) gross output; (ii) commodity demand; (iii) factor returns; and (iv) household. Table 5 provides a description of the endogenous and exogenous accounts and multiplier effects.

30. The economy-wide impacts of the infrastructure I investment are examined by changing the total exogenous injection vector, especially government expenditure (g) and investment demand (investment in construction and infrastructure). More specifically, the total exogenous account is manipulated to estimate their effects on output (through an output multiplier), value-added or GDP (through the GDP multiplier), and household income (through household income multiplier) and commodity demand (via commodity multipliers).

Table 5: Description of Endogenous and Exogenous Accounts and Multiplier Affects

Endogenous (y)	Exogenous (x)
The activity (gross output multipliers) indicates the total effect on the sectoral gross output of a unit-income increase in a given account *i* in the SAM, and is obtained via the association with the commodity production activity account *i*.	
The consumption commodity multipliers, which indicate the total effect on the sectoral commodity output of a unit-income increase in a given account *i* in the SAM, are obtained by adding the associated commodity elements in the matrix along the column for account *i*.	Intervention into through activities (x = i + g + e), where I = GFC + ST (GFCF) Exports (e) Government expenditure (g) Investment demand (i) Inventory demand (i)
The value-added or gross domestic product (GDP) multiplier, giving the total increase in GDP resulting from the same unit-income injection, is derived by summing up the factor-payment elements along account *i*'s column.	
The household income multiplier shows the total effect on household and enterprise income, and is obtained by adding the elements for the household groups along the account *i* column.	Intervention via households (x = r + gt + ct), where Remittance (r) Government transfers (gt) Corporation transfers (ct)

3. Simulation and Results

31. In the SAM multiplier framework two scenarios are considered. In the first scenario it is assumed that the $6.7 billion extra revenue from the gas sector (if gas is priced at the liquid natural gas landing price in India) is invested annually over a period from 2013 to 2030 (18 years) in such a way such that the investment demands in construction, utility, transportation, health, and education services are increased annually by 13.4%, 480%, 17.5%, 4.4%, and 2.2%, respectively. In the second scenario, the $2.9 billion extra revenue from the gas sector (if gas is priced at average gas price in India and Pakistan) is invested annually over the same period in such a way that the investment demands in construction, utility, transportation, health, and education services are increased annually by 5.8%, 207.8%, 7.5%, 1.9%, and 1%, respectively.

32. Simulated outcomes of the two scenarios by four endogenous accounts are reported in Table 6. Under the first scenario, as a result of the rise in investment in the infrastructure sectors, the gross output of the economy would increase by 15.8% annually compared to the base-year value. The commodity demand would increase by 15.4% annually. Value-added or GDP of the economy is expected to increase by more than 17% annually compared to the base case. The agriculture sector, which a large majority of poor are in, would experience about 14% in output increase per annum while industry records about 11%. Services records the largest growth of 20%. Total household consumption would increase by 15.3% annually compared to the base case, indicating significant welfare improvements.

33. Under the second scenario, with the relatively lower annual investment demands than those of the first scenario, the gross output of the economy and the commodity demand would increase annually by 6.8% and 6.7% respectively, compared to the base-year values. Value-added or GDP of the economy would increase annually by 7.5% compared to the base case. Finally, total household consumption would increase by 6.6% annually compared to the base case.

Table 6: Economy-Wide Benefits of Infrastructure Investment
(Annual % Change from Base Value, 2013–030)

Endogenous accounts	Scenario 1: $6.7 billion annual investment	Scenario 2: $2.9 billion annual investment
Activity		
Cereal crop sectors	15.01	6.50
Commercial crops	12.71	5.50
Livestock rearing	15.24	6.60
Poultry rearing	15.30	6.62
Fishing	12.69	5.49
Forestry	13.88	6.01
Agriculture	**13.96**	**6.04**
Rice milling	15.12	6.54
Grain milling	15.34	6.64
Food processing	15.13	6.55
Leather industry	9.37	4.06
Yarn	4.06	1.76
Cloth milling	10.05	4.35
Woven readymade garments	0.98	0.43
Knitting	1.24	0.54
Toiletries	18.59	8.05
Cigarette industry	14.80	6.40
Furniture industry	9.77	4.23
Paper, printing, and publishing Industry	21.32	9.23
Pharmaceuticals	17.72	7.67
Fertilizer industry	12.72	5.51
Petroleum	16.36	7.08
Chemical industry	12.77	5.53
Glass industry	12.44	5.38
Earth-ware and clay industry	13.58	5.88
Cement	17.55	7.60
Metal	15.93	6.90
Miscellaneous industry	8.41	3.64
Mining and quarrying	13.61	5.89
Industry	**10.92**	**4.73**
Construction	13.47	5.83
Electricity and water generation	17.78	7.69

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Table 6 *continued*

Endogenous accounts	**Scenario 1: $6.7 billion annual investment**	**Scenario 2: $2.9 billion annual investment**
Gas extraction and distribution	18.16	7.86
Wholesale and retail trade	12.43	5.38
Transport	30.52	13.21
Health services	65.53	28.36
Education services	63.06	27.29
Public administration and defense	2.05	0.89
Bank insurance and real estate	16.54	7.16
Hotel and restaurant	15.42	6.67
Communication	14.28	6.18
Information technology and e-commerce	9.63	4.17
Other services	18.00	7.79
Services	**20.26**	**8.77**
TOTAL GROSS OUTPUT	**15.81**	**6.84**
Commodity		
Cereal crop sectors	15.01	6.50
Commercial crops	12.71	5.50
Livestock rearing	15.24	6.60
Poultry rearing	15.30	6.62
Fishing	12.69	5.49
Forestry	13.88	6.01
Agriculture	**13.91**	**6.02**
Rice milling	15.12	6.54
Grain milling	15.34	6.64
Food processing	15.13	6.55
Leather industry	9.37	4.06
Jute and yarn	4.06	1.76
Cloth milling	10.05	4.35
Woven readymade garments	0.98	0.43
Knitting	1.24	0.54
Toiletries	18.59	8.05
Cigarette industry	14.80	6.40
Furniture industry	9.77	4.23
Paper, printing, and publishing Industry	21.32	9.23
Pharmaceuticals	17.72	7.67
Fertilizer industry	12.72	5.51
Petroleum	16.36	7.08
Chemical industry	12.77	5.53
Glass industry	12.44	5.38
Earth-ware and clay industry	13.58	5.88
Cement	17.55	7.60
Metal	15.93	6.90
Miscellaneous industry	8.41	3.64
Mining and quarrying	13.61	5.89

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Table 6 *continued*

Endogenous accounts	Scenario 1: $6.7 billion annual investment	Scenario 2: $2.9 billion annual investment
Industry	**11.03**	**4.78**
Construction	13.47	5.83
Electricity and water generation	17.78	7.69
Gas extraction and distribution	18.16	7.86
Wholesale and retail trade	12.43	5.38
Transport	30.52	13.21
Health services	65.53	28.36
Education services	63.06	27.29
Public administration and defense	2.05	0.89
Bank insurance and real estate	16.54	7.16
Hotel and restaurant	15.42	6.67
Communication	14.28	6.18
Information technology and e-commerce	9.63	4.17
Other services	18.00	7.79
Services	**20.35**	**8.81**
TOTAL COMMODITY DEMAND	15.42	6.67
Value-added		
Value-added labor, unskilled	15.86	6.86
Value-added labor, skilled	19.30	8.35
Value-added capital	17.52	7.58
Value-added land	13.97	6.05
TOTAL VALUE-ADDED	17.33	7.50
Households		
Rural landless	15.50	6.71
Rural marginal farmers	15.11	6.54
Rural small farmers	14.38	6.23
Rural large farmers	14.23	6.16
Rural nonfarm	15.41	6.67
Urban low education	14.09	6.10
Urban high education	16.50	7.14
TOTAL HOUSEHOLD CONSUMPTION	15.33	6.64

Source: social accounting matrix multiplier simulation results.

B. General Equilibrium Model for the Bangladesh Economy

34. The majority of computable general equilibrium (CGE) models are static in nature and thus unable to account for growth effects in the long-run analysis of the economic policies. Dynamic CGE models, in contrast, can include accumulation effects and can allow the study of transition path of an economy where short-run policy impacts are likely to be different from those of the long-run. In this study, we use a sequential dynamic CGE model. This kind of dynamics will not be the result of inter-temporal optimization by economic agents. Instead, these agents have myopic behavior. It is a series of static CGE models that are linked between periods by updating procedures for exogenous and endogenous variables. Capital stock is updated endogenously with a capital accumulation equation, whereas population (and total labor supply) is updated exogenously between periods. Below we present a brief description of static and dynamic aspects of the model.

1. Static Module

35. In each sector there is a representative firm that earns capital income, pays dividends to households, and pays direct income taxes to the government. A nested structure for production is adopted. Sectoral output is a Leontief function of value-added and total intermediate consumption. Value-added is in turn represented by a constant elasticity of supply function of capital and composite labor. The latter is also represented by a constant elasticity of supply function of two labor categories: skilled labor and unskilled labor. Both labor categories are assumed to be fully mobile in the model. Capital is fully mobile only after the first year. In different production activities it is assumed that a representative firm remunerates factors of production and pays dividends to households.

36. Households earn their income from production factors: skilled and unskilled labor, and agricultural and nonagricultural capital. They also receive dividends, intra-household transfers, government transfers, and remittances, and they pay direct income tax to the government. Household savings are a fixed proportion of total disposable income. Household demand is represented by a linear expenditure system derived from the maximization of a Stone-Geary utility function. The model includes nine household categories according to characteristics of the household head, as identified in the household expenditure survey (HES). Five of these categories correspond to rural households and four to urban households. Minimal consumption levels are calibrated by using general estimates of the income elasticity and the Frisch parameters.

37. We assume that foreign and domestic goods are imperfect substitutes. This geographical differentiation is introduced by the standard Armington assumption with a constant elasticity of substitution function between imports and domestic goods. On the supply side, producers make an optimal distribution of their production between exports and local sales according to a constant elasticity of transformation function. Furthermore, we assume a finitely elastic export demand function that expresses the limited power of the local producers on the world market. In order to increase their exports, local producers may decrease their free-on-board prices.

38. The government receives direct tax revenue from households and firms, and indirect tax revenue on domestic and imported goods. Its expenditure is allocated between the consumption of goods and services (including public wages) and transfers. The model accounts for indirect or direct tax compensation in the case of a tariff cut. Furthermore, general equilibrium is defined by the equality (in each period) between supply and demand of goods and factors and the investment-saving identity. The nominal exchange rate is the numéraire in each period.

2. Dynamic Module

39. In every period, capital stock is updated with a capital accumulation equation. We assume that the stocks are measured at the beginning of the period and that their flows are measured at the end of the period. We use an investment demand function to determine how new investments will be distributed between the different sectors. This can also be done through a capital distribution function.[7] Investment here is not by origin (product) but rather by sector of destination. The investment demand function used here is similar to those proposed by Bourguignon et al. (1989) and Jung and Thorbecke (2003). The capital accumulation rate (ratio of investment to capital stock) is increasing with respect to the ratio of the rate of return to capital and its user cost. The latter is equal to

7 Abbink et al. (1995) use a sequential dynamic CGE model for Indonesia in which total investment is distributed as a function of base year sectoral shares in total capital remuneration and sectoral profit rates.

the dual price of investment times the sum of the depreciation rate and the exogenous real interest rate. The elasticity of the accumulation rate with respect to the ratio of return to capital and its user cost is assumed to be equal to two. By introducing investment by destination, we respect the equality condition with total investment by origin in the SAM. Besides this, investment by destination is used to calibrate the sectoral capital stock in base run.

40. Total labor supply is an endogenous variable, although it is assumed to simply increase at the exogenous population growth rate. Note that the minimal level of consumption in the linear expenditure system function also increases (as do other nominal variables, like transfers) at the same rate. The exogenous dynamic updating of the model includes nominal variables (which are indexed), government savings, and the current account balance. The equilibrium between total savings and total investment is reached by means of an adjustment variable introduced in the investment demand function. Moreover, the government budget equilibrium is met by a neutral tax adjustment.

41. The model is formulated as a static model that is solved sequentially.[8] The model is homogenous in prices and calibrated in a way to generate "steady state" paths. In the baseline all the variables are increasing, in level, at the same rate and the prices remain constant. The homogeneity test (for example, a shock on the numéraire—the nominal exchange rate—with the "steady state" characteristics) generates the same shock on prices, and unchanged real values, along the counterfactual path. This method is used to facilitate welfare and poverty analysis since all prices remain constant along the business-as-usual path.

42. It is, however, important to note that, in contrast to the static CGE models, which make counterfactual analysis with respect to the base run (generally the initial SAM), a dynamic CGE model allows the economy to grow even in the absence of a shock. This scenario of the economy (without a shock) is termed as the business-as-usual scenario. The counterfactual analysis of any simulation under the dynamic CGE model is, therefore, done with respect to this growth path. One of the salient features of the dynamic model is that it takes into account not only efficiency effects, as also present in the static models, but also accumulation effects. The sectoral accumulation effects are linked to the ratio between the rate of return to the capital stock and the cost of investment goods.

C. Simulation Results

43. In the dynamic CGE model the SAM 2007 of Bangladesh is used, but the sectors are aggregated into 15 sectors. Two scenarios are considered. In the first scenario, the $6.7 billion extra revenue from the gas sector (if gas is priced at liquid natural gas landing price in India) is invested in the physical and social infrastructure annually over a period from 2013 to 2030 (18 years). In the CGE framework, this scenario is introduced by increasing the capital stocks in the physical (construction) and social infrastructure (services) by 13.4% and 55.8% annually. Under the second scenario, the $2.9 billion extra revenue from the gas sector (if gas is priced at average gas price in India and Pakistan) is invested in the physical and social infrastructure annually over the same period and capital stocks in the physical (construction) and social infrastructure (services) are increased by 5.8% and 24.2% annually. In both these scenarios an added simulation is conducted considering the withdrawal of the gas subsidy. That scenario would lead to reductions in growth in GDP, exports, and imports, and a rise in the consumer price index (CPI). When the scenario of withdrawal of the gas subsidy is added to the

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8 The model is formulated as a system of nonlinear equations solved simultaneously as a constrained nonlinear system with GAMS/Conopt3 solver.

scenario of increased investments in the physical and social infrastructure, the combined scenario produces overall positive results.

1. Results of Scenario 1

44. The macro impacts of the first scenario are reported in Table 7. The growth path of real GDP, exports, and imports would be significantly higher than those of the business-as-usual paths and they will have increasing trends. Households' welfare (expressed in terms of equivalent variation) would rise significantly higher than the business-as-usual path in the short run and it would continue to rise in the long run. This scenario would lead to a reduction in CPIs in all years with a larger reduction in the long run.

Table 7: Macroeconomic Impacts of $6.7 Billion Annual Investment
(% deviation from the business-as-usual scenario)

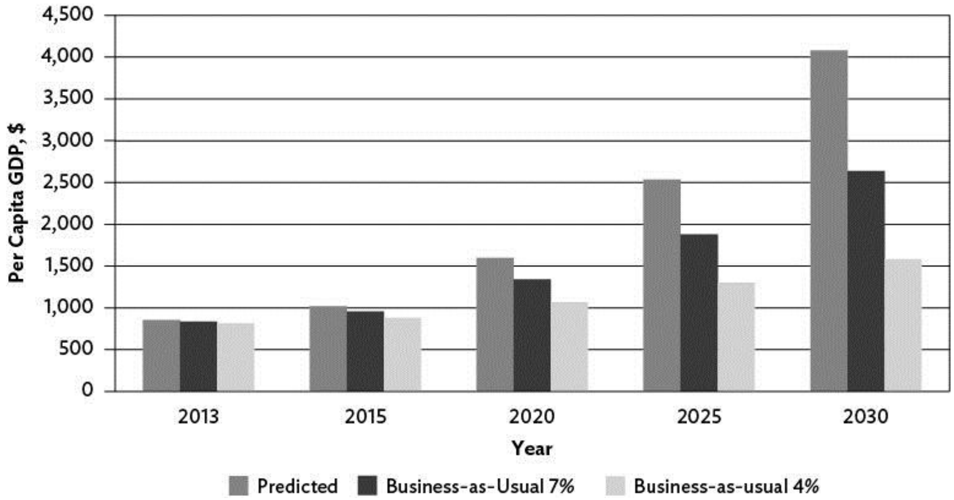
Year	GDP	Exports	Imports	Equivalent Variation	CPI
2013	9.23	9.56	2.42	7.22	(1.97)
2014	9.28	9.76	2.45	7.36	(2.01)
2015	9.32	10.12	2.49	7.53	(2.04)
2016	9.36	10.37	2.51	7.68	(2.09)
2017	9.40	10.65	2.55	7.84	(2.13)
2018	9.44	10.93	2.58	7.99	(2.18)
2019	9.48	11.21	2.61	8.15	(2.22)
2020	9.52	11.49	2.64	8.30	(2.27)
2021	9.57	11.77	2.67	8.46	(2.31)
2022	9.62	12.05	2.71	8.61	(2.36)
2023	9.67	12.33	2.74	8.77	(2.40)
2024	9.72	12.61	2.78	8.92	(2.45)
2025	9.77	12.89	2.82	9.08	(2.49)
2026	9.84	13.17	2.85	9.23	(2.55)
2027	9.91	13.45	2.89	9.39	(2.60)
2028	9.98	13.73	2.92	9.54	(2.65)
2029	10.05	14.01	2.96	9.70	(2.69)
2030	10.12	14.29	3.00	9.85	(2.63)

( ) = negative, CPI = consumer price index, GDP = gross domestic product.

Source: Estimates by authors.

45. In order to understand the growth impact of the invested gas revenue on infrastructure development, we estimated the related per-capita GDP through 2030. As shown in Figure 8, the per-capita GDP would be about $4,079 in 2030 if the augmented gas revenue was fully invested in social and physical infrastructure. This is about a 54% increase from the base-case scenario per-capita GDP of $ 2,636. The base case assumes 7% economic growth, which is unrealistic without resolving the power sector crisis and removing other infrastructure constraints. If a more realistic base case of 4% growth is assumed, the GDP increase is about 158%. These numbers clearly show the highly significant growth impact of investing gas resource revenue in the economy. The impacts on sectoral domestic prices are reported in Table 8. Prices in almost all sectors would decline over the years.

Figure 8: Growth Impact of Investing Gas Revenue in Infrastructure



Source: Estimates by the authors.

Table 8: Impact of $6.7 Billion Annual Investment on Sectoral Domestic Prices
(% deviation from the business-as-usual scenario)

	CROP	COMC	LIVS	FORS	RATM	FOOD	LEAT	CLOT	GARM	CHEM	MACH	PETR	OIND	CNST	SERV
2013	−0.58	−0.54	−1.79	−2.37	−1.19	−1.13	−1.12	−0.79	−0.21	−0.18	−0.25	−0.10	−0.34	−0.43	−0.15
2014	−1.13	−0.89	−2.07	−2.44	−1.36	−1.24	−1.25	−0.86	−0.42	−0.22	−0.30	−0.13	−0.39	−0.49	−0.20
2015	−1.36	−1.04	−2.23	−2.37	−1.39	−1.33	−1.38	−0.94	−0.29	−0.26	−0.36	−0.16	−0.44	−0.55	−0.24
2016	−1.43	−1.09	−2.46	−2.54	−1.42	−1.44	−1.51	−1.01	−0.21	−0.30	−0.42	−0.20	−0.49	−0.62	−0.30
2017	−1.61	−1.21	−2.64	−2.54	−1.47	−1.53	−1.64	−1.09	−0.16	−0.35	−0.48	−0.24	−0.55	−0.69	−0.36
2018	−1.76	−1.31	−2.84	−2.58	−1.50	−1.61	−1.75	−1.16	−0.14	−0.40	−0.56	−0.29	−0.62	−0.77	−0.44
2019	−1.91	−1.41	−3.03	−2.63	−1.54	−1.73	−1.86	−1.24	−0.14	−0.46	−0.63	−0.35	−0.69	−0.85	−0.53
2020	−2.06	−1.51	−3.23	−2.67	−1.58	−1.83	−1.97	−1.31	−0.15	−0.53	−0.72	−0.41	−0.77	−0.93	−0.62
2021	−2.21	−1.61	−3.42	−2.72	−1.62	−1.93	−2.04	−1.39	−0.18	−0.61	−0.81	−0.50	−0.85	−1.01	−0.75
2022	−2.36	−1.71	−3.62	−2.76	−1.67	−2.04	−2.08	−1.46	−0.21	−0.70	−0.91	−0.51	−0.95	−1.09	−0.76
2023	−2.51	−1.81	−3.81	−2.80	−1.73	−2.13	−2.14	−1.54	−0.25	−0.80	0.14	−0.56	−1.05	−1.17	−0.83
2024	−2.66	−1.91	−4.01	−2.85	−1.78	−2.21	−2.20	−1.61	−0.29	−0.92	−1.12	−0.60	−1.16	−1.23	−0.91
2025	−2.81	−2.01	−4.20	−2.89	−1.83	−2.33	−2.25	−1.69	−0.34	−1.06	−1.22	−0.65	−1.27	−1.28	−0.98
2026	−2.96	−2.11	−4.40	−2.94	−1.89	−2.43	−2.31	−1.76	−0.38	−1.23	−1.29	−0.70	−1.37	−1.29	−1.05
2027	−3.11	−2.21	−4.59	−2.98	−1.94	−2.54	−2.36	−1.84	−0.43	−1.44	−1.32	−0.75	−1.45	−1.26	−1.12
2028	−3.26	−2.31	−4.79	−3.02	−1.99	−2.63	−2.42	−1.91	−0.47	−1.68	−1.41	−0.80	−1.49	−1.19	−1.20
2029	−3.41	−2.41	−4.98	−3.07	−2.05	−2.75	−2.47	−1.99	−0.51	−1.94	−1.47	−0.85	−1.52	−1.13	−1.27
2030	−3.56	−2.51	−5.18	−3.11	−2.10	−2.83	−2.53	−2.06	−0.56	−2.07	−1.54	−0.89	−1.55	−1.40	−1.34

CROP = cereal crop, COMC = commercial crop, LIVS = livestock and poultry, FORS = forestry, RATM = rice and ata milling, FOOD = other food, LEAT = leather and leather goods, CLOT = mill clothing, GARM = ready-made garments, CHEM = chemicals, MACH = machinery, PETR = petroleum products, OIND = other industries, CNST = construction, SERV = other services.

Source: Estimates by authors.

46. Impacts on sectoral exports are reported in Table 9. There would be significant expansion of exports from the major export-oriented sectors both in the short and long run, and larger positive impacts would be observed in the long run. In the case of impact on production, much higher growth-path trajectories are observed for all sectors compared to the business-as-usual scenario (Table 10).

Table 9: Impact of $ 6.7 Billion Annual Investment on Sectoral Exports
(% deviation from the business-as-usual scenario)

	CROP	COMC	LIVS	FORS	RATM	FOOD	LEAT	CLOT	GARM	CHEM	MACH	PETR	OIND	CNST	SERV
2013	0	4.57	8.34	0	0	8.92	10.62	6.89	7.11	14.15	10.19	13.38	6.36	0	10.19
2014	0	7.49	10.42	0	0	10.29	12.80	8.87	7.53	14.25	10.27	13.64	6.62	0	10.55
2015	0	8.85	10.93	0	0	10.44	13.27	9.58	7.79	14.39	10.44	13.85	6.88	0	11.12
2016	0	9.31	11.44	0	0	10.59	13.74	9.64	8.16	14.50	10.55	14.09	7.14	0	11.55
2017	0	10.37	11.95	0	0	10.74	14.21	10.13	8.50	14.62	10.68	14.33	7.40	0	12.02
2018	0	11.28	12.46	0	0	10.89	14.68	10.52	8.84	14.74	10.80	14.56	7.66	0	12.48
2019	0	12.19	12.97	0	0	11.04	15.15	10.90	9.18	14.86	10.93	14.80	7.92	0	12.95
2020	0	13.10	13.48	0	0	11.19	15.62	11.29	9.52	14.98	11.05	15.03	8.18	0	13.41
2021	0	14.01	13.99	0	0	11.34	16.09	11.67	9.86	15.10	11.18	15.27	8.44	0	13.88
2022	0	14.92	14.50	0	0	11.49	16.56	12.06	10.20	15.22	11.30	15.50	8.70	0	14.34
2023	0	15.83	15.01	0	0	11.64	17.03	12.44	10.54	15.34	11.43	15.74	8.96	0	14.81
2024	0	16.74	15.52	0	0	11.79	17.5	12.83	10.88	15.46	11.55	15.97	9.22	0	15.27
2025	0	17.65	16.03	0	0	11.94	17.97	13.21	11.22	15.58	11.68	16.21	9.48	0	15.74
2026	0	18.56	16.54	0	0	12.09	18.44	13.60	11.56	15.70	11.80	16.44	9.74	0	16.20
2027	0	19.47	17.05	0	0	12.24	18.91	13.98	11.90	15.82	11.93	16.68	10.00	0	16.67
2028	0	20.38	17.56	0	0	12.39	19.38	14.37	12.24	15.94	12.05	16.91	10.26	0	17.13
2029	0	21.29	18.07	0	0	12.54	19.85	14.75	12.58	16.06	12.18	17.15	10.52	0	17.60
2030	0	22.20	18.58	0	0	12.69	20.32	15.14	12.92	16.18	12.30	17.38	10.78	0	18.06

CROP = cereal crop, COMC = commercial crop, LIVS = livestock and poultry, FORS = forestry, RATM = rice and ata milling, FOOD = other food, LEAT = leather and leather goods, CLOT = mill clothing, GARM = ready-made garments, CHEM = chemicals, MACH = machinery, PETR = petroleum products, OIND = other industries, CNST = construction, SERV = other services.

Source: Dynamic computable general equilibrium simulation results.

Table 10: Impact of $6.7 Billion Annual Investment on Sectoral Production
(% deviation from the business-as-usual scenario)

	CROP	COMC	LIVS	FORS	RATM	FOOD	LEAT	CLOT	GARM	CHEM	MACH	PETR	OIND	CNST	SERV
2013	6.43	6.13	6.92	4.21	7.98	9.56	11.23	6.97	7.33	12.09	10.58	12.88	10.34	6.29	9.21
2014	6.66	6.32	7.11	4.56	8.22	9.69	11.35	7.12	7.53	12.29	10.72	13.15	10.76	6.46	9.40
2015	6.89	6.46	7.23	4.72	8.31	9.76	11.49	7.31	7.78	12.43	10.88	13.68	10.92	6.53	9.71
2016	7.12	6.63	7.40	5.01	8.50	9.87	11.62	7.47	8.00	12.61	11.03	14.04	11.25	6.67	9.95
2017	7.35	6.80	7.55	5.26	8.67	9.97	11.75	7.64	8.22	12.78	11.18	14.44	11.54	6.79	10.20
2018	7.58	6.96	7.71	5.52	8.83	10.07	11.88	7.81	8.45	12.95	11.33	14.84	11.83	6.91	10.45
2019	7.81	7.13	7.86	5.77	9.00	10.17	12.01	7.98	8.67	13.12	11.48	15.24	12.12	7.03	10.71
2020	8.04	7.29	8.02	6.03	9.16	10.27	12.14	8.15	8.90	13.29	11.63	15.64	12.41	7.15	10.96
2021	8.27	7.46	8.17	6.28	9.33	10.37	12.27	8.32	9.12	13.46	11.78	16.04	12.70	7.27	11.21
2022	8.50	7.62	8.33	6.54	9.49	10.47	12.40	8.49	9.35	13.63	11.93	16.44	12.99	7.40	11.47
2023	8.73	7.79	8.48	6.79	9.66	10.57	12.53	8.66	9.57	13.80	12.08	16.84	13.28	7.52	11.72
2024	8.96	7.95	8.64	7.05	9.82	10.67	12.66	8.83	9.80	13.97	12.23	17.24	13.57	7.64	11.97
2025	9.19	8.12	8.79	7.30	9.99	10.77	12.79	9.00	10.02	14.14	12.38	17.64	13.86	7.76	12.22
2026	9.42	8.28	8.95	7.56	10.15	10.87	12.92	9.17	10.25	14.31	12.53	18.04	14.15	7.88	12.48
2027	9.65	8.45	9.10	7.81	10.32	10.97	13.05	9.34	10.47	14.48	12.68	18.44	14.44	8.00	12.73
2028	9.88	8.61	9.26	8.07	10.48	11.07	13.18	9.51	10.70	14.65	12.83	18.84	14.73	8.12	12.98
2029	10.11	8.78	9.41	8.32	10.65	11.17	13.31	9.68	10.92	14.82	12.98	19.24	15.02	8.24	13.24
2030	10.34	8.94	9.57	8.58	10.81	11.27	13.44	9.85	11.15	14.99	13.13	19.64	15.31	8.36	13.49

CROP = cereal crop, COMC = commercial crop, LIVS = livestock and poultry, FORS = forestry, RATM = rice and ata milling, FOOD = other food, LEAT = leather and leather goods, CLOT = mill clothing, GARM = ready-made garments, CHEM = chemicals, MACH = machinery, PETR = petroleum products, OIND = other industries, CNST = construction, SERV = other services.

Source: Estimates by authors.

47. The impacts on households' real consumption are reported in Table 11. It appears that all household categories would experience a rise in real consumption both in the short and long run with larger impacts observed in the long run. In the short run, the richer households would have higher increases in real consumption than the poorer households; however, in the medium and long run, the gains of the poorer households would be higher than their nonpoor counterparts. This finding clearly demonstrates that there is no evidence to support that an energy price increase will adversely affect the poor in Bangladesh.

Table 11: Impact of $6.7 Billion Annual Investment on Household Real Consumption (% deviation from the business-as-usual scenario)

	H1	H2	H3	H4	H5	H6	H7	H8	H9
2013	8.59	8.25	8.72	8.88	8.11	8.73	8.83	8.95	9.11
2014	8.78	8.31	8.86	8.92	8.16	8.93	8.99	8.99	9.15
2015	8.94	8.35	8.93	8.95	8.27	9.11	8.98	9.05	9.19
2016	9.12	8.40	9.05	8.99	8.34	9.30	9.08	9.10	9.23
2017	9.30	8.45	9.15	9.02	8.42	9.49	9.16	9.15	9.27
2018	9.47	8.50	9.26	9.06	8.50	9.68	9.23	9.20	9.31
2019	9.65	8.55	9.36	9.09	8.58	9.87	9.31	9.25	9.35
2020	9.82	8.60	9.47	9.13	8.66	10.06	9.38	9.30	9.39
2021	10.00	8.65	9.57	9.16	8.74	10.25	9.46	9.35	9.43
2022	10.17	8.70	9.68	9.20	8.82	10.44	9.53	9.40	9.47
2023	10.35	8.75	9.78	9.23	8.90	10.63	9.61	9.45	9.51
2024	10.52	8.80	9.89	9.27	8.98	10.82	9.68	9.50	9.55
2025	10.70	8.85	9.99	9.30	9.06	11.01	9.76	9.55	9.59
2026	10.87	8.90	10.10	9.34	9.14	11.20	9.83	9.60	9.63
2027	11.05	8.95	10.20	9.37	9.22	11.39	9.91	9.65	9.67
2028	11.22	9.00	10.31	9.41	9.30	11.58	9.98	9.70	9.71
2029	11.40	9.05	10.41	9.44	9.38	11.77	10.06	9.75	9.75
2030	11.57	9.10	10.52	9.48	9.46	11.96	10.13	9.80	9.79

H1 = Landless households, H2 = marginal farmers, H3 = small farmers, H4 = large farmers, H5 = rural nonfarm households, H6 = urban non-educated households, H7 = urban low-education households, H8 = urban medium-education households, H9 = urban high-education households.

Source: Estimates by authors.

2. Results of Scenario 2

48. The results of the second scenario are reported in Tables 12–16. The direction of the impacts under the second scenario would be the same as in the first, although the magnitudes of the impacts would be lower under the second scenario.

Table 12: Macroeconomic Impacts of $2.9 Billion Annual Investment
(% deviation from the business-as-usual scenario)

Year	GDP	Exports	Imports	Equivalent Variation	CPI
2013	4.00	4.14	1.05	3.13	−0.85
2014	4.02	4.22	1.06	3.19	−0.87
2015	4.03	4.38	1.08	3.26	−0.88
2016	4.05	4.49	1.09	3.32	−0.90
2017	4.07	4.61	1.10	3.39	−0.92
2018	4.09	4.73	1.12	3.46	−0.94
2019	4.10	4.85	1.13	3.53	−0.96
2020	4.12	4.97	1.14	3.59	−0.98
2021	4.14	5.09	1.16	3.66	−1.00
2022	4.16	5.22	1.17	3.73	−1.02
2023	4.19	5.34	1.19	3.80	−1.04
2024	4.21	5.46	1.20	3.86	−1.06
2025	4.23	5.58	1.22	3.93	−1.08
2026	4.26	5.70	1.23	4.00	−1.10
2027	4.29	5.82	1.25	4.06	−1.13
2028	4.32	5.94	1.26	4.13	−1.15
2029	4.35	6.06	1.28	4.20	−1.16
2030	4.38	6.19	1.30	4.26	−1.14

CPI = consumer price index, GDP = gross domestic product.

Source: Estimates by authors.

Table 13: Impact of $2.9 Billion Annual Investment on Sectoral Domestic Prices
(% deviation from the business-as-usual scenario)

	CROP	COMC	LIVS	FORS	RATM	FOOD	LEAT	CLOT	GARM	CHEM	MACH	PETR	OIND	CNST	SERV
2013	−0.25	−0.23	−0.77	−1.03	−0.52	−0.49	−0.48	−0.34	−0.09	−0.08	−0.11	−0.04	−0.15	−0.19	−0.06
2014	−0.49	−0.39	−0.90	−1.06	−0.59	−0.54	−0.54	−0.37	−0.18	−0.10	−0.13	−0.06	−0.17	−0.21	−0.09
2015	−0.59	−0.45	−0.97	−1.03	−0.60	−0.58	−0.60	−0.41	−0.13	−0.11	−0.16	−0.07	−0.19	−0.24	−0.10
2016	−0.62	−0.47	−1.06	−1.10	−0.61	−0.62	−0.65	−0.44	−0.09	−0.13	−0.18	−0.09	−0.21	−0.27	−0.13
2017	−0.70	−0.52	−1.14	−1.10	−0.64	−0.66	−0.71	−0.47	−0.07	−0.15	−0.21	−0.10	−0.24	−0.30	−0.16
2018	−0.76	−0.57	−1.23	−1.12	−0.65	−0.70	−0.76	−0.50	−0.06	−0.17	−0.24	−0.13	−0.27	−0.33	−0.19
2019	−0.83	−0.61	−1.31	−1.14	−0.67	−0.75	−0.81	−0.54	−0.06	−0.20	−0.27	−0.15	−0.30	−0.37	−0.23
2020	−0.89	−0.65	−1.40	−1.16	−0.68	−0.79	−0.85	−0.57	−0.06	−0.23	−0.31	−0.18	−0.33	−0.40	−0.27
2021	−0.96	−0.70	−1.48	−1.18	−0.70	−0.84	−0.88	−0.60	−0.08	−0.26	−0.35	−0.22	−0.37	−0.44	−0.32
2022	−1.02	−0.74	−1.57	−1.19	−0.72	−0.88	−0.90	−0.63	−0.09	−0.30	−0.39	−0.22	−0.41	−0.47	−0.33
2023	−1.09	−0.78	−1.65	−1.21	−0.75	−0.92	−0.93	−0.67	−0.11	−0.35	0.06	−0.24	−0.45	−0.51	−0.36
2024	−1.15	−0.83	−1.74	−1.23	−0.77	−0.96	−0.95	−0.70	−0.13	−0.40	−0.48	−0.26	−0.50	−0.53	−0.39
2025	−1.22	−0.87	−1.82	−1.25	−0.79	−1.01	−0.97	−0.73	−0.15	−0.46	−0.53	−0.28	−0.55	−0.55	−0.42
2026	−1.28	−0.91	−1.90	−1.27	−0.82	−1.05	−1.00	−0.76	−0.16	−0.53	−0.56	−0.30	−0.59	−0.56	−0.45
2027	−1.35	−0.96	−1.99	−1.29	−0.84	−1.10	−1.02	−0.80	−0.19	−0.62	−0.57	−0.32	−0.63	−0.55	−0.48
2028	−1.41	−1.00	−2.07	−1.31	−0.86	−1.14	−1.05	−0.83	−0.20	−0.73	−0.61	−0.35	−0.64	−0.52	−0.52
2029	−1.48	−1.04	−2.16	−1.33	−0.89	−1.19	−1.07	−0.86	−0.22	−0.84	−0.64	−0.37	−0.66	−0.49	−0.55
2030	−1.54	−1.09	−2.24	−1.35	−0.91	−1.22	−1.10	−0.89	−0.24	−0.90	−0.67	−0.39	−0.67	−0.61	−0.58

CROP = cereal crop, COMC = commercial crop, LIVS = livestock and poultry, FORS = forestry, RATM = rice and ata milling, FOOD = other food, LEAT = leather and leather goods, CLOT = mill clothing, GARM = ready-made garments, CHEM = chemicals, MACH = machinery, PETR = petroleum products, OIND = other industries, CNST = construction, SERV = other services.

Source: Estimates by authors.

Table 14: Impact of $2.9 Billion Annual Investment on Sectoral Exports
(% deviation from the business-as-usual scenario)

	CROP	COMC	LIVS	FORS	RATM	FOOD	LEAT	CLOT	GARM	CHEM	MACH	PETR	OIND	CNST	SERV
2013	0	1.98	3.61	0	0	3.86	4.60	2.98	3.08	6.12	4.41	5.79	2.75	0	4.41
2014	0	3.24	4.51	0	0	4.45	5.54	3.84	3.26	6.17	4.45	5.90	2.87	0	4.57
2015	0	3.83	4.73	0	0	4.52	5.74	4.15	3.37	6.23	4.52	5.99	2.98	0	4.81
2016	0	4.03	4.95	0	0	4.58	5.95	4.17	3.53	6.28	4.57	6.10	3.09	0	5.00
2017	0	4.49	5.17	0	0	4.65	6.15	4.38	3.68	6.33	4.62	6.20	3.20	0	5.20
2018	0	4.88	5.39	0	0	4.71	6.35	4.55	3.83	6.38	4.67	6.30	3.32	0	5.40
2019	0	5.28	5.61	0	0	4.78	6.56	4.72	3.97	6.43	4.73	6.41	3.43	0	5.61
2020	0	5.67	5.83	0	0	4.84	6.76	4.89	4.12	6.48	4.78	6.51	3.54	0	5.80
2021	0	6.06	6.06	0	0	4.91	6.96	5.05	4.27	6.54	4.84	6.61	3.65	0	6.01
2022	0	6.46	6.28	0	0	4.97	7.17	5.22	4.41	6.59	4.89	6.71	3.77	0	6.21
2023	0	6.85	6.50	0	0	5.04	7.37	5.38	4.56	6.64	4.95	6.81	3.88	0	6.41
2024	0	7.25	6.72	0	0	5.10	7.57	5.55	4.71	6.69	5.00	6.91	3.99	0	6.61
2025	0	7.64	6.94	0	0	5.17	7.78	5.72	4.86	6.74	5.06	7.02	4.10	0	6.81
2026	0	8.03	7.16	0	0	5.23	7.98	5.89	5.00	6.80	5.11	7.12	4.22	0	7.01
2027	0	8.43	7.38	0	0	5.30	8.18	6.05	5.15	6.85	5.16	7.22	4.33	0	7.22
2028	0	8.82	7.60	0	0	5.36	8.39	6.22	5.30	6.90	5.22	7.32	4.44	0	7.41
2029	0	9.22	7.82	0	0	5.43	8.59	6.38	5.45	6.95	5.27	7.42	4.55	0	7.62
2030	0	9.61	8.04	0	0	5.49	8.80	6.55	5.59	7.00	5.32	7.52	4.67	0	7.82

CROP = cereal crop, COMC = commercial crop, LIVS = livestock and poultry, FORS = forestry, RATM = rice and ata milling, FOOD = other food, LEAT = leather and leather goods, CLOT = mill clothing, GARM = ready-made garments, CHEM = chemicals, MACH = machinery, PETR = petroleum products, OIND = other industries, CNST = construction, SERV = other services.

Source: Estimates by authors.

Table 15: Impact of Annual $ 2.9 Billion Investment on Sectoral Production
(% deviation from the business-as-usual scenario)

	CROP	COMC	LIVS	FORS	RATM	FOOD	LEAT	CLOT	GARM	CHEM	MACH	PETR	OIND	CNST	SERV
2013	2.78	2.65	3.00	1.82	3.45	4.14	4.86	3.02	3.17	5.23	4.58	5.57	4.48	2.72	3.99
2014	2.88	2.74	3.08	1.97	3.56	4.19	4.91	3.08	3.26	5.32	4.64	5.69	4.66	2.80	4.07
2015	2.98	2.80	3.13	2.04	3.60	4.22	4.97	3.16	3.37	5.38	4.71	5.92	4.73	2.83	4.20
2016	3.08	2.87	3.20	2.17	3.68	4.27	5.03	3.23	3.46	5.46	4.77	6.08	4.87	2.89	4.31
2017	3.18	2.94	3.27	2.28	3.75	4.32	5.09	3.31	3.56	5.53	4.84	6.25	4.99	2.94	4.41
2018	3.28	3.01	3.34	2.39	3.82	4.36	5.14	3.38	3.66	5.61	4.90	6.42	5.12	2.99	4.52
2019	3.38	3.09	3.40	2.50	3.90	4.40	5.20	3.45	3.75	5.68	4.97	6.60	5.25	3.04	4.64
2020	3.48	3.16	3.47	2.61	3.96	4.45	5.25	3.53	3.85	5.75	5.03	6.77	5.37	3.09	4.74
2021	3.58	3.23	3.54	2.72	4.04	4.49	5.31	3.60	3.95	5.83	5.10	6.94	5.50	3.15	4.85
2022	3.68	3.30	3.61	2.83	4.11	4.53	5.37	3.67	4.05	5.90	5.16	7.12	5.62	3.20	4.96
2023	3.78	3.37	3.67	2.94	4.18	4.58	5.42	3.75	4.14	5.97	5.23	7.29	5.75	3.25	5.07
2024	3.88	3.44	3.74	3.05	4.25	4.62	5.48	3.82	4.24	6.05	5.29	7.46	5.87	3.31	5.18
2025	3.98	3.51	3.80	3.16	4.32	4.66	5.54	3.90	4.34	6.12	5.36	7.64	6.00	3.36	5.29
2026	4.08	3.58	3.87	3.27	4.39	4.70	5.59	3.97	4.44	6.19	5.42	7.81	6.12	3.41	5.40
2027	4.18	3.66	3.94	3.38	4.47	4.75	5.65	4.04	4.53	6.27	5.49	7.98	6.25	3.46	5.51
2028	4.28	3.73	4.01	3.49	4.54	4.79	5.70	4.12	4.63	6.34	5.55	8.15	6.38	3.51	5.62
2029	4.38	3.80	4.07	3.60	4.61	4.83	5.76	4.19	4.73	6.41	5.62	8.33	6.50	3.57	5.73
2030	4.48	3.87	4.14	3.71	4.68	4.88	5.82	4.26	4.83	6.49	5.68	8.50	6.63	3.62	5.84

CROP = cereal crop, COMC = commercial crop, LIVS = livestock and poultry, FORS = forestry, RATM = rice and ata milling, FOOD = other food, LEAT = leather and leather goods, CLOT = mill clothing, GARM = ready-made garments, CHEM = chemicals, MACH = machinery, PETR = petroleum products, OIND = other industries, CNST = construction, SERV = other services.

Source: Estimates by authors.

Table 16: Impact of Annual $ 2.9 Billion Investment on Household Real Consumption
(% deviation from the Business-As-Usual Scenario)

	H1	H2	H3	H4	H5	H6	H7	H8	H9
2013	3.72	3.57	3.77	3.84	3.51	3.78	3.82	3.87	3.94
2014	3.80	3.60	3.83	3.86	3.53	3.87	3.89	3.89	3.96
2015	3.87	3.61	3.87	3.87	3.58	3.94	3.89	3.92	3.98
2016	3.95	3.64	3.92	3.89	3.61	4.03	3.93	3.94	4.00
2017	4.03	3.66	3.96	3.90	3.64	4.11	3.96	3.96	4.01
2018	4.10	3.68	4.01	3.92	3.68	4.19	4.00	3.98	4.03
2019	4.18	3.70	4.05	3.93	3.71	4.27	4.03	4.00	4.05
2020	4.25	3.72	4.10	3.95	3.75	4.35	4.06	4.03	4.06
2021	4.33	3.74	4.14	3.96	3.78	4.44	4.09	4.05	4.08
2022	4.40	3.77	4.19	3.98	3.82	4.52	4.12	4.07	4.10
2023	4.48	3.79	4.23	4.00	3.85	4.60	4.16	4.09	4.12
2024	4.55	3.81	4.28	4.01	3.89	4.68	4.19	4.11	4.13
2025	4.63	3.83	4.32	4.03	3.92	4.77	4.22	4.13	4.15
2026	4.70	3.85	4.37	4.04	3.96	4.85	4.25	4.16	4.17
2027	4.78	3.87	4.41	4.06	3.99	4.93	4.29	4.18	4.19
2028	4.86	3.90	4.46	4.07	4.03	5.01	4.32	4.20	4.20
2029	4.93	3.92	4.51	4.09	4.06	5.09	4.35	4.22	4.22
2030	5.01	3.94	4.55	4.10	4.09	5.18	4.38	4.24	4.24

Note: H1 = Landless households, H2 = marginal farmers, H3 = small farmers, H4 = Large farmers, H5 = rural nonfarm households, H6 = urban no-educated households, H7 = urban low educated households, H8 = urban medium educated households and H9 = urban high educated households.

Source: Estimates by authors.

III. CONCLUDING OBSERVATIONS

49. Natural gas is heavily subsidized in Bangladesh, and this leads to waste of a valuable resource, lower revenues, and gas and power shortages. This paper has estimated the opportunity cost of underpricing (or subsidizing) gas in Bangladesh. Following Hartwick's rule, the paper examines the impacts of optimal gas pricing and investment of the augmented gas revenues in physical and social infrastructure. The paper has used two different techniques, SAM multiplier analysis and general equilibrium analysis. The general conclusion is that there is a high opportunity cost connected to the gas subsidy. Despite the fact that withdrawal of the gas subsidy would have some negative effects on macro and sectoral economies, such negative effects would be well compensated by the large positive effects generated by the investment of gas revenue in the physical and social infrastructure.

50. The SAM multiplier model indicates a significant annual rise in gross output, commodity demand, household consumption, and value-addition that would derive from increased investments in physical and social infrastructure. In the first scenario, increased investment demands in physical and social infrastructures would lead to a 15.8% annual rise in gross output, 15.4% annual rise in commodity demand, 17% annual rise in value-added or GDP, and 15.3% annual rise in household consumption. Under the second scenario, even with relatively lower annual investment demands than the first scenario, the gross output of the economy and the commodity demand would increase annually by 6.8% and 6.7% respectively, compared to the base-year values. Value-added or GDP of the economy would increase annually by 7.5% compared to the base case. Finally, total household consumption would increase by 6.6% annually compared to the base case.

51. Calculations using a dynamic CGE model suggest that withdrawal of the gas subsidy along with increased investments in physical and social infrastructure would lead to significant positive macroeconomic and sectoral effects in Bangladesh. Under the first scenario, in the short run, the real GDP would rise by 9.23% compared to the business-as-usual scenario, while in the long run it would increase by more than 10%. Exports would grow by 9.5% in the short run and 14.3% in the long run. The fall in CPI would be higher in the long run than in the short run. Also, households would experience a rise in real consumption both in the short and long run. Though withdrawal of the gas subsidy would potentially lead to reductions in growth in GDP and exports and imports and a rise in the CPI, increased investments in the physical and social infrastructure would generate large positive effects and there would be net positive effects for the overall economy. In the longer run, the poor would benefit more from infrastructure development, and there is no evidence to support adverse effects on the poor due to the gas price increase in combination with infrastructure developments.

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Opportunity Cost of Natural Gas Subsidies in Bangladesh

The paper examines the impact of optimal gas pricing policy—aligning the price with international market price—together with better gas revenue management regime, in which augmented gas revenue is used to invest in physical and social infrastructure. Inflationary pressures from higher energy prices would be completely offset by positive impacts of infrastructure constraint removal. Optimal gas pricing and investment in infrastructure would benefit all sectors of the economy without any adverse effects on the poor.

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