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THE ROLE OF CAPTIVE POWER PLANTS IN THE BANGLADESH ELECTRICITY SECTOR

Sakib Amin, Tooraj Jamasb,
Manuel Llorca, Laura Marsiliani,
and Thomas Renström

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Sakib Amin is an Associate Professor at the School of Business and Economics of North South University, Dhaka, Bangladesh. Tooraj Jamasb is a Professor and Director of the Copenhagen School of Energy Infrastructure (CSEI), Department of Economics, Copenhagen Business School, Denmark. Manuel Llorca is a Postdoctoral Fellow at CSEI, Department of Economics, Copenhagen Business School, Denmark. Laura Marsiliani is an Assistant Professor at Durham University Business School, Durham, United Kingdom, and a Fellow at the Durham Energy Institute. Thomas Renström is an Associate Professor at Durham University Business School, Durham, United Kingdom.

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Please contact the authors for information about this paper.

Email: tj.eco@cbs.dk

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Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

Captive power plants (CPPs) in many emerging and developing countries play a significant role in the electricity sector. This is mainly due to unreliable electricity supplies from state-owned utilities and challenges in accessing the national grid, especially in remote and rural areas. Integrating the captive capacity with the on-grid supply can improve resource utilization in the electricity market. In this study, we focus on the role of CPPs in Bangladesh. We start by providing recent stylized facts and survey the experience of other countries. We then use a dynamic stochastic general equilibrium (DSGE) model to examine the effects of allowing CPPs to sell their excess output to the national grid at regulated prices. We find that opening the grid to CPPs would reduce the industrial output and GDP due to pre-existing energy price distortions. We also show that the Bangladesh economy would become more vulnerable to oil price shocks if CPPs were connected to the national grid. We conclude that the government should not open the grid to CPPs yet. Instead, it should first consider alternative reforms, such as taking steps to reduce the price distortions and enabling a competitive market environment.

Keywords: Bangladesh, captive power plants (CPPs), DSGE model, electricity generation, second-best theory

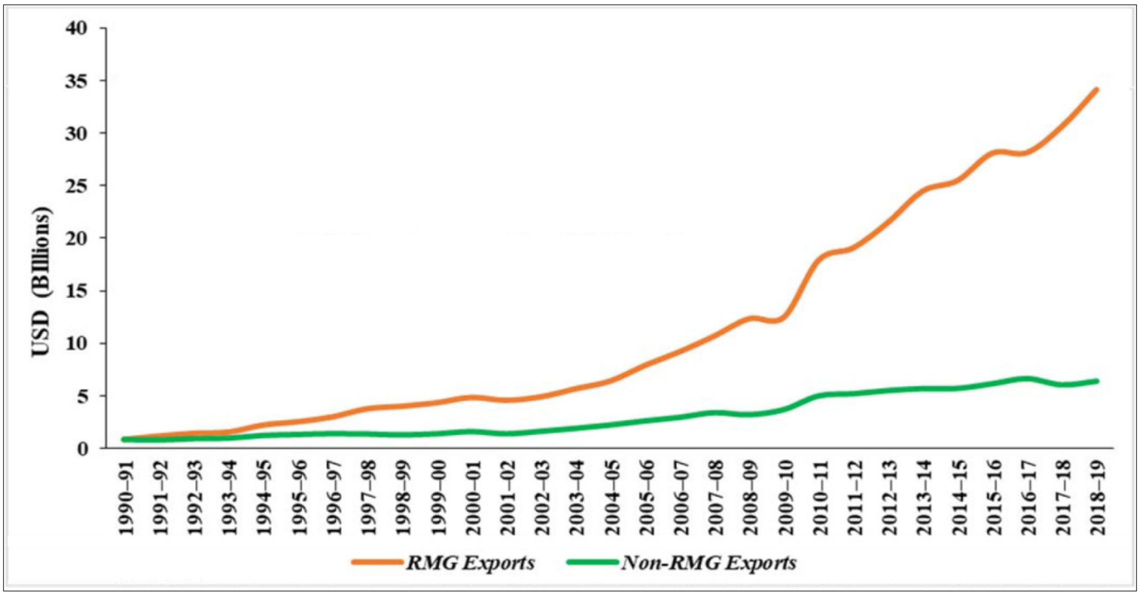
JEL Classification: D58, L94, Q43, Q48

Contents

1. INTRODUCTION

Since the mid-1990s, a structural shift has taken place in the Bangladesh economy. Until the mid-1990s, Bangladesh was mainly an agrarian economy. In the 1970s and 1980s, the agricultural sector accounted for 55.30% and 32.20% of the GDP, respectively, decreasing to 26.57% in the 1990s and 17.34% in the 2000s. Since 1998, the GDP share of the industrial sector has exceeded the agriculture sector's share. At the same time, Bangladesh has exhibited a dramatic shift in its export composition. The GDP share of the so-called traditional exports (such as raw jute and jute goods, tea, leather, and frozen fish) has decreased from more than 75% to about 10%. In 2018–19, exports were worth USD40.5 billion, the apparel industry being the leading contributor. In the period 1990–2019, the export earnings from apparel expanded from less than USD1 billion to USD34.1 billion (Figure 1), with an annual average growth rate of over 15% against the 6.5% growth rate of non-apparel industries. In the process, apparel, popularly known as readymade garments (RMGs), emerged as the flagship export product of Bangladesh and singlehandedly shaped its structural transformation.

Figure 1: Growth of Bangladesh's Exports

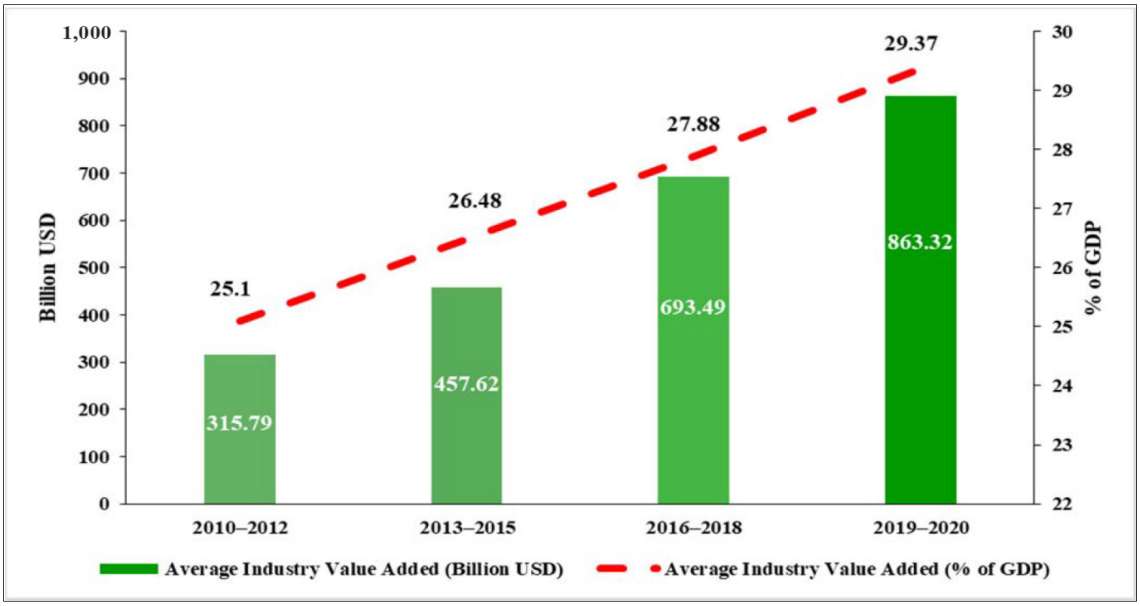


Source: Authors' own compilation using data from the Export Promotion Bureau of Bangladesh.

Figure 2 shows the time path of the GDP share of the industrial sector in Bangladesh for the last 11 years. In 2010–12, the average share was 25.10% (USD315.79 billion), steadily increasing to 29.37% of the GDP (USD868.32 billion) in 2019–20.

Throughout this structural transformation and until recent times, access to adequate electricity was one of the major constraints that industries faced. The national grid supply as well as transmission and distribution were relatively poor in relation to the growing demand from the industrial sector; hence, high electricity prices were observable. This situation led to the proliferation of captive power plants in Bangladesh.

Figure 2: Trend of the GDP Share of the Industrial Sector in Bangladesh



Source: World Bank (2020).

The Bangladesh Energy Regulatory Commission (BERC) stated: "There are two main sources of electricity for the industrial sector: Grid electricity and the captive power plants (natural gas based or diesel based). Natural gas based captive power plants are generally used for standby supply of electricity for the industries which use grid power as main supply. Natural gas is generally supplied by the gas distribution companies."[1] Captive power plants (CPPs) therefore generate in-house electricity for privately owned industries. Recent data from the BERC show that there are currently 799 captive power plants of more than 1 MWh production capacity and that their cumulative generation capacity is 3,184 megawatts (MW). Moreover, 2,502 smaller captive power plants of up to 1 MWh production capacity are in operation and their accumulated power generation capacity is 1,302 MW. Most of these CPPs (around 82% of all CPPs) use natural gas.[2] According to the BERC, some big companies sell CPPs' surplus electricity to the Rural Electrification Board. There is no evidence of companies selling CPPs' surplus electricity to the Bangladesh Power Development Board and therefore to the national grid.[3]

Many industries viewed CPPs as an attractive off-grid option to generate their own electricity and increase their competitiveness. Since the 1990s, CPPs have on average contributed to nearly one-sixth of the total electricity generation in Bangladesh. Amin et al. (2019) reported that "The most striking benefits of the CPPs are to protect industries from the blackouts which can damage the machinery, inventories, and increase the overhead expenses. The captive power plants can also increase productivity in the off-grid region and reduce the need for distribution companies to make expensive investments to extend the grid to remote locations."[4]

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1 For more details, see http://www.berc.org.bd/site/view/policies/Policies.

2 For more details, see https://ep. bd.com/view/details/article/NTU0MA%3D%3D/title?q=captive+power+is+double-edged+sword.

3 For more details, see https://sari-energy.org/oldsite/PageFiles/What_We_Do/activities/sariei_conference_website_october-2013/5th_October_2013/Session-IV/MRMANZ-2.pdf.

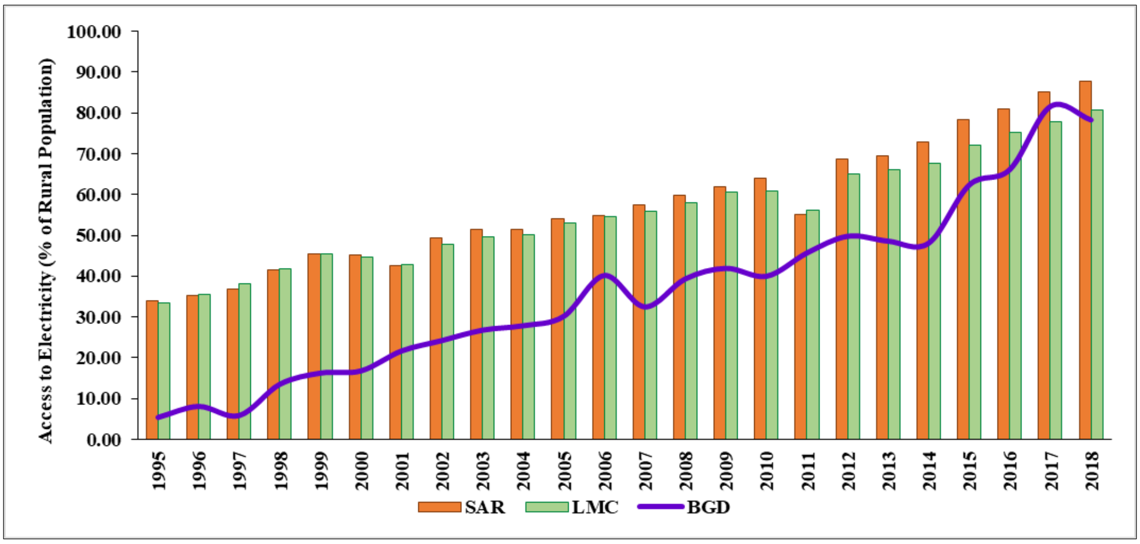
4 For more details, see http://www.berc.org.bd/site/view/policies/Policies.

Figure 3 shows that, despite recent improvements, electrification in rural areas remains a challenge in Bangladesh due to the high transmission and distribution costs of providing grid connections in those areas and to infrastructural bottlenecks. In 2018, 78% of the rural population in Bangladesh (BGD) had access to electricity compared with 87.59% in the South Asia Region (SAR) and 80.60% in lower middle-income countries (LMCs). Since 63% of the total population in Bangladesh lives in rural areas, this situation has a significant impact on the entire country's development. Therefore, CPPs can play a major role in overcoming the problem of access to electricity, at least in the short–medium term.

Furthermore, industries prefer to use CPP-generated electricity to avoid the blackout-prone national power distribution system. This problem has resulted from the government's massive investments in power generation during the last decade at the expense of upgrading the power distribution system.[5]

Despite the above arguments, the political climate in Bangladesh is currently not favorable to CPPs. First, the electricity generation share of CPPs has declined in the last decade as the country is now capable of supplying industries with electricity from the national grid. Second, captive generators produce electricity with a generation efficiency capacity of 25–30% against the 52–60% efficiency of the national power plants.[6] Third, there is a growing consensus that CPPs use natural gas at an unsustainable rate, accelerating the depletion of this natural resource. Fourth, despite the option existing in the legislation, CPPs have so far failed to sell back their surplus to the national grid due to the lack of incentives associated with the distorted electricity price. We discuss these issues below.

Figure 3: Overview of Rural Electrification in Bangladesh



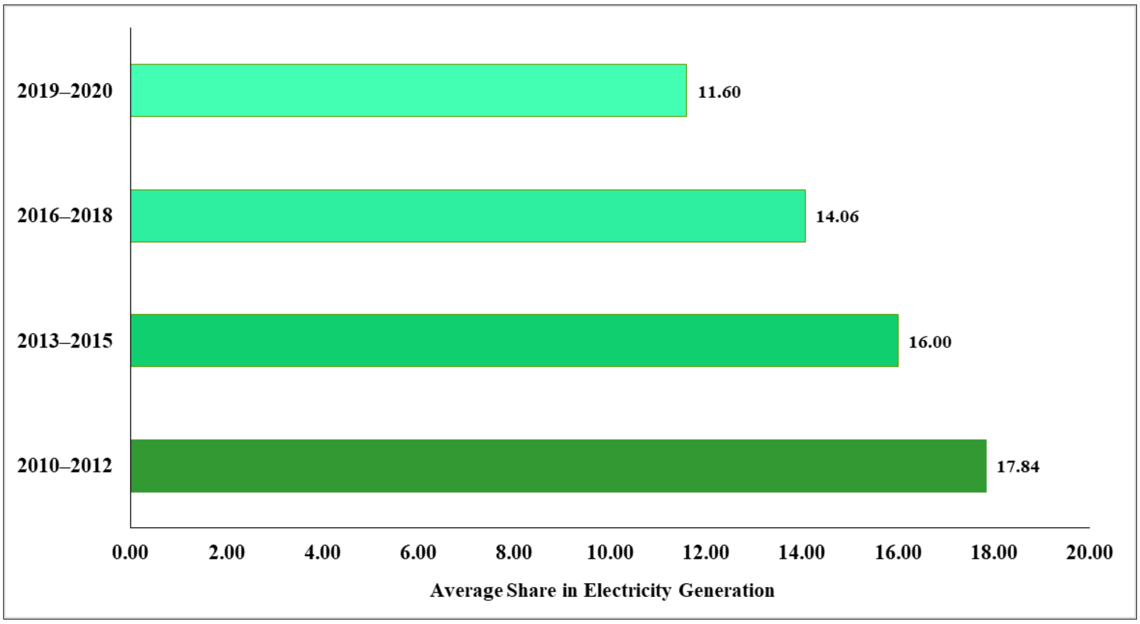
Source: World Bank (2020).

5 For more details, see https://tbsnews.net/bangladesh/energy/low-quality-surplus-power-makes-industries-rely-captive-power.

6 It is worth noting that CPPs typically use open-cycle gas turbines (OCGTs) to generate electricity, whereas the national electricity generators adopt the more efficient combined-cycle gas turbines (CCGTs).

The share of CPPs' electricity generation has decreased slowly over time since the country achieved landmark success in the electricity sector by increasing the generation capacity, enhancing access to electricity (both urban and to a lesser extent rural) and reducing system losses. Currently, the installed capacity is 20,168 MW, a dramatic increase from the 5,272 MW that the sector recorded in 2009. Furthermore, around 95% of the population now has access to grid electricity (Amin, Kabir, and Khan 2020). Figure 4 shows the declining share of CPPs in the Bangladesh electricity generation. In 2010–12, on average, the share of CPPs was 17.84%, decreasing to 14% in 2016–18 and further to 11.60% in 2019–20.

Figure 4: Electricity Generation from CPPs



Source: Bangladesh Economic Review (2019).

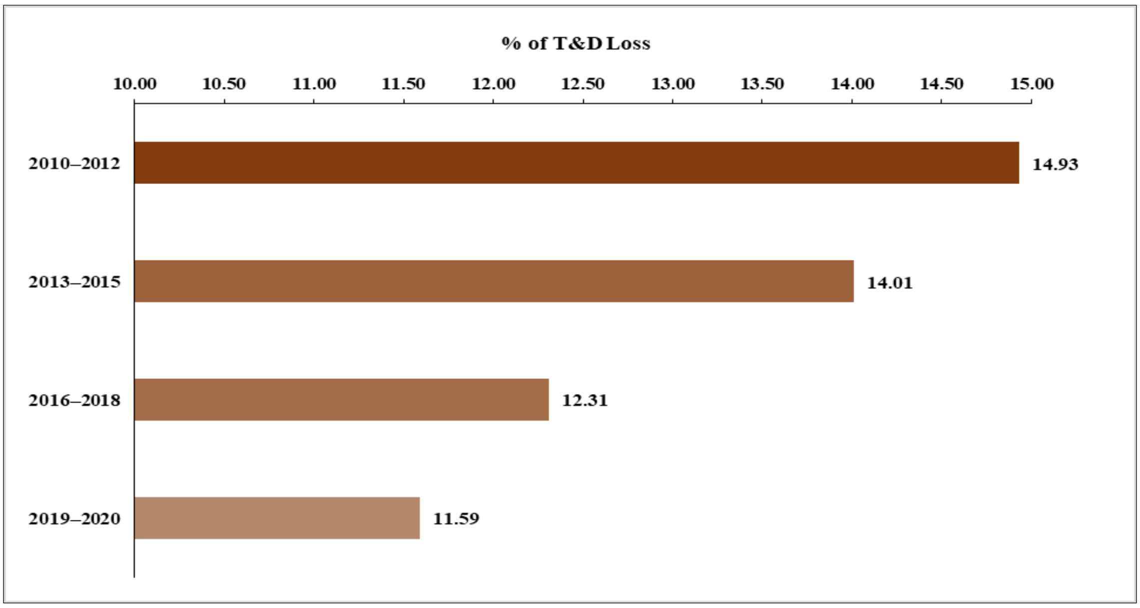
The reduced level of transmission and distribution (T&D) losses from the national grid is another reason for the industrial sector slowly reducing the use of CPPs. Figure 5 shows the improvement in the T&D losses, indicating better access to electricity throughout Bangladesh. The T&D losses were relatively high in 2010–12, about 14.93%, decreasing to 11.59% in 2019–20. From 2013–15 onward, both the T&D losses and the CPPs' share in the overall electricity generation decreased steadily (Figures 4 and 5).

The low generation efficiency capacity of CPPs has attracted plenty of criticism from the regulator. CPPs' reluctance to innovate may be due to the uncertainty surrounding the CPP government policy. News of reforms and/or shutting down CPPs cause industrialists to avoid investing in new technology. Furthermore, as the current price of on-grid electricity for industrial consumers is on average 8.50 taka per unit (depending on various electricity supply line voltages), while the CPPs' electricity generation cost is 3 taka per unit, industrialists aiming to achieve economic efficiency at the lowest cost do not have any incentives to improve their plant's generation efficiency or to buy electricity from the national grid.[7] Most of the industries in Bangladesh use electricity

[7] Bangladesh has four types of supply line depending on voltages: 230 kV, 132 kV, 33 kV, and 11 kV.

that CPPs generate, while they consider electricity from grid connection to be a stand-by supply (Asian Development Bank [ADB] 2014).

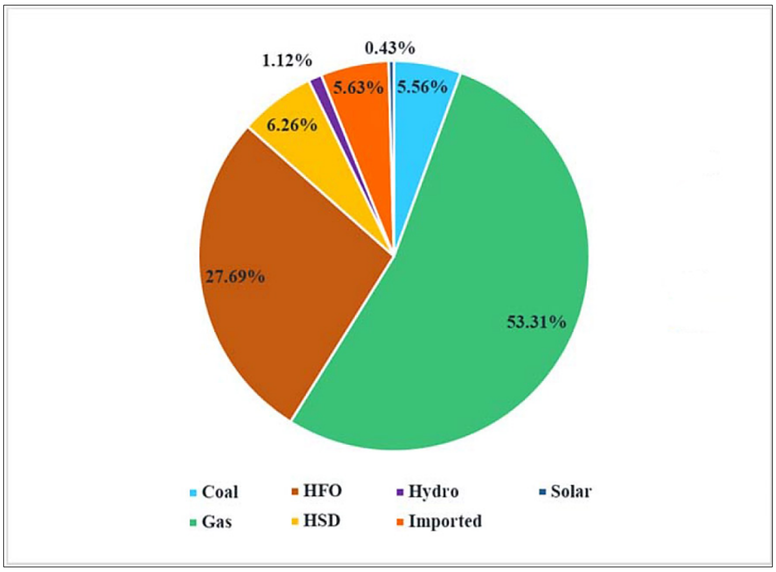
Figure 5: Average Transmission and Distribution (T&D) Losses



Source: Bangladesh Power Development Board (2019).

Power plants in Bangladesh mainly use natural gas for generating electricity. Figure 6 shows the recent fuel mix (up to December 2020) for generating electricity in Bangladesh, with the share of natural gas accounting for 53.31%. After natural gas, the second-most-used fuel is oil. The shares of high-speed diesel (HSD) and heavy fuel oil (HFO) are 6.26% and 27.69%, respectively. The shares of coal, hydro, and solar power are 5.56%, 1.12%, and 0.43%, respectively. The government also imports electricity from India through a cross-border electricity trading system.

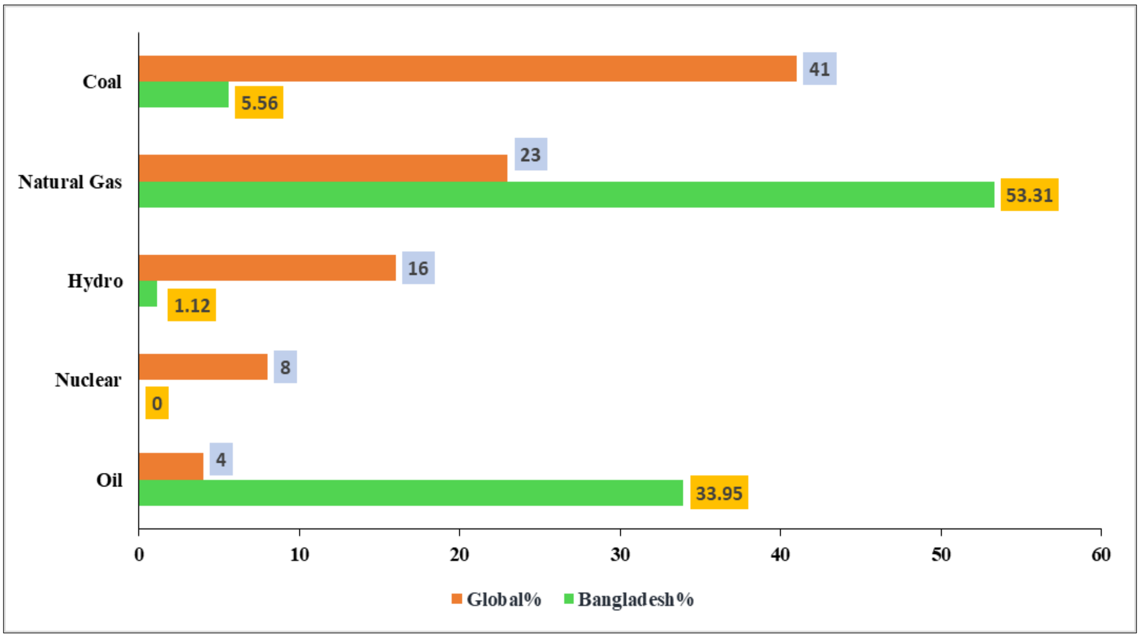
Figure 6: Electricity Generation Fuels in 2020



Source: Bangladesh Power Development Board (2020).

Although the country has experienced a declining trend in the usage of natural gas in electricity generation, the share is large in comparison with global standards (Figure 7), raising the fear of resource depletion. In many circles, people argue that, to ensure the sustainable development of Bangladesh, it is advisable to limit the amount of natural gas that the public and private sectors use, including the CPPs.

Figure 7: Global and Bangladesh Fuel Mix Comparison



Source: IEA (2020) and Bangladesh Power Development Board (2019).

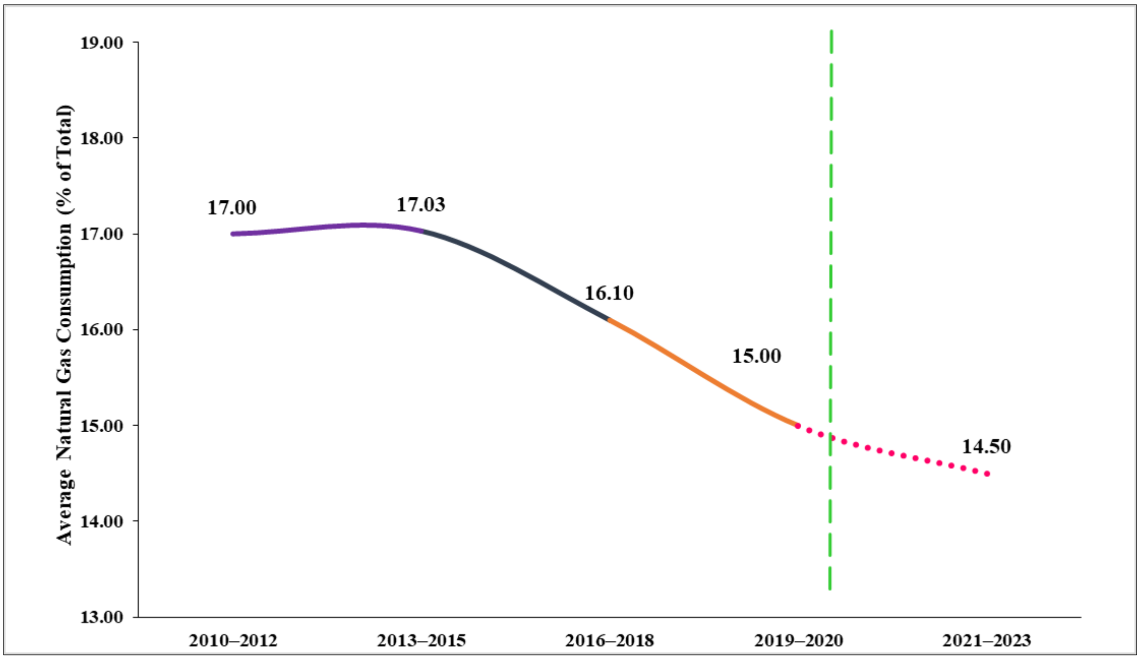
Figure 8 shows that, on average, the natural gas consumption of CPPs was about 17% of the total natural gas consumption in the period 2010–15. Subsequently, the share declined from 16.1% in 2016–18 to the current 15% in 2019–20. According to the *Bangladesh Economic Review* (2019), the share of natural gas that CPPs consume will decrease further in the near future, and, for the period 2021–23, CPPs' average forecasted natural gas consumption is 14.50% of the total natural gas consumption in the Bangladesh economy. Nevertheless, due to fast economic development, the CPPs' absolute consumption of natural gas has increased by 38.9 billion cubic feet during the last 10 years.[8]

Table 1 shows that the government has steadily increased the natural gas tariff for CPPs to discourage industries from using them to generate electricity.[9] Before 2010, the natural gas supply to CPPs had a tariff of around 105.59–103.50 taka/MCF. In 2010–12, the natural gas tariff for CPPs was 118.26 taka/MCF, rising to 236.73 taka/MCF between 2013 and 2015, a 100% increase. By 2016–18, the tariff had further increased to 272.41 taka/MCF, and it maintained that rate for 2019–20.

[8] Source: *Bangladesh Economic Review* (2019).

[9] For details, see https://bangladeshpost.net/posts/goverment-to-restrict-captive-power-plants-26679.

Figure 8: Natural Gas Consumption Pattern of CPPs



Source: Bangladesh Economic Review (2019).

Table 1: Natural Gas Tariff Scheme for CPPs in Bangladesh

Year	Natural Gas Tariff for CPPs (Taka/MCF)
2010–12	118.26
2013–15	236.73
2016–18	272.41
2019–20	272.41

Source: Authors' own compilation using data from Petro Bangla.

Finally, another important issue is that, although legislation allows CPPs to sell excess electricity to the national grid, the Bangladesh Power Development Board (BPDB) has recorded no evidence of this until now.[10] According to the BERC, there are plans to shift 30–35% of electricity from CPPs to the national grid in the near future.[11] Unlike other countries, such as India, Bangladesh has not been proactive in providing incentives to link CPPs to the grid. The case study of India shows that not connecting CPPs to the national grid can be a lost opportunity for a country.

In the remainder of this paper, we focus on the latter issue by assessing whether opening up the national grid to CPPs could be beneficial for Bangladesh. Contrary to the anecdotal evidence, we show that such a policy does not result in a welfare improvement for the Bangladesh economy.

[10] For more details, see https://berc.portal.gov.bd/site/view/policies/Policies.

[11] For more details, see https://powerdivision.portal.gov.bd/sites/default/files/files/powerdivision.portal.gov.bd/page/4f81bf4d_1180_4c53_b27c_8fa0eb11e2c1/Revisiting%20PSMP2016%20%28full%20report%29_signed.pdf.

This paper proceeds as follows. Section 2 reports the main features of the existing CPP regulatory framework in Bangladesh. Section 3 surveys other countries' experience with regard to connecting CPPs to the national grid. Sections 4 and 5 present our model and the results for Bangladesh. Section 6 concludes the paper, including some policy implications on the way forward for CPPs in Bangladesh.

2. THE CPP REGULATORY FRAMEWORK IN BANGLADESH

In 2007, the Bangladesh Government issued a new regulatory policy guideline to allow CPPs to trade their surplus electricity with the distribution companies under the BERC Act 24 (1) and 24 (2)[12] to reduce the gap between the demand and the supply for electricity, especially in peak periods,[13] as well as to utilize energy resources optimally.[14] According to the above policy, the BERC allowed CPPs to sell their surplus electricity to i) host distribution licensees[15] and ii) any other distribution licensees.[16] CPPs need to comply with several requirements, as Table 2 lists.

Table 2: Overview of the CPP Policy Criteria

Criterion	Description
1	CPPs have to sell their excess electricity in accordance with the BERC tariff criteria
2	CPPs need to obey all the laws of Bangladesh, including environmental standards
3	CPPs' owners have to obtain statutory clearance of their own accord
4	CPPs' owners need to obtain synchronization permission beforehand
5	The purchase tariff should not exceed that at which the BPDB sells electricity (excluding wheeling charges)
6	The BERC may change the purchase tariff in the event of fuel price changes
7	Electricity purchasers have the option to buy electricity from CPPs either in peak or in off-peak hours. The BERC permits the period of supply
8	CPPs should bear the costs of interconnection (synchronization) networks and equipment
9	CPPs' owners have to pay the transmission wheeling charges, which the BERC pre-fixes
10	CPPs must maintain the voltage condition all the time. They must be able to handle abnormal fluctuations that can hamper the grid lines
11	There are no tax/VAT incentives for purchasing CPP-related machinery
12	CPPs have to take the necessary measures to control inadvertent power flow
13	No banking of energy is permissible
14	CPPs' owners should carry out metering arrangements
15	CPPs' owners have to install all the protection measures at the delivery point
16	The BERC will provide all types of assistance. The BERC will also have the regulatory power to resolve any disputes

Source: Ministry of Power, Energy and Mineral Resources (2007).

[12] For more details, see https://berc.portal.gov.bd/site/view/policies/Policies.

[13] The peak period refers to 17.00 to 23.00 every day according to Bangladesh's CPP policy of 2007.

[14] To sell electricity, CPPs need to purchase a license from the BERC.

[15] This is a distribution company that owns the electricity network to which the CPP is connected.

[16] This is a distribution company that does not own the electricity network to which the CPP is connected; it uses the host distribution licensee's network to obtain CPP-generated electricity.

It is worth noticing that the existing policy framework contains no incentives for CPPs' owners to sell their excess electricity, effectively discouraging this sale. First, CPPs need to bear all the T&D-related costs. Second, CPPs' owners must carry out the grid synchronization as well as being responsible for any damage to the grid system. Third, there is no scope for the banking of energy in Bangladesh. Fourth, CPPs can only supply electricity during peak hours (however, they can obtain permission to supply in the off-peak period if necessary). Finally, the government-regulated electricity prices to purchase electricity from captive generators fail to ensure a profit for CPPs.[17,18]

3. OTHER COUNTRIES' EXPERIENCE

Several countries, such as India, Uganda, Nigeria, and Saudi Arabia, are also utilizing CPPs to meet the electricity demand. In addition, India, Uganda, and Saudi Arabia are providing incentives for CPPs to sell their surplus to the grid. India, one of the neighboring countries of Bangladesh, has been successful in reforming the CPP system (Jamasb and Sen 2012). India has introduced a transparent regulation on the fixed and variable charges that CPP owners bear, reduced the wheeling charges, facilitated the banking of the industry,[19] and lowered cross-subsidy surcharges to induce more CPPs to sell their surplus electricity to bulk electricity purchasers (IEA 2020). The CPP producers' association of India plays a crucial role in developing the industry by liaising with the government to formulate CPP-related policies.[20,21] Furthermore, the Indian Government is open to developments in the CPP system. One example is group captive power plants (GCPPs), which have been very popular in India since the late 1990s. These are power plants that a group of consumers has set up for its own consumption in remote areas. The Indian Electricity Act 2003 allows the waiving of GCPPs' cross-subsidies[22] and surcharges.[23] This helps to reduce the government's fiscal burden and ease the process of setting up CPPs for industrial consumers. The Indian Government has also supported renewable-based CPPs (powered by solar, wind, bagasse, and biomass).[24]

Even though Uganda does not have any explicit CPP policies, the country follows the subsidiary regulations of the National Electricity Act of 1999. CPPs with grid capacity smaller than 500 kilowatts (kW) and no grid or third-party connectivity do not need any license to generate electricity. On the other hand, CPPs with capacity greater than 500 kW but less than 2 MW need a license for both generating and selling electricity to

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[17] Although the CPP guidelines highlight the concept of a market-driven mechanism according to which the fuel's market price influences the electricity tariff, in practice, the government still heavily regulates and controls the electricity market in Bangladesh.

[18] For more details, see https://berc.portal.gov.bd/site/view/policies/Policies.

[19] Suppose that a power plant generates (and sells) electricity during daily peak hours but also wants to sell to a consumer who needs electricity during nighttime peak hours. In this case, the banking of electricity allows the generator to use banked grid-supplied electricity to serve the customer's needs at night.

[20] For more details, see https://energy.economictimes.indiatimes.com/news/power/new-norms-may-lead-to-group-captive-plants-equity-shareholding-rejig/64288620.

[21] For more details, see https://economictimes.indiatimes.com/industry/energy/power/rules-for-captive-power-plants-to-be-amended/articleshow/70121180.cms?fbclid=IwAR0RLUAUMVFJe_zcogu1-tJ0K7CGQt8WdCCxNhkrUAgu2V6dQT6NhfRlOgs.

[22] This is a type of subsidy whereby a group of consumers pays more than the overall cost of supply, with the government utilizing the additional amount to provide a subsidy for another group.

[23] This refers to an extra charge, tax, or payment in addition to the existing cost of a good or service.

[24] For instance, rooftop solar photovoltaic-based CPPs receive net metering benefits. For details, see the Indian Electricity Act (2003).

the national grid as well as to a third party. These CPPs can also act as a mini grid or as local distributors of electricity, and, in that case, it is possible to obtain license exemptions. CPPs that are bioenergy based need to obtain a license (regardless of their size) for selling surplus electricity. In addition, Uganda has different CPP tariff structures for different industries.

In Nigeria, the definition of CPPs is power plants with the capacity to generate more than 1 MW electricity, and they are responsible for supplying electricity only to the off-grid area and for their own use. To generate electricity, CPPs need to obtain a license from the National Electricity Regulatory Commission (NERC) of Nigeria under the Power Sector Reform Act of 2005. The NERC formulates the tariff structure for CPPs.

In Saudi Arabia, CPPs that are connected to the grid need a license from the Electricity Cogeneration Regulatory Authority (ECRA), whereas CPPs that are not connected to the grid do not need a license to operate irrespective of their size and capacity (Abdul-Majeed et al. 2013). Only for licensed CPPs is there a provision to sell surplus electricity to the national grid and registered third parties.

The international comparison shows that other countries have integrated CPPs into their national electricity generation and distribution system and that some have supported the sale of CPPs' electricity surplus to the grid. Often this has occurred through subsidization and heavy regulation and therefore at a high cost in terms of public finances and overall welfare. Therefore, the question of whether a country should pursue the policy of allowing the sale of CPPs' electricity surplus to the national grid is not clear cut. The following sections aim to explore the economic consequences for Bangladesh of allowing CPPs to sell their surplus electricity to the grid.

4. THE MODEL

To our knowledge, this is the first study to quantify the impact of opening the national grid to CPPs in Bangladesh.[25] We follow the methodological structure of Amin (2015) and Amin et al. (2019), who constructed a dynamic stochastic general equilibrium (DSGE) model for Bangladesh. We calibrate and simulate the benchmark model for the Bangladesh economy, with the CPPs as electricity producers that can sell excess electricity to the national grid.

We can divide the Bangladesh economy into four sectors: the household sector, the production sector, the energy sector (which generates electricity using two different types of fuels: oil and natural gas), and the government sector.

4.1 The Household Sector

Households gain utility from: a general consumption good, *c*, a service good, *x*, leisure, 1-*l*, and electricity, *e*. Households pay taxes at rates $\tau^k and\ \tau^l$ on their capital income $(r.k_t)$ and labor income $(w.l_t)$, respectively. We denote the capital depreciation rate as δ. We normalize the price of the general consumption good to 1 and denote the prices of the service good and electricity as *n* and q^e, respectively. The budget equation of the household reads as follows:

$$k_{t+1} + c_t + n.X_t + q_t^e.e_t = (1-\tau^l)w.l_t + ъ + (1-\tau^k)r.k_t + (1-\delta)k_t + \pi_t \quad (1)$$

[25] For more details, see Amin et al. (2020).

where ъ is a lump-sum transfer from the government and π are the profits from the firms. Denoting the household discount factor as *β*, the Lagrangian reads:

$$L = \sum_{t=0}^{\infty} \beta^t [(\varphi \, log \left[X_t^{\gamma} \left(\theta c_t^{\rho} + (1-\theta) e_t^{\rho} \right)^{\frac{1-\gamma}{\rho}} \right]) + (1-\varphi) \, log(1-l_t)] - \lambda_t [k_{t+1} + c_t + n.X_t + q_t^e.e_t - \left(1-\tau^l\right) w.l_t - ъ - \left(1-\tau^k\right) r.k_t - (1-\delta) k_t] \quad (2)$$

4.2 the Production Sector

Type 1 firms produce Y_1, purchasing electricity from the grid, while type 2 firms, Y_2, produce their own electricity, potentially selling any surplus to the grid. *l* represents labor, *k* capital, and *j* electricity. We assume constant elasticity of substitution (CES) production functions for the industry and service sectors:

$$Y_{1,t} = A_{1,t}^{Y} l_{Y1,t}^{\alpha,1} [(1-\Psi_{Y1}) k_{Y1,t}^{-\nu^{g,1}} + \Psi_{Y1} g_{1,t}^{-\nu^{g,1}}]^{-\frac{1-\alpha_{Y1}}{\acute{\upsilon}^{gg,1}}} \quad (3)$$

$$Y_{2,t} = A_{2,t}^{Y} l_{Y2,t}^{\alpha,2} [(1-\Psi_{Y2}) k_{Y2,t}^{-\nu^{g,2}} + \Psi_{Y2} g_{2,t}^{-\nu^{g,2}}]^{-\frac{1-\alpha_{Y2}}{\acute{\upsilon}^{gg,2}}} \quad (4)$$

$$X_t = A_t^X l_{X,t}^{\alpha_X} [(1-\Psi_X) k_{X,t}^{-\nu^s} + \Psi_X s_t^{-\nu^s}]^{-\frac{1-\alpha_X}{\acute{\upsilon}^{ss}}} \quad (5)$$

where A_t^i is the total factor productivity (stochastic), α_i is the labor share, and Ψ_i is the electricity share. $\acute{\upsilon}^{jj}$ gives the degree of homogeneity, and the substitution elasticity between capital and electricity is $\frac{1}{1+\nu^j}$.

Denoting the wage rate and the interest rate as *w* and *r*, respectively, the profit functions are:

$$\pi_{i,t} = \max Y_{i,t} - r_t k_{i,t} - w_t l_{i,t} - q^i g_{i,t} \quad (6a)$$

for *i* = {1,2}, and

$$\pi_{X,t} = \max X_t - r_t k_{X,t} - w_t l_{X,t} - q^s s_t \quad (6b)$$

where q^i and q^s are the electricity prices.

4.3 The Energy Sector

We denote electricity that public power producers, independent power producers, captive power producers, and rental power producers generate as *G*, *I*, g_2, and *R*, respectively.[26] We assume, following Amin (2015), CES technologies:

$$\mathrm{G_t} = A_t^G l_{G,t}^{\alpha_G} [(1-\Psi_G) k_{G,t}^{-\nu^{m,G}} + \Psi_G m_{G,t}^{-\nu^{m,G}}]^{-\frac{\vartheta^G}{\nu^{m,GG}}} \quad (7)$$

[26] Since most government-owned firms and CPPs use natural gas in the generation process, we model natural gas as the leading choice of fuels in the government's electricity production function. In Bangladesh, around 82% of CPPs use natural gas to generate electricity. For more details, see https://ep-bd.com/view/details/article/NTU0MA%3D%3D/title?q=captive+power+is+double-edged+sword.

$$\mathrm{I_t}=A_t^I l_{I,t}^{\alpha_I}[(1-\Psi_I)k_{I,t}^{-v^{m,I}}+\Psi_I m_{I,t}^{-v^{m,I}}]^{-\frac{\vartheta^I}{v^{m,II}}} \tag{8}$$

$$\mathrm{g_{2,t}}=A_t^C l_{C,t}^{\alpha_C}[(1-\Psi_C)k_{C,t}^{-v^{m,C}}+\Psi_C m_{C,t}^{-v^{m,C}}]^{-\frac{\vartheta^C}{v^{m,CC}}} \tag{9}$$

$$\mathrm{R_t}= A_t^R l_{R,t}^{\alpha_R}[(1-\Psi_R)k_{R,t}^{-v^R}+\Psi_R h_t^{-v^R}]^{-\frac{\vartheta^R}{v^{H,RR}}} \tag{10}$$

where *m* is natural gas and *h* is oil. The interpretation of the parameters is as in section 4.2.

4.4 The Government

The government collects revenue from labor and capital income taxation, from selling natural gas to other electricity-generating firms $\left((v^m-\delta^C)(m_{I,t}+m_{G,t})\right)$, and from selling electricity on the grid ($P^G.G_t$). The government uses its revenue to pay for labor ($w.l_{G,t}$), capital ($r.k_{G,t}$), and natural gas ($v^m.m_{G,t}$) and a lump-sum transfer payment to households (ъ). The government also offers subsidies to the electricity generators to cover the gap between the world oil price (v^e) and the domestic oil price (v^h) that the producers face. It fixes the price of natural gas at v^m below the extraction cost (δ^C) to avoid overconsumption due to underpricing of this limited natural resource.

The government faces the following cost minimization function:

$$c_{G,t}=w.l_{G,t}+r.k_{G,t}+v^m.m_{G,t}-P^G.A_t^G l_t^{\alpha_G}\left[(1-\Psi_G)k_{G,t}^{-v^{m,G}}+\Psi_G m_{G,t}^{-v^{m,G}}\right]^{-\frac{\vartheta^G}{v^{m,GG}}} \tag{11}$$

Since the government consumes electricity at a high price and sells it to households at a lower price, the subsidy equation is:

$$b=P^G.G_t+P^I.I_t+P^R.R_t-q^e.e_t-q^s.s_t-q^{g_1}.g_t \tag{12}$$

where q^S and q^{g_1} are the electricity prices for the service and industrial sectors, and P^I and P^R are the selling prices of the electricity for IPPs and quick rentals. Moreover, due to the prevailing price-setting mechanism, the government takes the role of the residual producer to clear the market.

The government budget constraint is as follows:

$$\begin{aligned}&\tau^l.w.l_t+\tau^k.r.k_t+(v^m-\delta^C)(m_{I,t}+m_{G,t}+m_{C,t})+(v^h-v^e).h+P^G.G_t\\&-r.k_{G,t}-w.l_{G,t}-v^m.m_{G,t}-\text{ъ}=b\end{aligned} \tag{13}$$

Finally, equation 14 defines the economy-wide resource constraint.

$$k_{t+1}=Y_{A,t}-c_t+(1-\delta).k_t-\delta^C(m_{I,t}+m_{G,t}+m_{C,t}) \tag{14}$$

4.5 Equilibrium Conditions

The following equations represent the equilibrium in the labor, capital, and electricity markets:

$$l = l_H + l_I + l_G + l_Y + l_X + l_2 + l_C \tag{15}$$

$$k = k_H + k_I + k_G + k_Y + k_X + k_2 + k_C \tag{16}$$

$$e_t + s_t + g_t + g_{2,t} = \left(G_t + I_t + g_{2,t} + R_t\right) \tag{17}$$

4.6 The Captive-Grid Augmented DSGE Model

In this section, we allow CPPs to sell their surplus electricity (g_g) to the national grid. Therefore, we define the production function of industry 2 as follows:

$$Y_{2,t}{=}A^{Y}_{2,t} l^{\alpha,2}_{Y2,t}[(1 - \Psi_{Y2}) k^{-\nu^{g,2}}_{Y2,t} + \Psi_{Y2}(g_2 - g_g)^{\ \nu^{g,2}}]^{-\frac{1-\alpha_{Y2}}{\acute{\upsilon} g g,2}} \tag{18}$$

It is worth noting that q^{g_1} is the government-regulated buying price of electricity for industry and CPPs have to sell electricity at this price. The profit function for industry 2 and the new equilibrium in the electricity market are as follows:

$$\pi_Y = P^Y . A^Y_t l^{\alpha_Y}_{2,t} \left[(1 - \Psi_Y) k^{-\nu^g}_{2,t} + \Psi_Y g_2^{-\nu^g}\right]^{-\frac{\vartheta^Y}{\acute{\upsilon} g g}} - r(k_c + k_2) - w(l_c + l_2)$$
$$-v^m . m_{C,t} + q^{g_1} . g_g \tag{19}$$

$$e_t + s_t + \ g_t + g_{2,t} = \left(G_t + I_t + {+R_t} + g_g\right) \tag{20}$$

Finally, we compute the welfare effect in terms of equivalent changes in consumption $\frac{\hat{c}-c_1}{c_1}$, where:[27]

$$\hat{c}{=}(c_2^{\rho}{+}\frac{1-\theta}{\theta} e_2^{\rho})(\frac{X_2}{X_1})^{\gamma \frac{\rho}{1-\gamma}} . (\frac{1-l_2}{1-l_1})^{\frac{1-\varphi}{\varphi} . \frac{\rho}{1-\gamma}} - \frac{1-\theta}{\theta} e_1^{\rho} \tag{21}$$

4.7 Model Shocks

To analyze the magnitude of the vulnerability of grid-connected CPP firms to oil price shocks, we assume the following stochastic oil price shock in this study, following Amin and Marsiliani (2015):

$$ln\ v^e_t = \acute{\Omega}^v + \omega ln v^e_{t-1} + \eta^O_t \tag{22}$$

where $\acute{\Omega}^v$ and η^O_t signify the coefficients and residuals, respectively.

[27] For the calculation, see Amin (2015).

Following Amin (2015) and Amin and Marsiliani (2015), we rely on official data, the existing literature, and the model steady-state or equilibrium conditions to derive our parameters. Due to the lack of data, we calibrate the parameters for annual frequency.[28] Tables 3 and 4 present the parameter values.

Table 3: Value of the Calibrated Parameters

Preference Parameters	
1. β, discount factor	0.96
2. ρ, CES parameter of a household's utility function	–0.11
3. θ, share of non-electricity consumption in the household aggregator	0.91
4. φ, share of electricity and non-electricity consumption in the household utility	0.60
5. γ, share of service in the household consumption aggregator	0.81
Production Parameters	
7. $\alpha_{Y,1}$ and $\alpha_{Y,2}$, labor shares in the industrial sector	0.2
8. α_X, labor share in the service sector	0.313
9. α_I, labor share in IPP	0.036
10. α_C, labor share in CPP	0.036
11. α_R, labor share in rental production	0.004
12. α_G, labor share in public production	0.0420
13. $\psi_{Y,1}$ and $\psi_{Y,2}$, capital shares in the industrial sector	0.0733
14. ψ_X, capital share in the service sector	0.0790
15. ψ_G, capital share in public production	0.3020
16. δ, depreciation rate	0.025

Table 4: Value of Electricity and Fuel Prices (Taka/kWh)

Parameters	Description	Values
q^e	Buying price of electricity by households	4.93
q^{g_1}	Buying price of electricity by industry	6.95
q^s	Buying price of electricity by services	9.00
P^I	Selling price of electricity by independent power producers	3.20
P^R	Selling price of electricity by rental power producers	7.79
P^G	Selling price of electricity by the government	2.3
v^e	International price of imported oil	8.19
v^h	Selling price of imported oil to rental power producers	5.72
v^m	Selling price of domestically produced natural gas	0.77

Source: Bangladesh Power Development Board (BPDB) (2017).

28 For more details about the calibrated parameters, see Amin, S., T. Jamasb, M. Llorca, L. Marsiliani, and T.I. Renström. 2020. *Captive Power, Market Access, and Welfare Effects in the Bangladesh Electricity Sector*. Working Paper / Department of Economics. Copenhagen Business School No. 8-2020CSEI Working Paper No. 8-2020. Copenhagen Business School.

5. RESULTS

Table 5 shows the long-run steady-state values of different economic variables when the government allows CPPs to sell excess electricity to the national grid (Policy Experiment).[29] We find that, when CPPs are grid-connected, the steady-state value of industrial output, GDP, consumption, and electricity consumption falls due to the pre-existing inefficiency in the energy market pricing. This inefficiency derives from the government-controlled distorted market prices. In Bangladesh, industries without CPPs have to buy electricity from the national grid at government-controlled prices (deviating from the would-be equilibrium market prices), which induces inefficient use of production factors.

Industries that own CPPs, when producing their own electricity only, will do so by allocating the factors of production efficiently (as they maximize the joint profits at an optimal shadow price for electricity). Since the resource use is more efficient, they will allocate more capital and labor, in equilibrium, to those industries. In that benchmark case, CPPs account for 3% of the total electricity generation. This advantage of CPPs disappears if they are connected to the grid at controlled prices, implying that the overall output will shrink. Our model shows that opening up the grid reduces the long-run aggregate industrial output by 1.4% and the GDP by 1%. We also show that the aggregate use of natural gas increases by 1.7% due to the inefficiency in the price schedule. Therefore, under distorted prices, joining CPPs to the grid actually worsens the economy of Bangladesh.

We also examine the effects of oil price shocks on the Bangladesh economy by investigating how the impulse response functions (IRFs) affect the variables after an increase in international oil prices. Figure 9 reveals that a higher oil price (v_e) in the global market reduces all types of consumption in Bangladesh. Moreover, given the fixed taxes and regulated prices, a higher oil price crowds out government transfers (g_t) from households to the industrial and service sectors. Households respond by offering more labor and wages (w) decline.

Table 5: Steady-State Values of Different Economic Variables

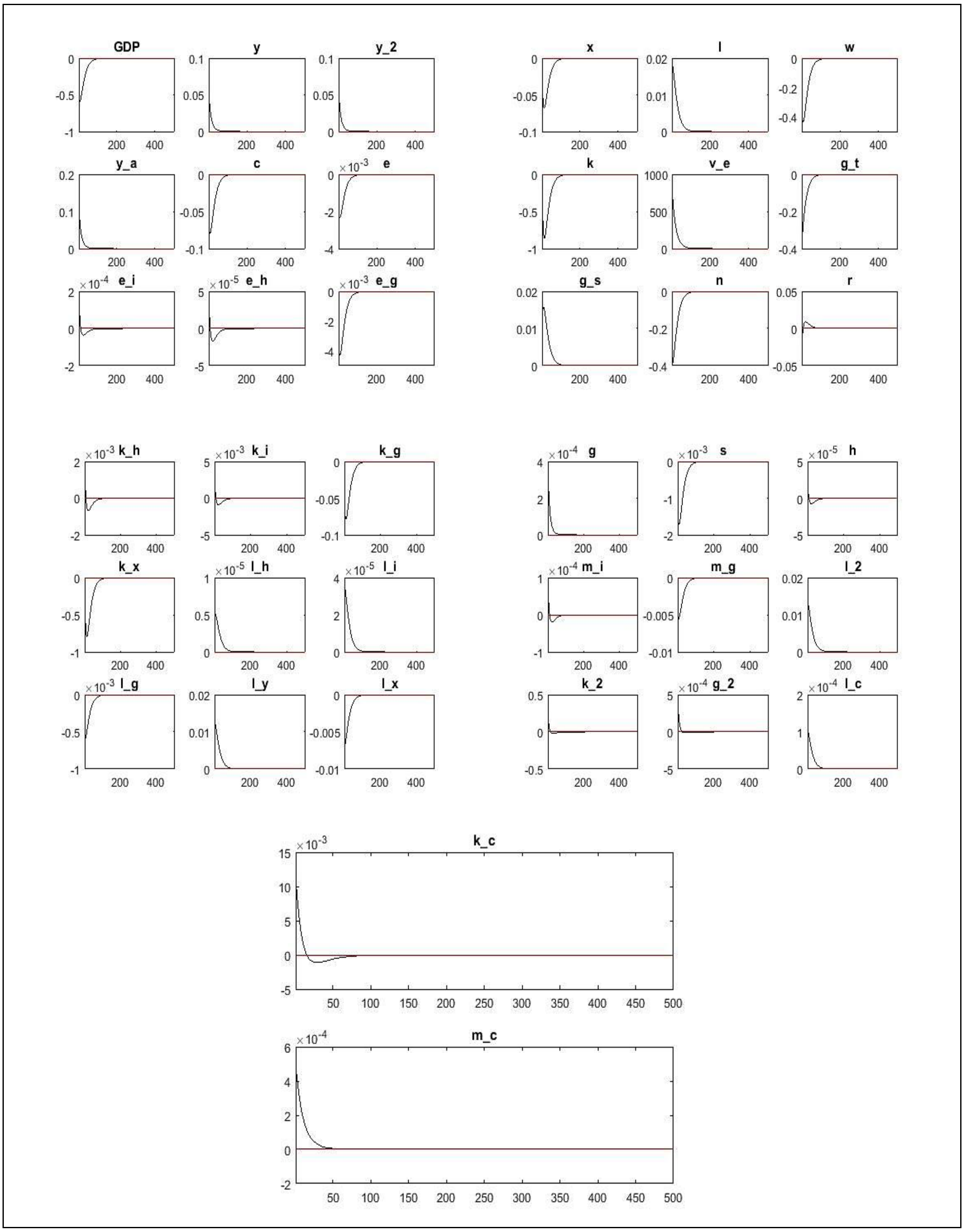
	Benchmark Model	**Policy Experiment**
Real output (GDP)	2.41147	2.38814
Standard consumption	0.287629	0.284563
Household electricity consumption	0.00839815	0.00830862
Industrial electricity consumption	0.00446656	0.00344651
Electricity generation	0.0209206	0.01799797
Aggregate industrial output	0.5562	0.548362
Labor supply	0.323096	0.322855
Aggregate capital	3.36687	3.30013

The IRF further shows that, since the higher oil price reduces the volume of the trade balance, the production of the industrial sectors (y_a) increases the exports of goods to keep the trade balance unchanged. Since all types of consumption and capital decrease, the economic output also falls. When the CPPs are connected to the grid, the behavior of the IRFs for the variables that an oil price shock affects is very similar;

[29] For our simulations, we use the software Dynare 4.4.3. Dynare is a pre-processor that includes a set of MATLAB. It allows us to solve for the DSGE model's steady states, linearize the necessary conditions around the steady states, and calculate the impulse response paths.

however, the changes are more significant. We argue that the country would face increased exposure to any external shocks when CPPs are grid-connected.

Figure 9: Impulse Responses to Oil Price Shocks



6. CONCLUSIONS

Having maintained an impressive growth rate for the last decade, Bangladesh plans to become a high-income country by 2041. Since the country has relied heavily on industry and mainly on RMG exports since the mid-1990s, CPPs have made a significant contribution to the country's development journey by supplying electricity to industries. However, there is a growing consensus in policy circles that the importance of CPPs for the Bangladesh economy has decreased substantially in recent years as the national grid connectivity capacity has increased. Given the present public power generation capacity of 19,000 MW, against a demand of 12,000 MW, the government is discussing the option of shutting down CPPs. The fact that CPPs use low-efficiency technologies to generate electricity, typically open-cycle gas turbines (OCGTs), further fuels this discussion.[30]

Amin et al. (2019) have already studied the role of CPPs in an economy that distortions characterize due to regulated prices. In their paper, they found that shutting down CPPs caused the GDP to fall by 1.64% in the long run. A more urgent policy was that of removing the price distortions by incorporating market mechanisms into the Bangladesh energy market. Furthermore, energy experts are adamant that it would not be wise to shut down CPPs without improving the country's distribution system.[31]

In this paper, we have investigated the alternative policy option of opening the grid to CPPs (popular in other countries) so that they can sell their electricity surplus to the national grid (still at regulated prices). This is consistent with the current Bangladesh CPP regulatory framework, although in practice it is not profitable for CPPs. We have developed a fit-for-purpose DSGE model to simulate the policy of connecting CPPs to the national grid. We reveal that, since the controlled prices on the grid fail to reflect the true cost of production, opening up the grid is ineffective as it slows down the industrial output by 1.4% and the GDP by 1% in the steady state. The impulse response functions also reveal that, if the grid opens up to CPPs, the Bangladesh economy will be more sensitive to exogenous fluctuations, like oil price shocks. As Amin et al. (2019) showed, the fundamental reason for these results is that regulated prices create distortions and regulatory policies that governments impose in a second-best world can only exacerbate those distortions.

Given our results, we suggest that, before undertaking any reforms in connection to CPPs, the Bangladesh Government should aim to ameliorate the existing distortions by creating a competitive market environment for cost-reflective tariffs. It would then be up to the market forces to determine whether to scrap CPPs or connect them to the grid.

Equally important is the need for the government to ensure than the energy sector is environmentally sustainable, for example by encouraging fuel efficiency and the use of renewable resources in electricity generation. At the same time, it should devote continuous effort to strengthening the power distribution system to mitigate energy inequalities among consumers (e.g., urban versus rural).

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[30] The national power plant efficiency is 27–30% higher than that of CPPs.

[31] For more details, see https://ep-bd.com/view/details/article/NTUzOQ%3D%3D/popular-article/title?q=stop+captive+generation+after+ensuring+quality+power+supply%3a++experts.

The recent Covid-19 pandemic has stalled the economic growth of Bangladesh and caused many job losses, prompting previous city dwellers to move to rural areas. The Bangladesh Government faces a new challenge in providing job opportunities for these people and should now focus on improving access to electricity in rural areas (currently only 78% of the rural population has access to electricity). At least as an interim measure, the government may consider standalone (off-grid and mini-grid) CPP support policies to tackle the Covid-19-induced electricity demand. In this regard, a good example is Africa, where standalone CPPs are helping rural communities and businesses to prosper.[32] If those policies were also to promote renewable energy (solar, biogas, and bagasse)-based hybrid CPP installations (like, for example, those in India), the country could achieve the goals of recovering from the Covid-19 pandemic and greening the economy at the same time.

[32] For more details, see https://www.esi-africa.com/top-stories/off-grid-captive-power-solutions-sustain-investment-in-africa/?fbclid=IwAR0ZAAFjW3yrz-1xn8RcgQ4h5mfEI82rmtyNkxoXWt77ZTyzaNnq LeohSuI.

REFERENCES

Abdul-Majeed, M.A., L.M. Al-Hadhrami, K.Y. Al-Soufi, F. Ahmad, and S. Rehman. 2013. "Captive Power Generation in Saudi Arabia—Overview and Recommendations on Policies." *Energy Policy* 62: 379–85. doi:10.1016/j.enpol.2013.07.101.

Amin, S.B. 2015. "The Macroeconomics of Energy Price Shocks and Electricity Market Reforms: The Case of Bangladesh." PhD thesis, Durham University. http://etheses.dur.ac.uk/11241/.

Amin, S.B., and L. Marsiliani. 2015. "Energy Price Shocks in Dynamic Stochastic General Equilibrium: The Case of Bangladesh." *Review of Business and Economics Studies* 30 (3): 12–21. http://dro.dur.ac.uk/17007/1/17007.pdf?DDD2+dhs4ke+d700tmt.

Amin, S.B., F.A. Kabir, and F. Khan. 2020. "Energy-Output Nexus in Bangladesh: A Two-Sector Model Analysis." *Energy Strategy Review* 32: 100566. DOI: https://doi.org/10.1016/j.esr.2020.100566.

Amin, S., T. Jamasb, M. Llorca, L. Marsiliani, and T.I. Renström. 2020. C*aptive Power, Market Access, and Welfare Effects in the Bangladesh Electricity Sector*. Working Paper / Department of Economics. Copenhagen Business School No. 8-2020CSEI Working Paper No. 8-2020. Copenhagen Business School.

Amin, S.B., T. Jamasb, M. Llorca, L. Marsiliani, and T. Renström. 2019. "Combining Private and Public Resources: Captive Power Plants and Electricity Sector Development in Bangladesh." *Emerging Markets Finance and Trade*. https://doi.org/10.1080/1540496X.2019.1703107.

Asian Development Bank (ADB). 2014. *Industrial Energy Efficiency Opportunities and Challenges in Bangladesh*. Report. New Delhi, India.

Bangladesh Economic Review. 2019.*Annual Report*. Dhaka, Bangladesh.

Bangladesh Power Development Board. 2017. *Annual Report 2016–2017*. Dhaka, Bangladesh.http://www.bpdb.gov.bd/download/annual_report/Annual%20Report%202016-17%20(2).pdf.

———. 2019. *Recent Statistics*. Dhaka, Bangladesh

———. 2020. *Recent Statistics*. Dhaka, Bangladesh

International Energy Agency (IEA). 2020. *India 2020: Energy Policy Review*. IEA, Paris.

Jamasb, T., and A. Sen. 2012. "Diversity in Unity: An Empirical Analysis of Electricity Deregulation in Indian States." *Energy Journal* 33 (1): 83–130.

Ministry of Power, Energy and Mineral Resources. 2007. *Policy Guidelines for Power Purchase from Captive Power Plant*. Government of the People's Republic of Bangladesh. Dhaka, Bangladesh.

World Bank. 2020. *Data Bank*. Washington, DC, US.