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RESEARCH ARTICLE

How much regulation is optimal for the brick manufacturing industry in developing economies? – Experiences from Bangladesh, India, and Nepal

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Abstract
Brick manufacturing is one of the fast-growing and economically important industries in Bangladesh and the neighboring developing countries. Its growth is synchronized with the increasing demand for bricks in the construction sector of these countries. However, the growth in this industry appears to be unplanned and thus, it is leading to the deterioration of the environment including air pollution, forest destruction, and soil degradation, aligned regulation is also gradually getting more stringent. In this study, the latest and relevant rules and laws have been summarized to highlight the historical development of brick kiln regulations in Bangladesh, India, and Nepal. Nevertheless, Bangladesh has been chosen as a case to understand brick kiln owners' compliance status with applicable regulations in Bangladesh, India, and Nepal. A total of 140 brick kilns were studied from four districts in the country. Socioeconomic factors affecting the degree of compliance of the industry to legal tools have been evaluated using logistic regression. The study shows that every brick kiln violated at least one Section of the Act. Per unit brick production cost has significantly increased due to compliance. This study also reveals that kilns with environmental clearance certificates were more likely to adopt modern technology. However, the kiln's age, penalty, and production cost had a negative relationship with the adoption of modern technology. Total income from brick kilns and possession of an environmental clearance certificate was positively linked to the choice of coal or gas as a fuel rather than wood. In contrast, bribe and production size were less likely to affect the fuel compliance of the kilns. The study has identified the factors that require the attention of policymakers to enhance the practicability of the law at the field level.

Keywords: Brick kilns; Economy; Environment; Industry; Regulation

Introduction

Bangladesh is a developing economy with tremendous economic growth in recent decades aiming to be an upper-middle-income country by 2031 and a high-income country by 2041 (Raihan et al., 2022a). Among the top 12

developing countries with a population of over 20 million, Bangladesh achieved 6-plus percent growth in 2016 (Hussain & Haque, 2017). The country is in transition from an agriculture-based economy to an economy of a mix of light and heavy industries and services (Raihan et al., 2022b). This has led to many infrastructural changes including a flourish in the real estate sector (Hossain et al., 2024). Bangladesh is estimated to construct four million new houses each year to accommodate the growing population (Khan et al., 2021). As a result, in a country with limited natural sources of stones, the boom of the brick manufacturing industry became obvious with a production size of 12 billion bricks a year (Islam et al., 2023). Bangladesh produces 17 billion bricks a year, which is 1.3% of the total Asian brick production (Khaliquzzaman et al., 2020). Being the major building material supplier the industry is generating about 1 million employments and contributing around one percent to the nation's GDP (Talut et al., 2022). However, the growth of the brick manufacturing industry has not been much planned, and thus, there exist many brick kilns that are illegal, unreported, and noncompliant. As of June 2022, Bangladesh possessed 7,881 brick kilns, comprising 3,248 legitimate and 4,633 illegal establishments. Sixty percent of brick kilns in the country are functioning without environmental authorization. Though the brick sector is significantly contributing to the economy, it is a major concern since it is reducing agricultural land, intensifying deforestation, increasing air pollution and greenhouse gas (GHG) emissions along with other social factors including labor right violation, gender discrimination, and social violence (Hossain et al., 2019). According to the Department of Environment (DoE), nearly two million tons of coal and two million tons of wood are combusted in about 5000 brick kilns every year (Muhib & Khan, 2022). With the net reduction and degradation of agricultural land, the brick manufacturing industry is posing strong threats to the country's food security (Haque et al., 2022). The industry is also widely blamed for environmental pollution and human health hazards (Haque et al., 2022). With contrasting issues with the brick kilns, the efforts for regulating this industry have of long regulatory history but with limited success (Brooks et al., 2024). The Government of Bangladesh (GoB) has demonstrated strong commitment by changing its strategies and policies. The first law in the brick sector was introduced in 1989, which saw two rounds of amendment in 1992 and 2001. Despite these amendments, the location requirements have not been enforced, and the use of firewood in the brick kilns could not be checked (Shahen, 2024). As continued effort to conserve environment and forest, the GoB enacted the Environment Conservation Act, 1995 that required environmental clearance certificate (ECC) for the kilns to operate, circulated a gazette notification in 2007 for the kilns to adopt improved technologies by 2010, enacted a new notification in 2010 to eliminate fixed chimney kilns (FCKs) by 2012, issues a final notification in 2012 that required all the kilns to install at least 120-ft high chimneys. This last notification was successfully enforced especially in the vicinity of urban areas where the DoE monitoring of the kilns was quite strong. To take a firmed stand on regulating the brick manufacturing industry, the government enacted the Brick Making and Brick Kiln Establishment (Control) Act, 2013 in July 2013 (Act 2013, hereafter). The law entered into operation in July 2014.

Not only in Bangladesh, but the brick manufacturing industry has also become a matter of concern and is under strong regulation in the neighboring brick-producing countries. Many countries imposed different regulations and set out rules to control pollution from brick kilns. The Government of India has issued notifications of emission standards for brick kilns which include maximum allowable levels for particulate matter concentration in flue gases, minimum stack height, and a proposed ban on the use of moving chimneys (Rajarathnam et al., 2014). In Nepal, various national regulations such as the Environment Protection Act 1997, Environment Protection Regulation 1997, and Industrial Enterprises Act 2004 govern the industrial operation including brick kilns (Thakuri et al., 2024). Industrial Enterprise Act, of 1992 is the main act that governs all types of industries including brick kilns in Nepal (Bhandari et al., 2016). Like Bangladesh and India, Nepal also banned the establishment of movable brick kilns in Kathmandu in 2003 and the restriction was extended throughout the

country in 2012 (Thakuri et al., 2024). The country also requires the submission of an environmental impact assessment (EIA) report, soil sources, and land reclamation plan prior to the establishment of a kiln (Bhandari et al., 2016). In Bangladesh, the Act 2013 has been in its initial stage of implementation with varying degrees of success and mixed criticisms from all parties involved – the GoB, the brick manufacturing industry, civil society, and the scientific community. After three years of enactment, the feasibility and enforceability of the provisions of this act are not beyond question (Haque & Sharif, 2021). According to the DoE, this act should be amended in the light of field-level study considering the issues with the participation of all stakeholders (Khaliquzzaman et al., 2020). More than three-decades-long brick manufacturing industry regulation is not so pleasing because of its poor and impractical implementation. Given this, it was enormously important to examine how well the Act 2013 has regulated the brick manufacturing industry. While most of the studies are, in one way or another, inclined towards focusing on how detrimental brick manufacturing industry is to the health, environment, and food security of the nation, technological compliance issue, and technological efficiency of brick production (Hossain et al., 2019; Khaliquzzaman et al., 2020; Aniyikaiye et al., 2021; Ncube et al., 2021; Akhtar et al., 2022; Bajracharya et al., 2022; Haque et al., 2022; Parvez et al., 2023; Shahen, 2024), there is clearly a dearth of any investigation addressing the degree of stringency of this act compared to similar acts in neighboring countries and the level of compliance of the brick manufacturing industry to regulation. That being said, this study was conducted (i) to evaluate the chronological development of regulatory tools governing brick kilns in Bangladesh and neighboring countries, (ii) to examine the status of the compliance of brick manufacturing industry to the Act 2013, (iii) to examine the socioeconomic factors affecting the brick kiln owners' attitudes to comply with the regulation, and (iv) to test the significance of the production cost of such compliance.

Method

Study boundary

The latest legislation that governs the brick industries in Bangladesh, Nepal, and a couple of states in India have been summarized and compared. The Indian states included in the study are Uttar Pradesh (UP), Jammu Kashmir (JK), and Assam (AS). Assuming the existence of similar compliance status in these Southeast Asian countries, Bangladesh was selected as a case to understand the status of brick manufacturers' compliance and attitude towards the regulations. Given this, the study was conducted in four north-central districts of Bangladesh - Brahminbaria, Kishoregonj, Mymensingh, and Netrokona. Mymensingh is 120 km to the north of the country's capital, Dhaka. Netrokona is 134 km to the north, Kishoregonj is 98 km to the northeast, and Brahmanbaria is 76 km to the southeast of Dhaka (Figure 1). These districts constitute a major brick manufacturing zone of the country that harbors 452 of the total of 6000 brick kilns across the country (Muhib & Khan, 2022). The districts are distributed across three administrative divisions - Brahminbaria is in the Chittagong division, Kishoregonj is in the Dhaka division, and Mymensingh and Netrokona are in Mymensingh division – totaling a land area of about 9022 square km. The economy of these districts is largely agrarian having vast areas of farmland and a significant number of rivers flowing through the area. Kishoregonj and Netrokona contain a large area of low-lying wetland, locally known as *haor*, containing Nikli, Austagram, Mithamain, and Birishiri *haors*.

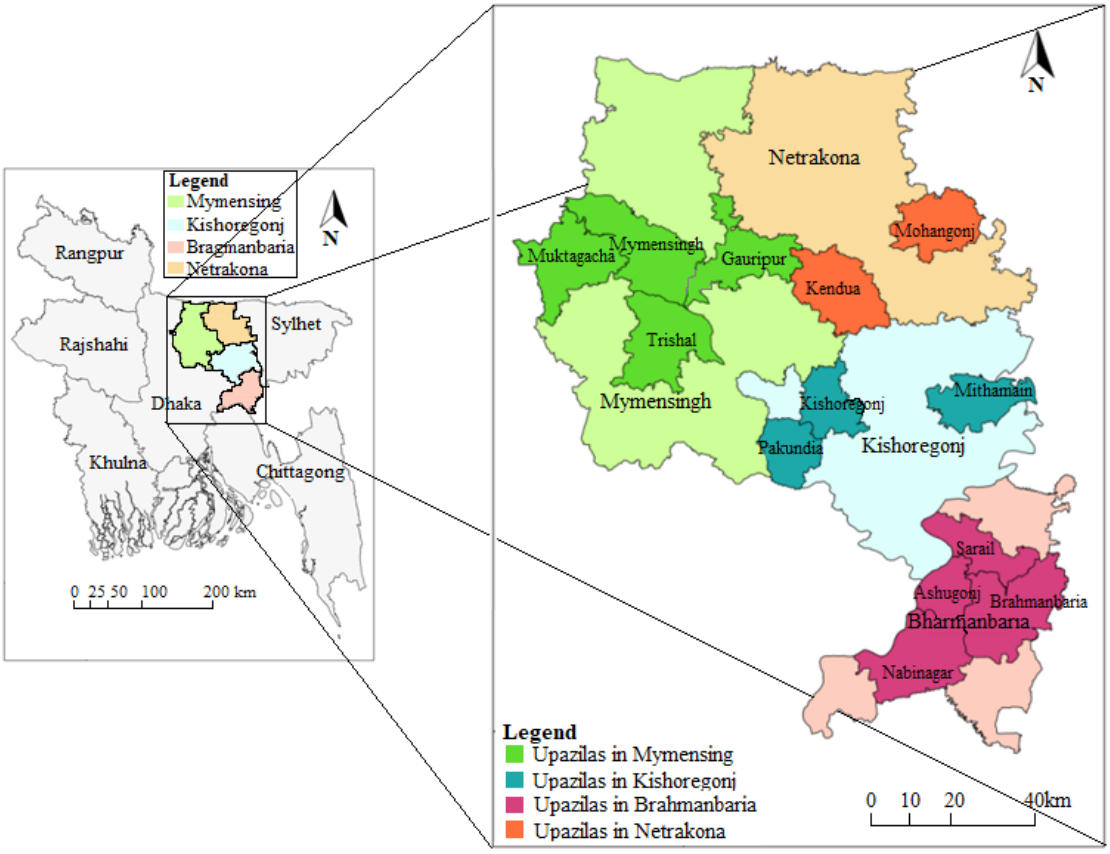

Figure 1. Map of the study area showing studied upazilas under the districts of Brahminbaria, Kishoregonj, Mymensingh, and Netrokona of Bangladesh

Sampling framework and data collection

Of the 452 brick kilns, 142 are in Mymensingh, 123 are in Brahmanbaria, 96 are in Kishoregonj, and 91 are in Netrokona districts. It was planned to select at least 30% of the total brick kilns in the study area for subsequent interviews with the brick kiln owners. Thus, a total of 140 brick kilns (31% of the total) were selected. The distribution of these brick kilns among four districts was done in proportion to the total number of brick kilns available in each of the districts. Thus, 44 brick kilns from Mymensing, 38 from Brahmanbaria, 30 from Kishoregonj, and 28 from Netrokona district were selected (Figure 2). The selection of brick kilns from each district for the final interview was made in such a way that the representation of the maximum number of upazilas under each district could be ensured. That being said, the final field surveys were conducted in the selected brick kilns of Pakundia, Kishoregonj central, and Mithamain upazillas of Kishoregonj district; Ashugonj, Sarail, Brahmanbaria central, and Bijaynagar upazilas of Brahmanbaria district; Trishal, Muktagacha, Mymensingh central, and Gauripurupazilas of Mymensingh district; and Mohongonj and KenduaupazilasofNetrokona district.

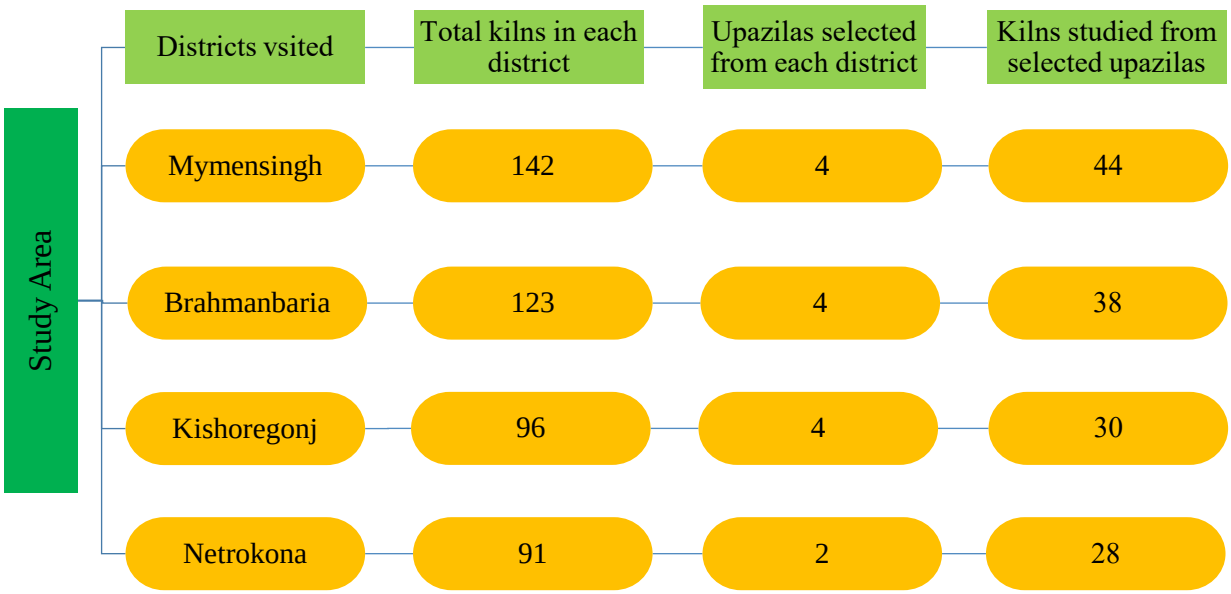

Figure 2. Selection of brick kilns from four districts in the study area

A semi-structured questionnaire was used to collect data from the selected 140 brick kilns. The major variables of interest for the interview have been specified in Table 1. To collect brick kiln-related information, we interviewed either brick kiln owners or the managers of respective brick kilns on the Owners' behalves. In addition to interviewing the brick kiln owners and managers, environment experts, entrepreneurs, secretaries of owners' associations, and brick manufacturing industry-related specialists were consulted to understand their views, opinions, and suggestions to conceptualize their thinking and future strategy toward the development of the brick sector of the country. The fieldwork for this study was conducted over three months, April-June, 2016. Relevant secondary data of the study area were collected from the offices of the Deputy Commissioner Office, the Department of Environment, and brick kiln Owners' Association in each of the districts. Some secondary information was also collected from the World Bank website, government reports, and newspaper articles.

Table 1. Specification and units of measurement of dependent and independent variables

Variable	Definition	Units of measurement
SHIFT_TECH	Brick kiln has shifted to modern technology	Yes=1, Otherwise=0
FUEL_COMP	Brick kilns used only coal and gas	Yes=1, Otherwise=0
ECC	Brick kiln has taken ECC	Yes=1, Otherwise=0
BUSI_LC	Brick kiln has taken a business license	Yes=1, Otherwise=0
AGE	Age of the brick kiln	Years
POL_LEADER	Brick kiln owner is a political leader	Yes=1, Otherwise=0
BRIBE	Bribing the law enforcement authority	Yes=1, Otherwise=0
PENALTY	Penalized ever by the law enforcement authority	Yes=1, Otherwise=0
PROD_COST	The Act-2013 has increased brick production cost	Yes=1, Otherwise=0
RESTRICT_SITE	Brick kiln owner knew legally the restricted locations	Yes=1, Otherwise=0
BRIC_PROD	Quantity of brick production per season	Number
INCOME_KILN	Income from brick kiln per production season	BDT (US$1= BDT80)
DIF_BUSI_LC	Difficulty in getting a business license	Yes=1, Otherwise=0

Analytical framework

Summarizing Acts and Rules enacted in Bangladesh, India, and Nepal

In this study, legal matters related only to brick manufacturing in Bangladesh and a couple of other developing countries have been analyzed. The issues have been discussed in two major segments: (i) Summarizing the chronological development of environmental acts, rules, and ordinances enacted in Bangladesh, and (ii) Comparing the latest regulations governing brick production in Bangladesh, Nepal, and India. In the first segment, how acts and rules were enacted and amended to address the contemporary issues related to the operations of brick kilns and their impacts on forests and the environment have been evaluated. The second segment has been developed to compare the willingness of different developing nations to care for their forest and environment while optimizing the volume and quality of brick production. The latest regulations that govern brick manufacturing in Bangladesh, Nepal, and the states AS, UP, and JK of India have been analyzed and compared. The comparison of the acts and rules in these countries and states was based on the requirement of environmental clearance certificates and business licenses for brick businesses, prohibited and permitted locations, fuel types, and soil sources for brick kilns, raw materials alternative to soil, permitted kiln types and their minimum chimney height, maximum emission level, and provisions for punishment for the law breakers. Through the comparison of all these provisions under the laws of these countries and states, an inference has been drawn on the degree of stringency of brick manufacture-related acts and laws in these countries and states.

Evaluating socioeconomic factors affecting compliance with the Act 2013

We have used a binary logistic regression model to analyze the socioeconomic factors that determine kiln owners' compliance status to the specific technology and fuel, and hurdle to obtain environmental clearance for brick manufacturing. The use of logistic regression is quite common in social science research. Logistic regressions are made up of three components: random, systematic, and link function. The random component identifies the binary dependent variable (*Y=0 or 1*) and its probability distribution, the systematic component identifies the set of explanatory variables (x_i), and the link function identifies a linear relationship between the explanatory variables and their probability function. That is,

$$P_r(Y = 1\ or\ 0 \mid X = x_i) = \alpha + \beta_i x_i \quad (1)$$

Where X is the vector of socioeconomic attributes of the respondents, $P_i(X \mid X = x_i)$ indicates the probability of respondents' compliance status (compliant = 1, otherwise =0) to regulatory tools for a given socioeconomic characteristic, $X = x_i$, and β_i is the vector of parameters to be estimated.

In the logistic regression model, a *logit-link* function is defined as follows:

$$P_r(Y = 1\ or\ 0 \mid X = x_i) = log\left(\frac{P_i(x_i)}{1-P_i(x_i)}\right) \quad (2)$$

A combination of equations (1) and (2) gives equation (3).

$$\alpha + \beta_i x_i = log\left(\frac{P_i(x_i)}{1-P_i(x_i)}\right) \quad (3)$$

Equation (3) reduces to (4)

$$p(x_i) = \frac{e^{\alpha+\beta_i x_i}}{1+e^{\alpha+\beta_i x_i}} \quad (4)$$

Now, if$X$ is binary ($x_i = 1\ or\ 0$), equation (1) yields the following outcomes:

If $x_i = 1, P_r(Y = 1\ or\ 0\ |X = 1) = \alpha + \beta_i$ and if $x_i = 0,\ P_r(Y = 1\ or\ 0\ |X = 0) = \alpha$. Thus, we can estimate the model beta using equation (5):

$$\beta_i = \log\left(\frac{P_i(1)}{1-P_i(1)}\right) - \log\left(\frac{P_i(0)}{1-P_i(0)}\right) \quad (5)$$

Thus, $\beta_i$can be interpreted as the change in the$log\ (odds)$ when x_i changes from 0 to 1. The same also applies when x_i is continuous and changes in an additive fashion. The specifications of all variables evaluated in this study have been described in Table 1.

Testing the significance of compliance cost

One of the major tasks of this study was to validate the claims of the brick kiln owners that the regulation significantly increased their brick production cost. Thus, we compared the mean production costs per brick in two states (with and without environmental regulation) using a t-test. To decide the type of t-test needed for such comparison, we compared the variances of mean production cost per brick to examine whether the variances of the per unit brick production costs in the two states differed significantly. Failure to reject the null hypothesis, that H_0 = the true ratio of the variance of the two groups was equal to one, will lead to conducting a paired t-test to evaluate if the Act 2013 has significantly raised the per unit brick production cost.

Results and discussion

Incremental development of brick manufacturing regulations in Bangladesh

Bangladesh's government has been committed to regulating the ominous side effects of the brick industry, which has led to the promulgation of a series of measures at different times related to the brick sector in Bangladesh. The incremental development of brick production-related legislation has been presented in Figure 3. The very first legislative action taken by the government on brick making back in 1989 was the Burning of Bricks (Control) Act 1989, which focused on the banning firewood, license for brick burning, an inspection of brick fields by the authorities, and the punishment for the violation of the act. Further clarifications were provided through the Brick Burning (Control) Amendment Act, 1992, which prohibited burning 'dead roots of bamboo' as firewood, transferred the inspection power to a deputy commissioner, extended a monetary penalty up to fifty thousand takas, and delegated the 'power of confiscating the fuel wood' to the court. 'The Environmental Conservation Act 1995' also known as the 'mother law of environmental conservation' of the country, which emphasized conserving the environment by controlling and mitigating pollution, made an environmental clearance certificate(ECC) mandatory for kiln operation. Later on, the Environmental Conservation Rule 1997 along with fixing the emission standard (1000mg/Nm^3) for stalk emission of Brickfields, categorized brick field as Orange-B and described the procedure of obtaining ECC. In 2001, the Burning of Bricks (Control) Act 1989) was amended which brought some specific changes like committee formation to verify the application for a license, replacing the firewood with fuel, and including imprisonment as a penalty for violating the law. This also prohibited the setting up of brick kilns within three km of the upazila or district center, municipal areas, residential areas (where at least fifty families live), gardens, and the government's reserve forests. In 2004, Brick burning rules were provoked to reduce aerial pollution, replacing the Bull chimney kiln with a fixed chimney kiln where the use of 120-ft chimneys for brick kilns was set mandatory.

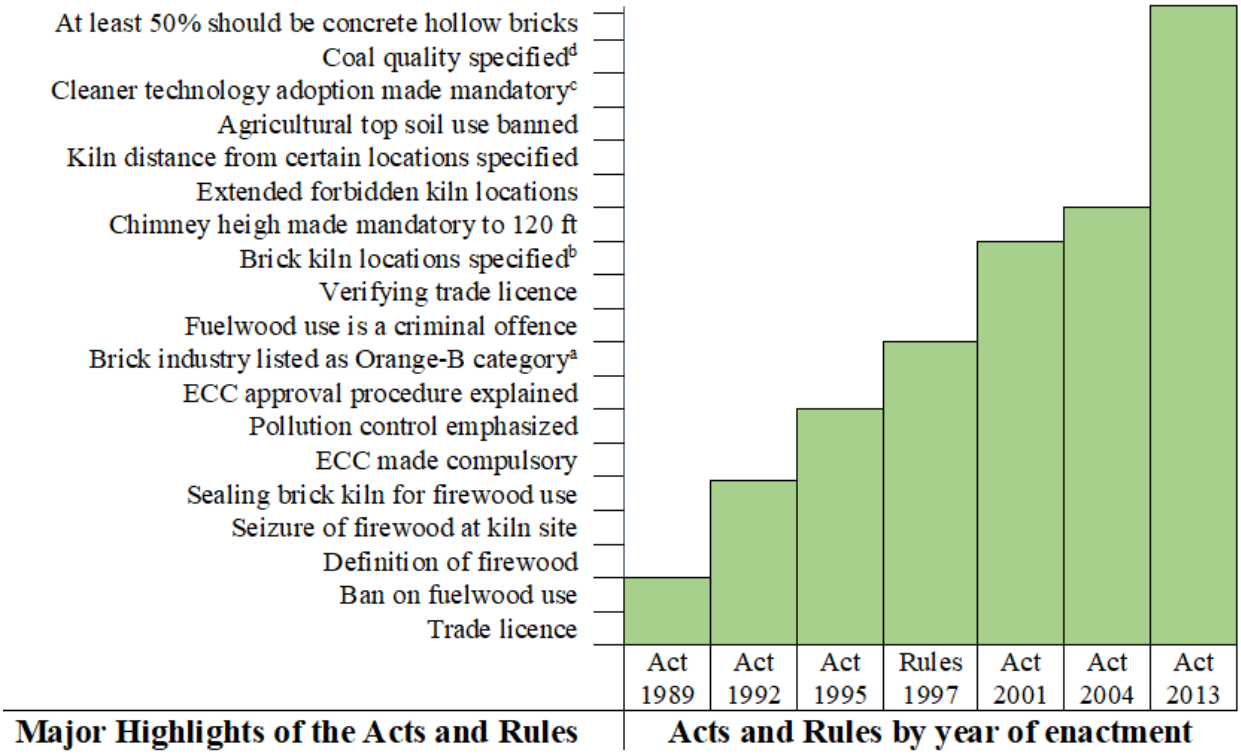

Figure 3. Incremental development of Acts and Rules related to brick kiln operations in Bangladesh

(Notes: Act 1989 =>Burning of Bricks (Control) Act; Act1992=>Burning of Bricks (Control) (Amendment) 1992; Act 1995=>Bangladesh Environment Conservation Act 1995; Rules1997=> Environmental Conservation Rules 1997; Act2001=>Burning of Bricks (Control) (Amendment) Act, 2001; Act2004=>Brick Burning (Control) Rules, 2004; Act2013=>Brick Making and Brick Kiln Establishment (control) Act, 2013; a = In Environmental Conservation Rules, 1997*;* b = Prohibits the establishment of brickfields in residential, protected, commercial and agricultural areas, and also in forests, sanctuaries, wetlands, and Ecologically Critical Areas; c = Cleaner technologies includes Zigzag, Hybrid Hoffman Kiln (HHK) and Vertical Shaft (VSBK) kilns; d=No person shall use coal as fuel, containing sulfur ash, mercury or similar material beyond the prescribed standard, in the brick kilns for burning bricks).

Afterward, in 2013, the Act, 2013 was passed to establish control over brick manufacturing and brick kiln establishment, which came into force from 1st July 2014 (Table 2). The main objective of this law is to protect biodiversity from brickfield-related pollution, which has prescribed different prohibitions and directions regarding the establishment and operation of brick kilns. According to section 4 of this Act, the construction of brick kilns is prohibited without business lice from the Deputy Commissioner's Office. Soil collection from agricultural land, hills, and hillocks has been prohibited in section 5(1) whereas section 5(2) allows soil collection from canals, marshlands, ponds, and rivers after getting permission from the authority.
It is addressed in section 5(4) that, at least 50% of the total bricks should be hollow bricks made of sand and cement along with a restriction on using heavy vehicles for the transportation of bricks and raw materials for bricks. Section 6 prohibits using fuel wood for burning brick whereas section 7 specifies that coal containing sulfur, mercury, or ash beyond permissible limits is not allowed to be burnt in brick kilns. Brick kilns are not allowed within the boundary of residential, protected, and commercial areas, at the headquarters of the City

Corporation, municipality, and upazila, in forests, wildlife sanctuaries, gardens, water bodies, agricultural land, ecologically critical areas, and degraded air-shed, which has been addressed in section 8(1). Per section 8(2), no authority can issue any license or environmental clearance certificate (ECC) in prohibited areas.

Table 2. Summary of environmentally important sections of the Brick Making and Brick Kiln Establishment (Control) Act 2013

Section	Focal Areas	Section-specific statements
4	Business License	Construction of brick kilns is prohibited without business lice from the Deputy Commissioner's Office.
5(1)	Prohibited soil sources	Soil collection from agricultural land, hills, and hillocks is prohibited
5(2)	Permitted soil sources	Soil collection from canals, marshlands, ponds, and rivers is not allowed unless permitted by the authority.
5(3)	Non-soil bricks	At least 50% of the total bricks should be hollow bricks made of sand and cement.
5(4)	Hauling roads	Any road constructed by the local government and engineering department (LGED) should not be used by heavy vehicles meant for the transportation of brick or its raw materials.
6	Fuelwood	Using fuel wood for burning brick is completely prohibited.
7	Coal specifications	Coal containing sulfur, mercury, or ash beyond permissible limits is not allowed to be burnt in brick kilns.
8(1)	Kiln location	Brick kilns are not allowed within the boundary of residential, protected, and commercial areas, at the headquarters of city corporations, municipality, and upazila, in forests, wildlife sanctuaries, gardens, water bodies, agricultural land, ecologically critical areas, and degraded air-shed.
8(2)	ECC control	No authority can issue any license or environmental clearance certificate (ECC) whatsoever for constructing brick kilns in the prohibited locations.
8(3)	Safe distance	Brick kiln construction is not allowed within one km of the prohibited areas, two km of any public forests, half a km of any hill, one km of any educational and research organization, hospital, and railway line, and half a km of any LGED road.
8(4)	Kiln relocation	Any kiln already constructed within the prohibited locations should be relocated to a permitted area within two years of this law being enforced.
9(1)	ECC for License	A business license cannot be issued without an environmental clearance certificate (ECC)
9(5)	Length of license	The license is valid for three years from the date of its issuance.
11(1)	License suspension	The license should be suspended if a criminal offense is committed by the kiln.
11(2)	Voiding license	The license can be voided by the deputy commissioner if the kiln is convicted by any relevant court.

Source: Ministry of Forest and Environment (2016)

Section 8(3) allowed brick kiln construction only beyond one km of the prohibited areas, two km of any public forests, half a km of any hill, one km of any educational and research organization, hospital, and railway line, and half a km of any LGED road. Again, according to section 8(4), any kiln already constructed within the prohibited locations should be relocated to a permitted area within two years of this law being enforced. Sections 9(1), 9(5), 11(1), and 11(2) of the Act 2013assert license related provisions such as environmental clearance certificate (ECC) are mandated for obtaining business licenses, validation, and

suspension or voiding of the license are also mentioned in those sections. However, the Act 2013 has highlighted most of the factors that are related to brick kiln-related pollution and its control. But the question remains whether the law is practicable given the socioeconomic conditions that the nation lives with.

Comparison of the brick kiln related Acts and Rules in Bangladesh, India, and Nepal

South Asian countries have more or less similar regulatory tools for the environmental management of brick manufacturing kilns. However, each country or state has also some uniqueness in its regulations. While Bangladesh and Nepal have their central regulatory controls on brick kilns, each of the states of India has its own rules and regulations for brick kiln administration. In all of the five countries and states (Bangladesh, Nepal, and UP, JK, AS of India), it is mandatory to secure an environmental clearance certificate (ECC) and business approval from the appropriate authority for manufacturing bricks (Table 3). As Bangladesh is one of the most densely populated countries in the world with severe limitations on land for agriculture and other purposes, the government has imposed extreme restrictions on shifting agricultural land to any other non-agricultural uses to ensure food security for the nation. This has been reflected in the land's laws too. Unlike Nepal and India, Bangladesh has no provision in its latest brick kiln regulation (Act 2013) to allow the kilns to be used in agricultural and hill soil. While Bangladesh, UP, and AS laws have specific recommendations on using brick raw materials alternative to soil, JK and Nepal have no such recommendations in their legislation. Manufacturing hollow bricks using cement and sand is found as a compliance factor in the Bangladesh regulations only; Nepal and Indian states have no regulatory bindings such as this. Another stringent factor that the kilns are forced and strongly monitored to abide by is not to use vegetative fuel of any sort in the brick kilns in Bangladesh (Table 3). In contrast, UP and Nepal have prohibitions in burning non-vegetative fuel including organic solvent, oily residue, pet coke, plastic, rubber, and leather but JK and AS have no such provision in their laws.

In regards to choosing a kiln type or the preference for the type of kilns JK and AS have no specification, while Bangladesh has made it mandatory to choose among Zigzag, HHK, and VSBK technologies, UP among BTK, DDK, and VSK technologies, and Nepal among BTK, VSBK, and tunnel technologies(Table 3). However, chimney height has been made quite specific in all these countries and states except in JK. Chimney height is at least 36.58m in Bangladesh, 22.30m in UP, at least 30m in AS, and 15-30m in Nepal. In addition, in the case of choosing the kiln locations, the latest regulations have been very specific in Bangladesh and beyond. The prohibited locations for brick kilns in Bangladesh are residential areas, forest and protected areas, commercial areas, agricultural land, and wetlands, in UP are fruit belt areas, in JK are agricultural land, and forest land, in AS are development zones, agricultural land, and in Nepal are forest area and highly populated areas. Again, maximum emission levels have also been specified in all the countries and states except JK. The maximum limits of emission allowed in the laws were 1000mg/Nm^3 in Bangladesh, 750-1000 mg/Nm^3 in UP and AS, and 400-700mg/Nm^3 in Nepal (Table 3). The penalty structures for violating laws also have some variations among the countries according to their dimensions of violations. The lawbreakers are liable to jail time or financial punishment everywhere except in UP. In Bangladesh, the punishment for the law breakers is two to five years of imprisonment or a financial penalty of BDT50,000 – BDT500,000 (US$1 = BDT82). This punishment in JK is two to five years of jail time or a financial penalty of INR50,000 (US$1 = INR64) and in AS is five to seven years of jail time or a financial penalty of INR100,000(Table 3). In Nepal, neither the jail term nor the financial amount of the penalty is explicitly stated. However, production might be halted if the brick kiln owner is convicted. From the comparison of the legal tools in all these countries and states, it is clear that the brick regulation in Bangladesh is excessively tougher than that in other

countries and states under study. UP and JK look to have lax regulations than those in other Indian states under study. Nepal's regulation of the brick industry is relatively moderate. It has areas of complaint almost similar to that of Bangladesh. However, the stringency of brick regulation in Nepal is not as high as that in Bangladesh. The degree of stringency might be a major reason for Bangladeshi brick kilns to be non-compliant with brick regulations at a very high percentage.

Table 3. Comparison of brick kiln-related latest legislations in Bangladesh, India, and Nepal

Compliance areas	Act in Bangladesh[a]	Act in UP, India[b]	Act in JK, India[c]	Act in AS, India[d]	Act in Nepal[e]
Environmental clearance	From DoE	From SPCB	From DEIAA*	From SPCB	From SPCB
Business approval	From DC*	From DA* From Panchayet	From PCB	From Panchayet	From PCB*
Prohibited soil sources	Agriculture soil hill soil	NSS	NSS	NSS	NSS
Alternatives to soil	Cement Sand to produce hollow bricks	Stone dust Rice husk ash Mud	NSS	Stone dust Rice husk Ash Red mud	NSS
Prohibited fuel	Firewood	Organic solvent Oily residue Pet coke Plastic & Rubber Leather	NSS	NSS	Wood Rubber Plastic
Permitted kiln type	Zigzag HHK VSBK**	BTK DDK VSK**	NSS	NSS	BTK VSBK** Tunnel kiln
Minimum chimney height	≥ 36.58m	22-30m	NSS	≥ 30m	15-30m
Prohibited kiln locations	Residential area Forest & PAs Commercial area, Agricultural land Wetland ECAs***	Fruit belt area	Agricultural land Forest land	Development zone Agricultural land	Forest Populated areas
Minimum Kiln distance	0.5-1km from: Hill bottom Rail tracks Schools Hospitals	1km from: Residential area School Hospital	NSS	300m-1km from: Residential area Hospital Public building Zoo & Sanctuary	500m-1km from: Populated areas 5 km from Forest
Maximum Emission	1000 mg/Nm^3	750-1000 mg/Nm^3	NSS	750-1000 mg/Nm^3	400-700mg/Nm^3

(PM/SPM)					
Plantation around kiln	NSS	10m wide	NSS	10m wide	Plantation
Punishment (Imprisonment or monetary fine)	2-5years Or BDT 50,000-500,000	NSS	2-5 years Or INR50,000	5-7 years Or INR100,000	Monetary fine Or Halt of production

[a]Brick Making and Brickfield Establishment (control) Act, 2013; [b]Uttar Pradesh Brick Kiln(Sitting Criteria for Establishment) Rules, 2012; [c]Jammu and Kashmir Brick Kiln (Regulation) (Amendment) Act 2016; [d]Assam Brick Kilns Establishment and Regulation Rules, 2013; [e]Protection Act, 2053, the Environment Protection Regulation, 2054 and Industrial Enterprise Act, 2049, *District Administration= DA, District commissioner =DC, SPCB= State Pollution Control Board, Divisional, Pollution Control Board=PCB**Hybrid Hoffman Kiln=HHK, Vertical Shaft Brick Kiln =VSBK, Bulls Trench Kilns=BTK, Down-draft Kiln=DDK, Vertical Shaft Kiln=VSK,***Ecologically Critical Areas=ECAs, NSS=No specific statement, *District Environment Impact Assessment Authority =DEIAA

State of brick kiln owners' compliance to the Act 2013 by sections

Figure 4 represents the summary findings on how the brick manufacturers were responding to the requirements imposed by the Act 2013 as well as their opinions on the applicability of the law in the current socioeconomic setup of the country. While only 52% of the respondents said they had a comprehensive idea about the new law, 10% of respondents had no idea about the law, even after three years of the law in action.

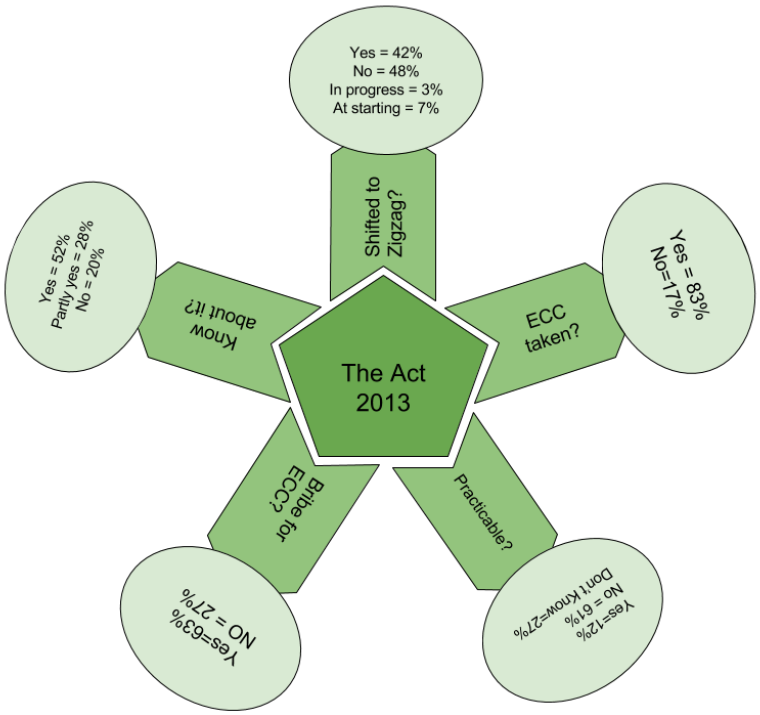

Figure 4. Summary of the state of brick kiln owners' compliance with the Act 2013 in Bangladesh

In addition, another 28% said they had just a bird's eye view of the law. Again, even though obtaining an environmental clearance certificate (ECC) for brick manufacturing is a basic environmental requirement for all industries including the brick manufacturing industry since 1995, 83% of the brick kiln owners said they had it. After more than two decades of such requirements being public, 17% of the studied brick kilns were operating without ECC. This non-compliance might be attributed not only to the purposive inaction of the owners, they might have also found it too costly for the business.

This can be supplemented by the fact that 63% of the owners claimed that they were to offer bribes to get ECC. However, the remaining 37% reported that they obtained ECC without any bribe. The Act 2013 also requires the brick kiln owners to convert their fixed chimney kilns to zigzag kilns. Of all the kilns, 7% were born zigzag, 42% switched to zigzag, and 2% were in the process of adopting the technology. That means, 48% of the surveyed brick kilns were still operating with a production technology that was not legal. Given the existing constraints and opportunities for the brick manufacturing industry in Bangladesh, only 12% of the kiln owners perceived that the Act 2013 is practicable and the vast majority of the owners, 61%, said the law is impracticable and needs immediate amendment. However, 27% had no idea about the applicability of the law. Overall, as evident from the voice of the kiln owners, the compliance status of the brick manufacturing industry does not look so pleasing.

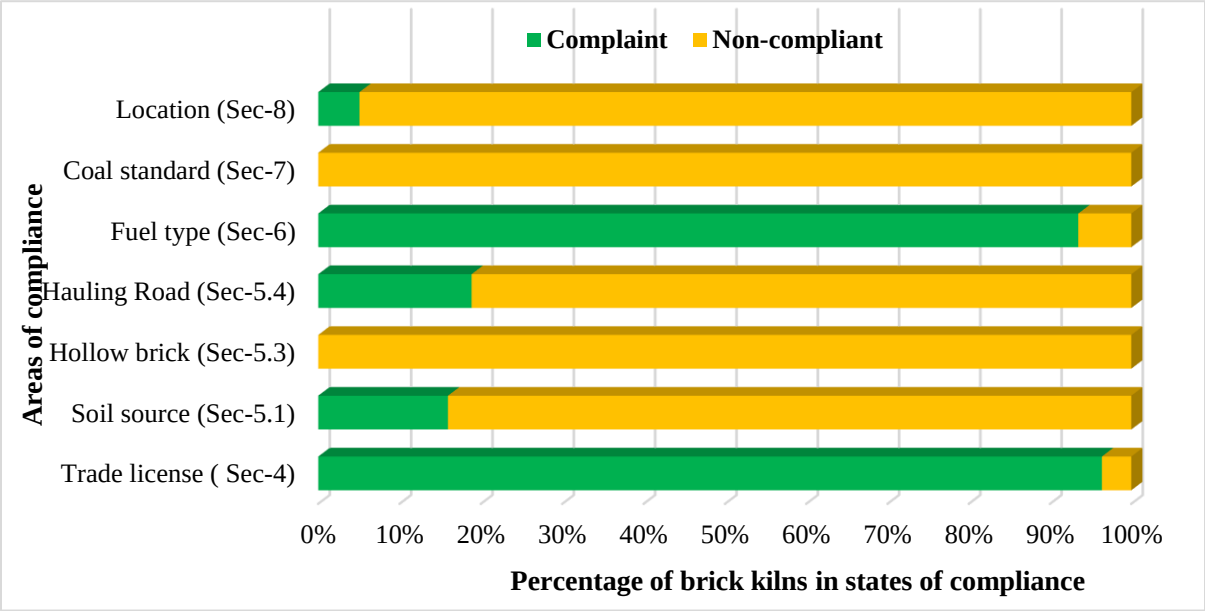

Figure 5. Compliance status of the brick kilns by sections of the Brick Making and Brick Kiln Establishment (Control) Act, 2013

Figure 5 portrays how the Act 2013 could be impracticable in its present form if brick kilns are allowed to continue the business with their present setup. In one way or another, every section of the Act is being violated by most of the brick kilns. The result shows that both Section 5(3) and Section 7 (See Table 2 for Section statement) were being violated by 100% of all the 140 brick kilns studied. While 93.48% of brick kilns were using coal instead of fuel wood just to minimize cost, none of them were using coals with environmental standards as specified in the Act 2013. The responsibility for this noncompliance is equally shared by the Government of Bangladesh since the publicly imported coal was not meeting the legal

requirements. Our field data also exhibits that the idea of hollow brick is something that has never been heard of by any of the surveyed brick kilns. The Act 2013 has vehemently emphasized the permitted and prohibited locations for the brick kilns, which has been specified in Section 8. Alarmingly, 94.3% of the kilns were not complying with this Section (Figure 5). Our primary data shows that 88.41% of the brick kilns were located within one km of agricultural land, 61.59% were located within half a km of the LGED roads, and 5.94%, 4.35%, and 3.62% of the brick kilns were within the prohibited boundaries of union or village road, residential area, and educational institute, respectively (Figure 5).

Although the Government's high priority is food security and agricultural land can no way be taken under brick manufacturing activities (Section 5.1), the reality is extremely different: 84.06% of the selected brick kilns were collecting soils from agricultural and other prohibited lands. The brick manufacturing industry consumes around 45 million tonnes of fertile soil – equivalent to around 2,600 hectares of agricultural land- each year (Hossain et al., 2019). An almost similar rate, 81.16%, of non-compliance with Section 5.4 was observed in selecting roads for hauling bricks. The heady trucks loaded with tons of bricks were using the local government-maintained narrow and unpaved roads and creating severe damage to the rural communication networks. However, a satisfactory level of compliance was found with Section 4 (on obtaining a trade license) and Section 6 (on using coal and gas instead of fuel wood). About 96.38% and 93.48% of the brick kilns were found complying with Section 4 and Section 6 of the Act 2013, respectively.

The state of compliance or non-compliance is attributed to many factors. Some of the factors are the size of the Department of Environment, the political power of the kiln owners and corruption, the high fixed cost of switching to the required technology, and the remoteness of the brick kilns. Above all of these, the Act 2013 itself is so tough on the provisions of kiln operations that the kilns could hardly comply with the regulations. The emergence of DoE in Bangladesh is very recent and the total manpower of the Department is less than 500 across the country. They could not have an office in each of the 64 districts in the country. Given this reality, it is not possible to monitor more than 6,000 brick kilns, most of which are located in rural areas, with the human resources they have. Again most of the brick kiln owners are politically strong and they have hardly any incentive to look into the details of the Act 2013 let alone complying with its stringent provisions. Finally, the kiln owners have gone through a series of shifts in kiln types and chimney types in recent years. Switching to expensive kiln types is not possible within the time (two years, which has already expired) they have been given. Thus, most of them were found non-compliant with most of the Sections of the Act 2013.

Factors affecting the brick kiln owners' compliance with the Act 2013

Factors affecting technology adoption

We have found four variables (ECC, BRIBE, PENALTY, and PROD_COST) that significantly affect brick kiln owners' preference for switching to brick manufacturing technologies as specified in the Act 2013 (Table 4). If the brick kiln had ECC, the corresponding *log(odds)* of choosing zigzag technology against fixed technology increased by 0.324. That means brick kilns having ECC were more likely to switch to adopt technology as prescribed in the law. The parameter estimate of BRIBE was -0.247, which was significant at a 1% level. That means hidden cost (need to bribe) was negatively linked to the choice of technology. If the brick kilns needed to offer bribes they were significantly reluctant to adopt better technology as directed in the law. PENALTY was found negatively linked (β = -0.3580) to the choice of a better technology. It turns out that, it was less likely that a penalized brick kiln owner would be willing to adopt modern technology. This finding implies that – the penalty was hardly changing kiln owners' behavior to opt for environment-friendly

technology. There might be several explanations behind this: (i) the profit coming through the practice of existing technology was easily offsetting the penalty size and (ii) the fixed cost of shifting to the modern technology was too high for the owners to bear. However, the parameter estimate of PROD_COST was -0.242, which was significant at a 5% level (Table 4). That means the brick kiln owners who opined that the Act 2013 had significantly increased their production cost were less likely to switch to one of the environment-friendly technologies the law advised.

Table 4. Factors affecting brick kiln owner's attitude toward technology compliance

Variables	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.564	0.170	3.321***	0.001
ECC	0.324	0.082	3.956***	0.000
BUSI_LC	0.209	0.162	1.294	0.198
AGE	-0.005	0.003	-1.788*	0.076
POL_LEADER	0.051	0.085	0.603	0.547
BRIBE	-0.247	0.073	-3.381***	0.000
PENALTY	-0.358	0.064	-5.606***	0.000
PROD_COST	-0.242	0.077	-3.150***	0.002
RESTRICT_SITE	0.021	0.057	0.366	0.715

Notes: ***, **, *Significant at 1% level, 5% level, and 1% level, respectively; Dependent variable = SHIFT_TECH (1 if shifted to technology specified in the Act 2013 and 0 otherwise)

Factors affecting fuel compliance

Table 5 explains the factors that identify the likelihood of a brick kiln using the fuels (gas and coal, and not fuel wood at all) as specified in the Act 2013. Of the seven variables tested, four were found to significantly affect the kiln owners' willingness to use recommended fuels.

Table 5. Factors affecting owner's attitude towards fuel compliance of brick kiln

Variables	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.972	0.136	7.127***	0.000
ECC	0.157	0.058	2.709***	0.008
BUSI_LC	0.020	0.115	0.173	0.863
BRIC_PROD	-0.007	0.002	-2.690***	0.008
AGE	-0.001	0.002	-0.568	0.571
INCOME_KILN	0.001	0.000	2.009**	0.046
BRIBE	-0.050	0.004	-2.135**	0.025
POL_LEADER	0.007	0.065	0.115	0.908

Notes: ***, **, *Significant at 1% level, 5% level, and 1% level, respectively; Dependent variable = FUEL_COMP (1 if using coal or gas and 0 otherwise)

The parameter estimate of the variable ECC was 0.157, which was significant at a 1% level. Since ECC approval requires a kiln owner to complete a large environmental checklist, it was expected that kilns with ECC were more likely to comply with the fuel requirement of the Act 2013. The parameter estimate of the variable BRIC_PROD was -2.690, which was significant at a 1% level. That means brick kilns with a higher

number of brick production per production season were less likely to comply with the Act 2013 as far as fuel use was concerned. Similarly, as expected, the beta estimate of the variable BRIBE was negative (-0.05) at significance at a 5% level. The brick kilns that bribed the monitoring authority were more likely to survive in the market yet after using illegal fuels (fuel wood and low-standard coal). The parameter estimate of INCOME_KILN was 0.001, which was significant at a 5% level. That means large brick kilns with larger income per production season were more likely to comply with the provision of gas and coal uses of the Act 2013.

Cost of compliance with the Act 2013

Since the F-statistic is not significant, we failed to reject the null hypothesis (Table 6). This means that the variances of the mean production costs per brick in the two states (with and without environmental regulation) didn't differ significantly.

Table 6. Comparison of the variances of cost per brick with and without regulation and the mean costs per brick with and without regulation

	With Regulation	Without Regulation	df	Statistics	p-value
Variance*	0.6297	0.5782	139, 139	F = 1.0891	0.6181
Mean**	5.8928	5.4040	139	t = 6.0805	0.0000

* H_0: True ratio of variances of cost per brick with and without regulation is equal to 1; ** H_0: True difference of mean cost per brick with and without regulation is equal to 0.

Again, the t-statistics of the mean of the differences were significant at a 1% level. That is, the mean cost per brick with regulation differed significantly from the mean cost per brick without regulation. Since the mean cost per brick with regulation (BDT5.8928, where BDT80=SU$1) was greater than that without compliance (BDT5.4040), it can be concluded that the Brick Burning Control Act 2013 has significantly increased the per unit production cost of bricks. Thus, the increase in cost per brick was BDT0.4888, which might be attributed to environmental compliance.

Recommended policy interventions for development prospects and probabilistic

The DoE proposed policy interventions aim to transition the brick sector in Bangladesh towards a sustainable enterprise, including social, environmental, and economic dimensions.

Revamp the policy on bricks

The Brick Kiln Policy 2008 sought to regulate the unrestrained building of brick kilns by the issuance of environmental clearance certificates by the DoE, in accordance with the Bangladesh Environment Conservation Act, 1995. This strategy was implemented to direct the environmental clearance process for the brick kiln project. This policy guideline outlines the overall procedure for environmental clearance and monitoring, while also addressing pertinent concerns related to brick-making, including locational considerations, environmental pollution management, and research and development components. Over 11 years have elapsed since the adoption of this policy. The government has adopted the Brick Manufacturing and Brick Kiln Establishment (Control) Act, 2013, without revising the Brick Policy. The administration has

initiated amendments to the Act. Before amending the statute, a Brick Policy for the next decade should be developed, taking into account the social, environmental, and economic concerns of the brick industry.

Amendment of the Brick Kiln Establishment (Control) Act, 2013

The Brick Manufacturing and Brick Kiln Establishment (Control) Act, 2013 was enacted in 2013 and came into force in July 2014. The primary objective of this act is to regulate pollutants emanating from brick kilns during the production process in technologically advanced facilities. Nonetheless, the regulatory authorities have numerous challenges in implementing this statute. The Act has significantly impeded the development of efficient brick-making technologies in Bangladesh due to restrictions on establishing brick kilns in certain regions and designated buffer zones. This Act should be changed to facilitate initiatives for sustainable brick manufacture.

Develop ancillary regulations in accordance with the 2013 Act

To enable the implementation and enforcement of the Act, a subordinate regulation under the Brick Manufacturing and Brick Kiln Establishment (Control) Act, 2013 should be established.

Draft comprehensive technical specifications for the brick manufacturing process

Technical guidelines must be developed for the approved brick-making technologies, covering the complete cycle of brick production, which includes clay extraction, green brick manufacturing, firing procedures, production organization, and business administration.

Enhancing capabilities

The shift to sustainable brick production necessitates substantial alterations in the regulatory agency's management of the brick-making sector. Regulatory authorities require enhanced methods, equipment, and capabilities for "state management" functions, including emissions measurement, environmental monitoring, clay resource management, planning, and the advancement of the brick-making business.

Launch a brick-based data service

The transition to a sustainable brick sector necessitates that policymakers establish a "foundation for decision-making," which can be accomplished by facilitating the conversion of accessible information and solutions into actionable measures. To ensure effective policy implementation, a brick information service must be built, providing trustworthy data on current circumstances and processes related to brickmaking, clay resources, energy efficiency, emissions, environmental impact, and enterprise economics.

Training and education

To ensure the sustainable development of the brick sector, the promotion of converting available knowledge and solutions into actionable measures is essential. Contributions in this context encompass: training programs; dissemination of plans, guidelines, and tools; technical support and field services for brick

manufacturers; in addition to policy instruments and capacity enhancement for regulatory bodies.

Experimental and scalable methodology for environmentally friendly brick manufacturing

The development of model brick production small-scale enterprises (SMEs) utilizing various efficient technologies should be supported by the government. The models' information must be recorded and differentiated.

Research and development

Research and development facilities ought to be established inside pertinent research institutions, such as Housing and Building Research institutions. Emphasis should be placed on green brick manufacturing technology, including efficient firing methods and renewable materials for brick production.

Modernization of the brick industry

Profitability differentials exist among brick-making technologies, with less efficient technology outperforming more efficient alternatives. In this context, converting the brick industry from seasonal and sporadic production to industrial brick manufacturing utilizing continuous brick-firing kilns and year-round production will facilitate a more environmentally sustainable brick industry in Bangladesh.

Technological uniformity in kilns

The relevant authorities should standardize brick kiln technologies.

Advance the resource-efficient brick (REB) market

The utilization of resource-efficient bricks (REBs) can lead to a decrease in the resources consumed during brick production and firing. The advancement of REBs, including hollow and perforated bricks, necessitates the management of both supply and demand, the formulation and implementation of supportive policies, and the establishment of financially viable brick production units.

Mechanizing the brick industry selectively

Bangladesh has a longstanding history in brick manufacture; however, this experience has been confined to antiquated techniques for kiln design and construction, as well as traditional molding and fire processes. There is a contemporary demand for an alternative method of brick production that accommodates diverse designs, dimensions, and hues. This can solely be accomplished by mechanization in brick production.

Build a setting that supports eco-friendly brick production

A conducive climate for sustainable brick production is essential. It entails the institutional establishment, expansion, and distribution of solutions, methodologies, and programs that must be formulated and tested through a collaborative manner. The cooperative strategy involves enhancing the policy framework,

specifically by establishing a platform for public-private collaboration, creating a "sustainable brick-making support unit," promoting the formation of a brick-makers association, aiding the formalization of SMEs, and propagating the sustainable brick-making methodology.

Facilitate the acquisition of business funding

The strategy to enhance access to finance entails establishing connections between brick SMEs and lending institutions; alleviating lending risks associated with brick SMEs through the implementation of a risk-sharing mechanism in the form of partial guarantees; providing banks with technical assistance to assess new technology brick projects and to subsequently oversee and monitor the loans issued; and creating a low-interest, long-term revolving fund utilizing government or international donor resources.

Keep employees safe and healthy

The brick business in Bangladesh has historically been a polluted sector, operating under challenging labor circumstances. It is the legal obligation of the owner or employer to guarantee the health and safety of employees in the workplace. A secure and healthy work environment minimizes the risks of accidents, injuries, or harm to lives and property, as well as reduces occurrences of workforce impairment.
To safeguard the workers from accident risks and guarantee a hazard-free workplace in the brick sector, the following guidelines are proposed for implementation at the plant level:

- A first aid kit must be accessible on-site. Personal Protective Equipment (PPE) such as gloves, footwear, helmets, masks, and protective clothes must be provided for workers.
- Offer Health and Accident Insurance protection for brick kiln laborers. Measures should be implemented to observe the combustion process within the kiln from a secure distance to prevent fire-related incidents.
- Arrangements for a restroom on-site and drinking water at the kiln have to be made.
- An essential occupational training program must be implemented to familiarize personnel with the specific hazards associated with their respective job assignments.
- Measures must be implemented to ensure that no employee is subjected to noise levels exceeding 85 dB(A) for more than 8 hours per day without appropriate hearing protection.
- Implement preventive and control strategies for fire and explosion risks.
- Employers must use suitable measures to preserve air quality in the workplace.
- The employer must implement protocols and mechanisms for documenting and reporting workplace accidents, diseases, and hazardous events.

Conclusions

The Brick Making and Brick kiln Establishment (Control) Act, 2013 is in place that has banned the use of fuel wood and fixed chimney kilns and has reconsidered the location and height of brick kiln chimneys. However, the study represents a scenario that hardly matches the requirements of the act. While the law has been an on-paper tiger, its application has been facing multi-faceted challenges at the field level. The situation has been worsened due to the bureaucratic complexity, political influence, and administrative weaknesses of the allied departments. While the country has thousands of brick kilns –large and small- legal and illegal – clustered and sporadic, brick kilns with large production sizes might be approved in specific brick production zones. The

government should adopt a mechanism for the phase-wise reduction in the total number of brick kilns by replacing small-scale brick kilns with large brick kilns with modern technology to produce a sufficient amount of quality bricks. High production capability and low energy consumption features of green brick technology should be utilized to attract the owner of the kilns. This would expectedly save agricultural land and soil as specified in the Act 2013. As a number of studies have already suggested, the Act 2013 is impracticable in its present form by many of its Sections. Comparing the Act with those of the neighboring countries portrays that the law has been relatively too tough for the kiln owners to be fully compliant with its sections. While forcing the kilns to use gas and coal only, the Bangladesh Government should ensure an adequate supply of quality coal and natural gas to stop fuel wood usage. At present situation, the publicly imported coal cannot meet the quality requirement as specified in the Act 2013. The recurrent shift in chimney types within short intervals discourages brick kiln owners from shifting chimneys into cleaner ones. During the fieldwork, the kiln owners explicitly expressed their concern and dissatisfaction over the recurrent shift of chimney types and chimney heights. Financial support through long-term loans might help smoothen the shift of legally required kilns and chimneys. All the studied brick kilns were producing traditional bricks with soil. They have no idea about hollow bricks, which the law requires to be produced at least by 50% of the total. After more than three years in application, the law enforcing authority was not aware of the kiln owners what and why hollow bricks are for. Albeit, the use of hollow bricks is important for saving agricultural topsoil from being used as brick raw materials. So, extensive awareness programs are needed to motivate kiln owners to produce hollow bricks. Another issue with hollow bricks is their market demand. Since the concept of producing hollow brick is relatively new in the country, brick users also need motivation on why and how to use it. Unless market demand is created, the kiln owners would hardly show any interest in producing hollow brick. Thus creating markets for hollow bricks is of prime importance. While it is praiseworthy that Act 2013 has put excessive importance on saving rural roads from heavily loaded brick-transporting vehicles, it is also the government's responsibility to arrange for alternative transportation tracks for the brick industry to haul the bricks. Rather than building new roads, the existing rural roads can be upgraded to withstand heavy loads. It would benefit both the rural folks and the kilns with a better rural lifestyle good communication and cost-effective brick transportation.

An overly rigid nature of the Act 2013 reduces its compatibility with society. Transformative development at the policy level through recurrent surveys and thus modification of the law into a more practicable one is necessary. During our present consultation with the DoE officials, the law is probably going to need an amendment. Responsible law-making authority should have deep insight into the problem to reform the law according to the current socioeconomic conditions of the country. Again, only an amendment might not work if the appropriate implementation agencies lack sufficient resources, especially human power, to implement the provisions of the law. The DoE needs to be strengthened with skilled manpower and efficient technology to do so. In the end, there should be strong administrative support and dedication from law enforcement agencies and the willingness of the brick kiln owners to comply with the law for the proper implementation of the legal tools.

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Authors contribution: Samanta Islam and Md Kamrul Islam contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Samanta Islam, Md Kamrul Islam, and Asif Raihan. All authors read and approved the final manuscript.

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