The Social Costs of Success: The Impact of World Trade Organization Rules on Insulin Prices in Bangladesh upon Graduation from Least Developed Country Status

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In 2021, the United Nations Committee on Development Policy adopted a resolution that Bangladesh would graduate from least developed country (LDC) status after a period of 5 years. This means that in 2026 Bangladesh would have to forego its exemption to intellectual property (IP) provisions of the World Trade Organization (WTO). Bangladesh has taken advantage of the policy space it was granted under the LDC exemption to build a generic medicines industry that not only serves Bangladesh but also other LDCs. We examine how IP provisions in the WTO will impact the price of insulin in Bangladesh and the subsequent impacts on welfare and poverty. We find that LDC graduation will trigger a significant jump in insulin prices that could cause about a 15% decline in the welfare of households in Bangladesh with one or more members living with diabetes, increasing the poverty rate of such households unless policy adjustments are carried out.

Keywords: affordability, cost of illness, insulin, intellectual property, low-income country

JEL codes: I10, I18, I32, I38

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I. Introduction

Least developed countries (LDCs) are exempt from granting pharmaceutical patents until 1 January 2033 (World Trade Organization [WTO] 2015). In addition, LDC members of the WTO have the option of not filing patent mailbox applications and obtaining exclusive marketing rights until January 2033 (WTO 2015). This implies that LDC members have the freedom to reject a pharmaceutical patent application if the exemption is active. This temporary exemption is important to ensure access to essential medicines in LDCs. The temporary exemption may facilitate local production of generic versions of many essential medicines among those LDC members who are capable, while allowing others to import generic medicines.

However, once this temporary exemption is over, LDC members must ensure patent protection and provide exclusive marketing rights for any patented medicines. This change may greatly restrict access to essential medicines in low-income countries. We use the case of Bangladesh's LDC graduation to carry out an ex ante analysis of the impact of such graduation on access to insulin, a lifesaving medicine for individuals with diabetes.

As an LDC, Bangladesh does not presently need to comply with global commitments under the WTO's Trade Related Intellectual Property Rights (TRIPS) provisions, commonly referred to as the TRIPS Agreement. Currently, Bangladesh can produce the generic version of any medicine, and patent protection for pharmaceuticals is not allowed. In 2021, the United Nations recommended Bangladesh for graduation from the LDC category in 2026. Consequently, firms will no longer be able to produce copies of medicines that are on patent in Bangladesh after the country's graduation from LDC status. Household out-of-pocket expenditure as a percentage of total health expenditure in Bangladesh was more than 67% in 2015, of which more than 75% was on pharmaceuticals (Government of Bangladesh, Ministry of Health and Family Welfare 2016). This implies that prices of some medicines may increase significantly after 2026, which will place an even larger burden of health expenditure on households.

Higher prices can affect access to medicines in several ways. First, higher prices of medicines may force some households to stop taking medicines or take less than the recommended dose. Second, households may also reduce other forms of consumption, such as food or spending on children's education, to cope with the additional expenditure on medicines. Thus, higher prices of medicines not only affect their usage but may also reduce consumption of foods, education, and other essential amenities that are necessary to lead a healthy life. This paper estimates the impact of these different types of expenditure substitution. We estimate the changes in household welfare following the implementation of pharmaceutical patenting and stricter intellectual property rights (IPRs) that would potentially increase the prices of some medicines. For this purpose, we choose the market for insulin to estimate these effects.

Insulin is a good tracer medicine to measure the effects of stronger IPR on access to medicines for several reasons. First, some types of insulin would still be under patent (in other countries) after Bangladesh's LDC graduation, which implies that IPR provisions will be a binding constraint on the insulin market. Second, the burden of diabetes is increasing in Bangladesh. More than 10% of adults have diabetes (mostly type 2), and more than 70,000 deaths per year are attributable to diabetes or high blood glucose (World Health Organization [WHO] 2016). This means that insulin is widely required to satisfy the health needs of the population. Finally, expenditure on insulin is mostly out of pocket (WHO 2016). Thus, after Bangladesh's LDC graduation, the price of insulin may significantly increase as patented versions are imported.

In this paper, we use 2016 Household Income and Expenditure Survey (HIES) data (Bangladesh Bureau of Statistics [BBS] 2019) and the quadratic almost ideal demand system (QUAIDS) to estimate household substitution patterns between food, medicines, and education for households with potential expenditure on insulin. In addition, we estimate the loss in household welfare and increase in household poverty resulting from the higher prices of insulins. Unlike other ex ante studies that investigate a similar question for different medicines in other LDCs or developing countries, we use household-level data to estimate elasticities of medicine demand and perform welfare analysis.

There are several advantages of using household data rather than the market share data of different brands and generic medicines, or aggregate sales and average prices data. First, household data allow us to control many characteristics of a household and individuals living in the household, which are important determinants of demand for medicines along with the price of medicine. Thus, controlling for those characteristics will enable us to estimate the demand parameters consistently and efficiently. Second, household data enable us to estimate the different types of substitution between medicines and other important expenditure items, such as food and education. Third, sales data for different brands or generic medicines are often proprietary, and it can be very hard and expensive to get access to that data. Moreover, sales data may not be very representative, especially for LDCs. On the other hand, HIES data are available for most LDCs, which is the best representative sample of the population. In addition, HIES data are often publicly available. Thus, our paper provides an effective way to estimate the demand parameters of insulin and perform household welfare analysis with household data for Bangladesh, which could also be applied for any other medicine and HIES data of any other LDC to carry out a similar analysis.

The paper finds that household demand for insulin is highly price inelastic, even more inelastic than household demand for food. The price elasticity of insulin is less than 1 in absolute value, and the price of insulin could increase more than 11 times its current price if a stronger IPR regime facilitates an unregulated monopoly for insulin; this would have a significant welfare effect for households with members who need insulin. We find that the aggregate annual expenditure of those households goes up by $336 million, which can be as low as $148 million and as high as $656 million. The welfare cost of the unregulated monopoly of insulin would vary from $71 million to $408 million under various estimation methods and measures of welfare. Moreover, the increase in the price of insulin would have a serious impact on household poverty: poverty rates for households needing insulin could increase between 3 and 40 percentage points.

The rest of the paper is organized as follows. Section II provides some background on Bangladesh's LDC graduation and the current status of IP regulation and the pharmaceutical industry in Bangladesh. Section III is a discussion of relevant studies. Section IV details the methodology and estimation techniques with a description of the data and sources. Section V shows the estimation results along with the household welfare and poverty analysis. Section VI discusses some policy implications, the limitations of our analysis, and our conclusions.

II. Background

Bangladesh is in the process of making its transition out from the group of LDCs (United Nations [UN] 2020). This involves a country meeting a graduation threshold under at least two of the following three predefined criteria: per capita income, human assets, and economic vulnerability.[1] Decisions on inclusion into, and graduation from,

[1]Income criterion is based on a 3-year average estimate of gross national income per capita for 2011–2013, based on the World Bank Atlas method (under $1,025 for inclusion and above $1,230 for graduation, as applied in the 2018 triennial review).

The Human Assets Index is based on indicators of (i) nutrition: percentage of population undernourished; (ii) health: mortality rate for children aged 5 years or under; (iii) education: the gross secondary school enrolment ratio; and (iv) adult literacy rate.

The Economic Vulnerability Index is based on indicators of (i) population size; (ii) remoteness; (iii) merchandise export concentration; (iv) share of agriculture, forestry, and fisheries; (v) share of population in low elevated coastal zones; (vi) instability of exports of goods and services; (vii) victims of disaster triggered by natural hazard; and (viii) instability of agricultural production.

the list of LDCs is made by the UN General Assembly based on recommendations from the Committee for Development Policy (CDP), a subsidiary body of the UN Economic and Social Council. The CDP is, among other things, mandated to review the category of LDCs every 3 years and to monitor their progress after graduation from the category (Bhattacharya 2009). In March 2018, the CDP found that Bangladesh met the criteria for graduation for the first time by satisfying all three criteria. Bangladesh met the graduation criteria in the triennial review in 2021, and therefore the CDP recommended the country for graduation from the LDC category in 2026 (United Nations 2021).

LDC classification accords a country duty-free access to the richer economies of the world, exemption from IPR enforcement, and other economic benefits (UN 2020). The loss of LDC privileges for Bangladesh would carry with it a 3-year grace period, during which time Bangladesh must prepare itself for graduation. The most visible trade-related implication of LDC graduation is the loss of preferential market access, such as the loss of concessions granted to LDCs under the global system of trade preferences among developing countries (UN 2019). Since LDCs are also exempt from the trade-related aspects of the TRIPS Agreement, graduation from LDC status may have significant implications for IPR enforcement in Bangladesh, which will have to be addressed by the pharmaceutical and software industries, among others (UN 2019).

Bangladesh has a burgeoning manufacturing capability and a relatively self-sufficient pharmaceutical sector. Companies generally manufacture finished medicine formulations by assembling known generic and, in some cases, patented components. Since pharmaceutical patents in Bangladesh were suspended in 2008, this created opportunities for local generic production of medicines patented outside Bangladesh, with several generic companies supplying the same medicine. For example, local firms manufacturing medicines patented abroad include Incepta, Beximco, Beacon, Renata, Square, and Eskayef. Domestically produced medicines patented abroad include sofosbuvir, sitagliptin, linagliptin, vildagliptin, rivaroxaban, and empagliflozin (Islam et al. 2017). Some firms have been engaged in producing active pharmaceuticals ingredients, excipients, and solvents that are used as raw material in producing the final medicine formulations. Innovative R&D activity is, however, virtually nonexistent in the Bangladesh pharmaceutical industry as it is a generics market and generic formulations represent the main business of the Bangladesh pharmaceutical industry. Presently, the market consists of approximately 8,000 generic products and 258 firms with manufacturing capability, in addition to imported already-patented products (Islam, Rahman, and Al-Mahmood 2018). This local production supplies over 95% of Bangladesh's pharmaceutical needs, and about 80% of these medicines are generics. The top 30–40 companies by value dominate almost the entire market in which the top 10 hold a 70% domestic market share, and the top two—Beximco and Square Pharma—capture over 25% of the market (Islam, Rahman, and Al-Mahmood 2018). In brief, the Bangladesh pharmaceutical market can be divided as follows:

1. High-end products (anti-cancer, insulin, and vaccines) produced by multinationals—if on patent, they are not patented yet in Bangladesh;
2. Branded generics (antibiotics, GI medicines);
3. Low-end generics; and
4. Contract manufacturing (domestic and export).

The dynamic nature of the Bangladesh pharmaceutical industry contrasts with its long-standing IP system. Patent rules and procedures are governed by the original Patents and Designs Acts of 1911. Bangladesh has not replaced or amended the 1911 Act. It only issued a Notification in 2008 that applications for pharmaceutical and agrochemical product patents were to be suspended since LDC members of the WTO could exempt pharmaceutical products from patent protection. This waiver has been extended until 2033 by the TRIPS Council. Bangladesh can benefit from these transition periods but only if it retains LDC status (Chowdhury 2018). Some companies in Bangladesh can make high-end products like insulin to compete with multinationals (Mohiuddin 2018). This is important as Bangladesh ranks as one of the 10 countries with the highest number of people with diabetes globally (IHME 2019).

A recent scoping review for Bangladesh (Biswas et al. 2016) found that a final estimate of diabetes prevalence, obtained after pooling data from individual studies among 51,252 participants, was 7.4%, somewhat less than the estimated overall global prevalence of 9.3% (Saeedi et al. 2019). For Bangladesh, with 165 million inhabitants in 2020 (World Bank 2020), this means there are 11.6 million people with diabetes, about half of them undiagnosed. Undiagnosed diabetes is more likely among people of lower socioeconomic status (Hasan et al. 2019). The prevalence of diabetes is higher in males compared to females in urban areas and vice versa in rural areas. Analyses revealed an increasing trend of diabetes prevalence among both the urban and rural populations.

Type 2 diabetes is the most common form of diabetes worldwide, comprising over 90% of all cases (WHO 2019). Management of type 2 diabetes includes diet, physical exercise, and weight management (National Institute of Diabetes and Digestive and Kidney Disease [NIDDK] 2020). Some patients with type 2 diabetes require medication such as oral anti-diabetes medicines and, in some cases, insulin (NIDDK 2020). Patients with type 1 diabetes require insulin. Since patients with diabetes have a higher risk of developing cardiovascular diseases, they may also require additional medicines (NIDDK 2020). Generally, insulin is more expensive than several commonly used oral anti-diabetes medicines that have been marketed for many decades and are available at a low price; these generics are recommended as a first-line pharmacological treatment for diabetes (WHO 2015).

Diabetes has emerged as a major public health problem worldwide, especially in low- and middle-income countries, where more than 80% of all people with diabetes are living. The International Diabetes Federation estimated that the global prevalence of diabetes among adults in 2013 was 8.3%, or roughly 382 million people, and this was projected to increase more than 592 million in less than 25 years, which might be a conservative estimate. Southeast Asia accounts for close to one-fifth of all diabetes cases worldwide and the prevalence of diabetes is projected to increase by 71% in this region by 2035. The International Diabetes Federation *Diabetes Atlas: Fourth Edition* projected in 2009 that diabetes prevalence in Bangladesh would increase more than 50% by 2017, ranking Bangladesh 8th in the number of people with diabetes globally. The economic and human costs provoked by diabetes in a large population such as in Bangladesh will continue to be substantial. This study estimates the effect of graduation out of LDC status and the attendant changes in IP protection for pharmaceuticals on the price of insulin and the subsequent impacts on welfare and poverty in Bangladesh.

III. Literature Review

This paper builds on an emerging body of literature on the impacts of trade and investment treaties on access to medicines. A full assessment of this literature can be found in Islam et al. (2019). This literature is commonly grouped into two categories—ex ante analyses that examine the extent to which proposed policies might impact access to medicines, and ex post analyses that examine the impact of trade and investment treaties that have already occurred. This paper falls in the ex ante category, attempting to estimate the extent to which access to insulin will be jeopardized in Bangladesh under a scenario where it loses its exemption from the TRIPs Agreement under the WTO if it graduates from LDC status in the coming years.

Most ex post studies find that trade and investment treaties adversely impact access to medicines in developing countries but to a lesser degree than do ex ante studies. With respect to ex post studies, some analyses look at the impacts of WTO-related provisions and others look at free trade agreements (FTAs). Of the WTO studies, Kyle and Qian (2014) examined the impact of IPR in the TRIPS Agreement on the launch of new medicines, prices, and sales using data from 59 countries at varying levels of development. They found that patented medicines have higher prices and quantities sold, and that new medicine launches were unlikely without patent protection. Other studies examine impacts from FTAs that have more stringent provisions than the TRIPS Agreement, particularly those of the United States (US). Examples of this literature are studies that examine the US–Jordan FTA and find that the FTA increased prices of essential medicines and delayed market entry of generics (Abbott et al. 2012). Shaffer and Brenner (2009) examined the Central American Free Trade Agreement and found that it reduced access to generics already on the market and delayed entry of other generics. Most recently, Trachtenberg et al. (2020) found that the US–Chile trade agreement increased both the price and sales volume of biologics.

This study builds on a set of ex ante studies that predictably estimate adverse impacts given the underlying assumptions they deploy from economic theory. The outcomes that ex ante studies predict reflect the models' underlying assumptions, which are rooted in economic theory. When a firm is granted a patent, economic theory predicts the firm will supply a restricted quantity at a higher price because the patent grants the producing firm a temporary monopoly over the product (Baker 2016).

Akaleephan et al. (2009) used a trade liberalization framework and attempted to find effects on prices and quantities following a reduction in tariffs or other trade barriers to estimate the potential cost savings in Thailand resulting from an absence of TRIPS-plus provisions and increased price competition between innovative and generic producers of 74 international nonproprietary-name imported medicines. These authors found that a proposed US–Thailand treaty would increase medical expenses and reduce the entry of generic medicines.

Chaves et al. (2017) used the IPR impact aggregate model to project the impact of TRIPS-plus provisions of the Mercosur–European Union FTA on the public expenditures and domestic sales of antiretroviral medicines and hepatitis C medicines in Brazil. They reckoned that the treaty would increase medicine expenditures and decrease sales by domestic producers.

This paper is like the work of Chaudhuri, Goldberg, and Jia (2006) and Dutta (2011) in terms of the nature of the research question being investigated. Chaudhuri, Goldberg, and Jia (2006) used a two-stage budgeting framework (using data from 1999 to 2000) to investigate the effects on prices and welfare when one or more domestic generics are withdrawn from the quinolone market in India due to the TRIPS Agreement of the WTO.[2] That study found considerable consumer welfare losses from a reduction in the variety of products available on the market after TRIPS. We used household survey data to estimate the effects of stronger IP laws in the market for insulin in Bangladesh and obtained similar results of welfare loss as in Chaudhuri, Goldberg, and Jia (2006) and Dutta (2011).

IV. Methodology, Estimation Framework, and Data

To estimate the effect of graduating from LDC status on the prices of essential medicines such as insulin, we analyze the effect of introducing patent protection for pharmaceuticals in Bangladesh. This introduction will potentially reduce competition in the pharmaceutical market, and even the market of innovative medicines might be monopolized by the patent holder if there is no further regulation of medicine prices. Hence, analyzing the effects of Bangladesh's LDC graduation on medicine prices is akin to estimating the price effect due to the pharmaceutical market becoming more monopolized through new patent protection and the withdrawal of generic versions of innovative medicines from the local market.

In this paper, we estimate the demand for insulin in Bangladesh as the burden of Type 2 diabetes is increasing in Bangladesh and the price of insulin affects many persons with Type 2 diabetes. We combine a variety of data sources for this purpose. To estimate the demand elasticities for pharmaceutical products and/or medicines, previous studies used market share data. For example, Chaudhuri, Goldberg, and Jia (2006) and Dutta (2011) used IQVIA market share data of different brands or generics of quinolones in the Indian market to examine the impact of the WTO agreement. While IQVIA market sales data of quinolones are representative of the Indian market, IQVIA market share data only cover 2% of total sales of medicines in Bangladesh, which is not representative enough to carry out a rigorous demand parameter estimation. Hence, we use the household-level expenditure data on medicine and other items instead of market share data. The household-level data have the advantage of reporting the cost of medicines faced by households rather than the price reported by manufacturers, but the drawback of using household-level data is that it does not provide the quantity or price of medicines but rather the total cost of medicines per person monthly or annually.

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[2]Quinolones are a subsegment of systematic antibacterials.

Accordingly, for our estimation purpose we use Bangladesh's 2016 HIES data for information on different categories of expenditures (e.g., food, medicines, and education); household characteristics (e.g., income, number of members, and geography of residence); and household head's characteristics (e.g., age, gender, religion, employment status, and employment sector). The summary statistics of these variables are provided in Tables A1 and A2 in Appendix 1. From the HIES data, we select the households with at least one member with diabetes. The 2016 HIES was conducted by BBS from April 2016 to March 2017 (BBS 2019). This most recent HIES is the most extensive household survey in Bangladesh.

The HIES data provide the most granular information on a wide range of individual and household characteristics. The survey was conducted at three levels (urban and rural breakdown, district level, and household level) and was designed to represent different socioeconomic groups in every part of the country. A sample design was adopted for the 2016 HIES with 2,304 primary sampling units in eight administrative and geographical divisions (Barisal, Chittagong, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur, and Sylhet) and 64 districts selected from the last Housing and Population Census in 2011. Within each primary sampling unit, 20 households were selected for interviews. The final sample size was 46,080 households. The sample was stratified at the district level and included a total of 132 substrata: 64 urban, 64 rural, and 4 main city corporations (BBS 2019). Details of the survey design of the 2016 HIES can be found in International Household Survey Network (2020).

From the 2016 HIES, we construct our sample consisting of all households with at least one member suffering from diabetes. We excluded individuals who are suffering from multiple chronic diseases as there is no breakdown of medicine expenditure in the HIES. Finally, we have a sample of 1,125 households with at least one member suffering from only one chronic disease (diabetes). We complement the HIES data with insulin prices from the Directorate General of Drug Administration (DGDA) of Bangladesh, where prices of all approved insulins and their respective strengths are reported.

To measure the effects of stronger IPR on the use of insulin and consumption of other essential items, we model a household's decision problem of allocating income in broad expenditure categories such as food, medicine, and education. We estimate the parameters at this stage using a version of QUAIDS.

Traditionally, elasticities of demand are estimated using a nested logit model of demand or a full random coefficient logit model of demand (Dutta 2011; Chatterjee, Kubo, and Pingali 2015). One potential issue of these demand models is that the demand for any medicine such as insulin generally depends on the physicians' prescription, especially if patients are not very well informed. So, taste for a particular brand of insulin is unlikely to be independent across consumers, which violates the key assumption in those demand modeling strategies. Moreover, to estimate a nested logit model of demand or a full random coefficient logit model of demand, we need data on sales of different brands and generic types of insulin, which are not available in the case of Bangladesh. IQVIA does have some sales data for Bangladesh, but the coverage is very limited and not representative. Hence, we choose the QUAIDS framework, which allows us to estimate the price elasticity of insulin using the household's expenditure on insulin. One advantage of using the household data to estimate the elasticities is that we can control many household characteristics, which is important in estimating the elasticities more consistently. The QUAIDS framework requires expenditure shares on these expenditure categories, price or price index, total household income, and other household-level controls, all of which are available in the 2016 HIES. Here, we use the Poi (2012) specification of QUAIDS, which incorporates the demographic variables.

A. Demand

The QUAIDS model in our estimation framework is based on the following indirect utility function used in Banks, Blundell, and Lewbel (1997):

$$\ln V(\boldsymbol{p}, m) = \left[\left\{ \frac{\ln m - \ln a(\boldsymbol{p})}{b(\boldsymbol{p})} \right\}^{-1} + \lambda(\boldsymbol{p}) \right], \tag{1}$$

where ln $a(\boldsymbol{p})$ is the transcendental logarithm function of prices or costs of individual expenditure items, p_i:

$$\ln a(\boldsymbol{p}) = \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{3} \sum_{j=1}^{3} \gamma_{ij} \ln p_i \ln p_j \tag{2}$$

and $b(\boldsymbol{p})$ is the Cobb–Douglas price aggregator, defined as follows:

$$b(\boldsymbol{p}) = \prod_{i=1}^{3} p_i^{\beta_i}$$

and $\lambda(\boldsymbol{p})$ is defined as follows:

$$\lambda(\boldsymbol{p}) = \sum_{i=1}^{3} \lambda_i \ln p_i.$$

Here, we need to estimate parameters $\{\alpha_i, \beta_i, \gamma_i, \lambda_i\}$ except α_0, which is generally set to some value lower than the lowest value of $\ln m$ (income) in the sample (Deaton and Muellbauer 1980; Banks, Blundell, and Lewbel 1997). The set of parameters satisfy some conditions:

adding up: $\sum_{i=1}^{3} \alpha_i = 1$, homogeneity: $\sum_{i=1}^{3} \beta_i = 0$, Slutsky symmetry: $\sum_{j=1}^{3} \gamma_{ij} = 0$, $\sum_{i=1}^{3} \lambda_i = 0$, and $\gamma_{ij} = \gamma_{ji}$.

Now, we specify the expenditure share equation of expenditure item i by applying the Roy's identity to equation (1)

$$\omega_i = \alpha_i + \sum_{j=1}^{3} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{m}{a(\boldsymbol{p})}\right) + \frac{\lambda_i}{b(\boldsymbol{p})}\left[\ln\left\{\frac{m}{a(\boldsymbol{p})}\right\}\right]^2, \quad i\epsilon\{1,2,3\}, \qquad (3)$$

where ω_i is the household's budget share for expenditure category i; and here we only consider expenditure on three items: food (1), medicine (2), and education (3), ω_i is defined as follows:

$$\omega_i \equiv \frac{p_i q_i}{\sum_j p_j q_j} = \frac{p_i q_i}{m}, \quad j\epsilon\{1,2,3\},$$

where q_i is the quantity of item i and p_i is the price or cost of expenditure category j, m is the household income spent on food, medicine, and education.

B. Demographics

Household and household head characteristics can be incorporated into the QUAIDS framework using the scaling techniques first used by Ray (1983). Poi (2002), using this scaling technique, introduces the demographic variables into the QUAIDS model. Suppose Z is the vector of demographic variables and $e(\boldsymbol{p}, u)$ is the expenditure function. Ray's scaling method decomposes the expenditure function into a scaling function, which depends on prices, level of utility, and demographics, and an expenditure function, which depends on prices and level of utility only. Specifically,

$$e(\boldsymbol{p}, u, \boldsymbol{Z}) = m_0(\boldsymbol{p}, u, \boldsymbol{Z}) \times e(\boldsymbol{p}, u).$$

Here, the scaling function $m_0(\boldsymbol{p}, u, \boldsymbol{Z})$ takes the following form:

$$m_0(\boldsymbol{p}, u, \boldsymbol{Z}) = \bar{m}_0(\boldsymbol{Z}) \times \phi(\boldsymbol{p}, u, \boldsymbol{Z}),$$

where $\bar{m}_0(\boldsymbol{Z})$ is the part of the scaling function that depends on demographics only; that is, a larger family will have a larger expenditure on food compared to a smaller family, and a family with more school-aged children is likely to have higher educational expenditure than a family with no school-aged children. The second part $\phi(\boldsymbol{p}, u, \boldsymbol{Z})$ accounts for the interaction between the consumption pattern and demographics; that is, a family with a member with diabetes may consume a different type of food compared to a family with no such member. Ray (1983) parametrizes $\bar{m}_0(\boldsymbol{Z})$ and $\phi(\boldsymbol{p}, u, \boldsymbol{Z})$ as follows:

$$\bar{m}_0(\mathbf{Z}) = 1 + \rho'\mathbf{Z}$$

$$\phi(\boldsymbol{p}, u, \boldsymbol{Z}) = \frac{u\prod_{j=1}^{3} p_j^{\beta_j}\left(\prod_{j=1}^{3} p_j^{\eta_j' Z} - 1\right)}{\frac{1}{u} - \sum_{j=1}^{3}\lambda_j \ln p_j},$$

where ρ and η are vectors of parameters to be estimated. The expenditure share equations specified in (3) become

$$\omega_i = \alpha_i + \sum_{j=1}^{3}\gamma_{ij}\ln p_j + (\beta_i + \eta_j'\mathbf{Z})\ln\left(\frac{m}{\bar{m}_0(\mathbf{Z})a(\boldsymbol{p})}\right) + \frac{\lambda_i}{b(\boldsymbol{p})c(\boldsymbol{p},\boldsymbol{Z})}\left[\ln\left\{\frac{m}{\bar{m}_0(\mathbf{Z})a(\boldsymbol{p})}\right\}\right]^2, \tag{4}$$

where $c(\boldsymbol{p}, \boldsymbol{Z}) = \prod_{i=1}^{3} p_i^{\eta_i'\boldsymbol{Z}}$ and the additional adding-up condition: $\sum_{i=1}^{3}\eta_i = 0$.

C. Elasticities

The uncompensated price elasticity of demand for good i with respect to the price of good j (ϵ_{ij}) is derived in Poi (2012) and given as follows:

$$\epsilon_{ij}^h = \frac{d\ln q_i}{d\ln p_j} = -\delta_{ij} + \frac{1}{\omega_i}\left(\gamma_{ij} - \left[\beta_i + \eta_i'\boldsymbol{Z} + \frac{2\lambda_i}{b(\boldsymbol{p})c(\boldsymbol{p},\boldsymbol{Z})}\ln\left\{\frac{m}{\bar{m}_0(\boldsymbol{Z})a(\boldsymbol{p})}\right\}\right] \times\left(\alpha_j + \sum_k \gamma_{ik}\ln p_k\right) - \frac{(\beta_j + \eta_j'\boldsymbol{Z})\lambda_i}{b(\boldsymbol{p})c(\boldsymbol{p},\boldsymbol{Z})}\left[\ln\left\{\frac{m}{\bar{m}_0(\boldsymbol{Z})a(\boldsymbol{p})}\right\}\right]^2\right),$$

where $\delta_{ij} = 1$ if $i = j$ and 0 otherwise, and h is the index for households. The expenditure or income elasticity for good i (μ_i) is derived as follows:

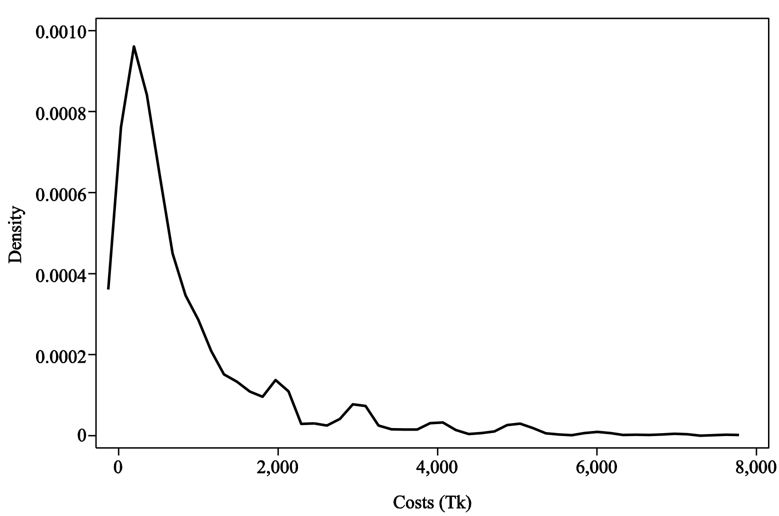
$$\mu_i^h = \frac{d\ln q_i}{d\ln m} = 1 + \frac{1}{\omega_i}\left[\beta_i + \eta_i'\boldsymbol{Z} + \frac{2\lambda_i}{b(\boldsymbol{p})c(\boldsymbol{p},\boldsymbol{Z})}\ln\left\{\frac{m}{\bar{m}_0(\boldsymbol{Z})a(\boldsymbol{p})}\right\}\right].$$

The formula for price elasticities here is at the household level. The price elasticities at the market level are then the average of the household-level price elasticities.

D. Econometric Issues

The 2016 HIES does not provide any information on whether a household with a person who is living with diabetes needs to purchase insulin for that member, so to estimate the demand parameters and elasticities for insulin demand, we construct a sample that has the highest probability of including the households that purchase insulin. For this purpose, we use the maximum retail price of each registered insulin to estimate the cost per daily dose as defined by WHO, and then calculate the monthly cost of insulin for an individual. First, we estimate the bounds on insulin cost per month for an individual, and our calculation shows that the monthly cost of using only insulin ranges from 436 taka (Tk) to Tk1,925. Second, for the purpose of this study we assume that the individuals who use only noninsulin diabetes medicines are in the lower bound of the abovementioned price range of insulins. That is, individuals whose monthly cost of diabetes medicines is below Tk436 are assumed to use only noninsulin diabetes medicines. The distribution of the costs of diabetes medicines is shown in Figure 1. From the distribution of costs of diabetes medicines, we obtain that around 47% of observations (534 out of 1,125) are below the lower bound of Tk436. Thus, the proportion of households using only insulin, insulin plus noninsulin, or expensive noninsulin medicines is about 53%. Hence, our sample for the analysis is

Figure 1. **Distribution of Monthly per Person Costs of Diabetic Medicines**



Source: Authors' calculations based on Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

the 38% of households with at least one member with diabetes in which per person costs of medicines range from Tk436 to Tk1,925 (424 out of 1,125).

Here, we do not include households with members suffering from diabetes along with other chronic illnesses. Our assumptions seem plausible given that Mohiuddin (2019) found that in Bangladesh about 15% of patients with diabetes use only insulin, whereas Islam et al. (2017) found that about 41% of patients with diabetes use insulin in Bangladesh.

Since our sample includes only those households that have at least one member with diabetes and the per person costs of medicines range from Tk436 to Tk1,925, the bounds on the cost of medicines ensure that our sample includes almost all households spending on insulin; however, this does not ensure the exclusion of households whose expenditures on medicine fall within the bounds, but these expenditures are not on insulin. This may introduce a sample selection bias into our estimation. To minimize this bias, we perform a Heckman type correction for selection bias. This correction is performed in two stages. In the first stage, we estimate the following Probit model:

$$\text{Prob}(D = 1|X) = \Phi(X\theta), \tag{5}$$

where X is the vector of explanatory variables that includes different individual characteristics such as age, gender, education, and ethnicity, as well as individual household characteristics such as household income, location, religion, household head's education, age, and gender. θ is a vector of unknown parameters, and Φ is the cumulative distribution function of the standard normal distribution. Here, vector X could be the same as Z or different than Z; that is, we can use the variable vector Z in place X, or we could use a subset of Z with some other control variables to construct X. The indicator variable D is defined as follows:

$$D = \begin{cases} 1, & \text{if monthly cost of diabetic medicine is less than BDT436} \\ 0, & \text{otherwise} \end{cases}$$

Estimation of this Probit model yields results that can be used to predict the probability for everyone with diabetes that uses only noninsulin diabetes medicines given the various individual and household characteristics. We use this estimated Probit model to predict the probability that an individual uses only noninsulin diabetes medicines for our sample, which comprises individuals with diabetes with monthly costs of more than Tk436. These predictions will be unbiased and consistent if the error terms in the Probit model are uncorrelated with control variables and are normally distributed. After estimating this Probit model, we obtain the correlation between the predicted values and the residuals of the model and this correlation is almost 0 (−0.0004). So, we can maintain the assumption that the error terms of the Probit model and the set of control variables are uncorrelated. Assuming that these assumptions are satisfied, we estimate the probabilities that the individuals using only insulin or insulin with other noninsulin medicines in our sample using the estimated Probit model:

$$\text{Prob}(D = 0|X) = 1 - \Phi(X\hat{\theta}). \tag{6}$$

Using these estimated probabilities, we estimate the inverse Mills ratio as follows:

$$\xi(X\hat{\theta}) = \frac{\Phi(X\hat{\theta})}{1 - \phi(X\hat{\theta})}, \tag{7}$$

where ϕ is the probability density function. After estimating the inverse Mills ratio, we estimate the QUAIDS model, where now Z includes $\xi(X\hat{\theta})$ as an additional control along with the other control variables described above. Assuming that the error terms are jointly normal, we estimate the QUAIDS model including the Mills ratio as an additional demographic variable.

A second issue in the estimation of the QUAIDS model is that the costs of diabetes medicines might be correlated with other unobserved individual or household characteristics (Islam et al. 2019). To overcome this problem, we construct an instrumental variable (IV) for the cost of diabetes medicines. To construct this IV, we argue that the cost of diabetes medicines of an individual might be correlated with unobserved individual and household characteristics, but these unobserved characteristics are orthogonal to the cost of medicines of individuals residing in the same geographic area. Thus, we use the average cost of medicines in the smallest geographic unit of the HIES as the IV for cost of diabetes medicines, as the price or cost of diabetes medicines is correlated within the same geographic region, but orthogonal to a specific individual's or household's characteristics, where the average is calculated by a leave-one-out method. That is, the IV for the cost of medicines for individuals in household *h* residing in region *r* is the average cost of medicines for all individuals residing in the same region *r* except members of household *h*. Let us refer to this IV as IV_1, so IV_1 is given as follows:

$$\text{IV}_{1\text{hr}} = \frac{\sum_{h \epsilon r \setminus h} p_{dhr}}{N_r}, \tag{8}$$

where $\text{IV}_{1\text{hr}}$ is the IV for the cost of medicines of individuals in household *h* in region *r*, p_{dhr} is the cost or price of diabetes medicines of an individual in household *h* in region *r*, $\sum_{h \epsilon r \setminus h} p_{dhr}$ is the sum of the cost of diabetes medicines of all individuals in region *r* except for individuals living in household *h*, and N_r is the total number of individuals with diabetes living in region *r* and incurring a cost of medicines ranging from Tk436 to Tk1,930. Similarly, we construct an IV for the prices of food and education.

Another issue in estimating the demand parameters is that error terms *u* may be spatially correlated as costs of diabetes medicines are generally correlated with the types of health care provider such as public hospitals, private hospitals, and pharmacies, and we have certain types of health care providers in each region (Islam et al. 2019). This may introduce heteroscedasticity in the QUAIDS model and hence reduce the efficiency of the estimators. To eliminate the heteroscedasticity due to spatial correlation in error terms *u*, we cluster the standard errors at the union or ward level, which is the lowest administrative unit in Bangladesh.

E. Computing Counterfactual Price Changes

To determine the range of potential increases in the prices of insulin following Bangladesh's graduation from LDC, we use estimated demand elasticities to compute the ranges of markups and marginal costs based on the current prices of insulin and insulin market structure. Since the expenditure items in our QUAIDS model are defined broadly (i.e., food, medicine, and education), it is expected that the price elasticities of demand would be very low. Hence, it would be impossible to determine the insulin prices under the monopoly market structure ensured by stronger IP laws as a monopoly's equilibrium output is always at the elastic part of the market demand curve. To compute the counterfactual prices of insulin under monopoly market structure, we need to estimate the slope of the demand function of insulin so that we can use this slope to estimate the price elasticities of demand at different points on the demand curve. This estimated elasticity is then used to derive the optimal monopoly markup. Here, we assume that the market demand for insulin is linear in insulin prices and estimate this linear demand function by estimating the following regression equation:

$$\omega_2 = \varphi_0 + \varphi_1 p_2 + \varphi_2 \bar{\omega} + Z'\Omega + u, \tag{9}$$

where ω_2 is the household expenditure on insulin, p_2 is the price of insulin faced by the household, $\bar{\omega}$ is the minimum level of income necessary to ensure a subsistence level of food consumption for the household. $\bar{\omega}$ is calculated by multiplying the household size and the national lower poverty level income as reported in the final report of the 2016 HIES (BBS 2019); Z' is the vector of household and household head's characteristics; u is the error term; and φ_0, φ_1, φ_2, and Ω are parameters to be estimated. Here, the main parameter of interest is φ_1, which then is used to calculate the slope of the insulin demand curve with respect to insulin price as follows:

$$\frac{d\omega_2}{dp_2} = \frac{d(p_2 q_2)}{dp_2} = q_2 + p_2 \frac{dq_2}{dp_2} = \hat{\varphi}_1,$$
$$\bar{b} = \frac{dq_2}{dp_2} = \frac{\hat{\varphi}_1}{\bar{p}_2} - \frac{\bar{q}_2}{\bar{p}_2}, \tag{10}$$

where $\bar{b}$ is the slope of the demand curve evaluated at the average price and quantity of the insulin. We also verify the estimated slope of the inverse demand curve using the own price elasticity of insulin demand obtained from our QUAIDS model as follows:

$$0 = p_2 + q_2 \frac{dp_2}{dq_2} = 1 + \frac{1}{E_{22}}, \tag{11}$$

$$\frac{dp_2}{dq_2} = 1 + \frac{1}{E_{22}} - \frac{\bar{p}_2}{\bar{q}_2} = \frac{1}{\bar{b}}, \tag{12}$$

where we use the fact that at the midpoint of the demand curve, marginal revenue is 0. Once we have the estimated slope of the insulin demand curve, we can estimate the price elasticities of the insulin demand curve

$$E_{22} = \bar{b} \frac{p_2}{q_2}. \tag{13}$$

Now, we can find the elasticities at different points of the demand curve. With these estimated elasticities, we can find the optimal markup for the monopoly. In addition to simulating the counterfactual markup and price under monopoly market structure, we also use the average insulin price in Pakistan, where the pharmaceutical market is less regulated and strong IP laws govern the market (Basant 2007). Nevertheless, most types of insulin are very affordable in Pakistan compared to other South Asian countries. The main reason that a stronger IPR regime did not lead to exorbitant price increases for insulin in Pakistan is the provision of the insulin supply by the public sector (Ewen et al. 2019). The reasons that we choose current insulin prices in Pakistan as another counterfactual price are as follows: (i) this provides an interesting scenario where strong IP laws coexist with public sector participation, which enables greater access to insulin; and (ii) the size and characteristics of the economy of Pakistan are comparable to those of Bangladesh.

F. Welfare Analysis

To have insights into the welfare effects of a stronger IPR regime in post-LDC Bangladesh under two counterfactual prices—simulated prices under monopoly market structure and prices in a less regulated neighboring country (Pakistan)—we use several measures of welfare as elaborated by Araar and Verme (2016). Our first measure is the consumer surplus (CS), defined as the difference between willingness to pay and the market price of insulin. The measure of CS is given as follows:

$$\mathrm{CS} = \int_{p_2}^{p_{2'}} D(p_2)dp_2, \tag{14}$$

where p_2 and $p_{2'}$ are the current and counterfactual prices of insulin, $D(p_2)$ is the demand function of insulin. Here, to estimate the CS we need to know the Marshallian demand function $D(p_2)$. For a linear demand system and moderate change in prices, CS can be estimated using the following equation:

$$\mathrm{CS} = -x_2\,\Delta p_2(1 + 0.5E_{22}\,\Delta p_2). \tag{15}$$

For the problem concerned in this paper, the price changes could be significantly higher and so the above formula will provide a highly overstated estimate for CS. Araar and Verme (2016) derived an approximation CS formula for a large price change:

$$\mathrm{CS} = -x_2\,\Delta p_2\left(1 - \frac{0.5\,\Delta p_{22}}{1 + \Delta p_2}\right). \tag{16}$$

CS as a measure of welfare is somewhat restrictive as it assumes that the marginal utility of real income is constant and there is no distributional effect of price changes. It also captures only the partial equilibrium effect and does not perfectly measure the change in welfare if the changes in prices are large. However, CS is a straightforward and easy-to-estimate welfare measure, which would be a good standard to compare with other measures of welfare. The next two welfare measures that we estimate are compensating variation (CV) and equivalent variation (EV). These measures are defined as follows:

$$\mathrm{CV} = e(p_2, v^0) - e(p_{2'}, v^0) = \int_{p_2}^{p_{2'}} h(p_2, v^0)dp_2, \tag{17}$$

$$\mathrm{EV} = e(p_2, v^1) - e(p_{2'}, v^1) = \int_{p_2}^{p_{2'}} h(p_2, v^1)dp_2, \tag{18}$$

where v^0 and v^1 are levels of generic indirect utility before and after the implementation of a stronger IPR regime, respectively, $e(.)$ is the generic expenditure function, and $h(.)$ is the Hicksian demand function. Here, CV is the monetary compensation required to bring the consumer back to the original utility level after the price change, and EV is the monetary change required to obtain the same level of utility after the price change (Araar and Verme 2016). One computational problem in calculating CV and EV is that we need to know the indirect utility level before or after the changes in prices. One solution to this computational problem is to derive CV and EV from CS as given in Chipman and Moore (1980)

$$\mathrm{CV} = (1 - e^{-\mathrm{CS}/m})m, \tag{19}$$

$$\mathrm{EV} = (e^{\mathrm{CS}/m} - 1)m, \tag{20}$$

where m is the income level. In addition to these measures of welfare, there are two simple straightforward measures of welfare: Laspeyres Variation (LV), which is defined as the exact change in income necessary to purchase the initial bundle of goods at prices after and before the change in the IPR regime. LV is defined as follows:

$$\mathrm{LV} = e(p_2', X^0) - e(p_2, X^0), \tag{21}$$

where X^0 is the initial bundle of goods purchased before the change in prices. The second measure is the Paasche Variation (PV), which is defined as the exact change in income required to purchase the final bundle of goods at prices after and before the change in the IPR regime. PV is given as follows:

$$\mathrm{PV} = e(p_2', X^1) - e(p_2, X^1), \tag{22}$$

where X^1 is the final bundle of goods purchased after the change in prices due to a change in the IPR regime. To estimate LV or PV, we just need the information of quantity purchased before or after the change in the policy regimes and the associated changes in prices, whereas to estimate the other measures of welfare requires some knowledge or assumptions on the demand function or the utility function.

V. Results

A. Price and Expenditure Elasticities

Table B1 in Appendix 2 reports the parameter estimates of our QUAIDS model. The estimated uncompensated price elasticities and expenditure elasticities are reported in Table 1. Here, all elasticities are the average elasticities across all households in the sample. The price elasticities are denoted as E_{ij}, where subscript i denotes the expenditure on item i, and j denotes the price of item j. The estimate of price elasticity of food, E_{11}, is consistently estimated across different models; E_{11} ranges from 93.7% to 99.0% under different specifications. The price elasticities of insulin have expected negative signs only under IV specification, and these vary from

Table 1. **Uncompensated Price and Expenditure Elasticities of Major Expenditure Items in Bangladesh**

	Not Corrected		Corrected	
	OLS	**IV**	**OLS**	**IV**
Price elasticities				
E_{11}	−0.988***	−0.945***	−0.990***	−0.937***
E_{12}	−0.103***	−0.004***	−0.106***	−0.004***
E_{13}	−0.071***	−0.054***	−0.072***	−0.060***
E_{21}	−0.043***	0.621***	−0.042***	0.563***
E_{22}	0.377***	−0.927***	0.413***	−0.943***
E_{23}	0.120***	0.107***	0.125***	0.090***
E_{31}	0.062***	−2.011***	0.082***	−2.124***
E_{32}	−0.010	0.013	−0.010	0.003
E_{33}	−0.180	−0.255	−0.180	−0.143
Expenditure elasticities				
E_1	1.162***	1.003***	1.168***	1.001***
E_2	−0.454***	0.203***	−0.495***	0.289***
E_3	0.133	2.251***	0.111	2.258***

IV = instrumental variable, OLS = ordinary least squares.
Notes: Subscript 1 refers to food, subscript 2 is insulin, and subscript 3 is education. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Source: QUAIDS model estimates based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016*. Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

92.7% to 94.3%, whereas the price elasticities of education vary from 14.3% to 25.5% under various specifications but are not statistically significant.

The cross-price elasticities show interesting demand patterns as well. The cross-price elasticities between food and insulin (E_{12}) or education (E_{13}) are always negative under all specifications and statistically different from zero. This indicates that expenditure on food falls in response to an increase in the price of insulin or education. However, the cross-price elasticities between insulin and food (E_{21}) or education (E_{23}) are positive under IV specifications, which indicates that an increase in the price of food or education may not lead to a decrease in demand for insulin.

B. Marginal Costs and Markups

Currently, the market for insulin in Bangladesh is oligopolistic. To find the markups in this market, we assume that the marginal cost (MC) of producing insulin is constant and the same for all producers. If there are *n* firms in the market with the same

MC, c, the markup is defined as follows:

$$\frac{P-c}{p}=-\frac{1}{n}\frac{Q}{P}\frac{dP}{dQ}=-\frac{1}{nE_D}.$$

The current insulin market in Bangladesh is to some extent competitive. There are seven domestic producers of insulin supplying 50 different insulin products in Bangladesh (DGDA 2019). The differences in these products are in terms of dosages size and the producers. In addition, there are six foreign producers, who have registered a combined 65 insulin products in Bangladesh (DGDA 2019). The licenses of products of two foreign producers expired in 2015 and early 2016.[3] Hence, there are now 11 suppliers of insulin in Bangladesh. Thus, the markup is given by the following formula: $\left(\frac{1}{1+\frac{1}{11*|E_{22}|}}\right)$. The MCs are calculated using the bounds of insulin prices, which is the amount paid by a household for 1 month of insulin supply. We use the maximum retail prices reported by DGDA to estimate this monthly expenditure on insulin, which is found to range from Tk436 to Tk1,925. The estimated markups and bounds of MC of a 1-month insulin supply are reported in Table 2.

From Table 2, we can see that the current markups range from 1.107 to 1.109, reflecting the fact that the current market is characterized by some competitive forces as the markups are around 10% over the MC. The lower and upper bounds of MC range from Tk393.24 to Tk1,740.73 and from Tk393.97 to Tk1,743.94, respectively. These bounds reflect end user MCs rather than MCs at the production level.

Table 2. **Implied Markups and Marginal Costs of Insulin in Bangladesh under Current Market Structure (Tk)**

	Not Corrected		**Corrected**	
	Lower Bound	**Upper Bound**	**Lower Bound**	**Upper Bound**
Price elasticities	−0.93	−0.93	−0.94	−0.94
Markups	1.109	1.109	1.107	1.107
Marginal costs	393.24	1,740.73	393.97	1,743.94

Tk = Bangladesh taka.
Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh; and Directorate General of Drug Administration. "Registered Products." Government of Bangladesh. http://www.dgda.gov.bd/index.php/manufacturers/allopathic (accessed 14 October 2019).

[3]Eli Lilly & Company's license in the US expired in May 2016. Lilly's license in France expired in May 2015. https://www.dgda.gov.bd/index.php/2013-03-31-05-16-29/registered-imported-drugs.

Thus, these are the MCs of all value added of insulin production: from production to final purchase by households.

C. Demand Function of Insulin and Counterfactual Prices

We estimate the insulin demand function as specified in regression equation (9) using the IV for insulin prices. The result of the regression equation (9) is reported in Table B3 in Appendix 2. The estimates of the coefficient of insulin price (p2IV) are negative under the estimation strategies of not correcting and correcting for sample selection bias. We use the estimate of the coefficient of p2IV in a regression corrected for sample selection bias, and this estimate is $\hat{\varphi}_1 = -0.11$. The estimated slope coefficient, $\bar{b} = -0.00137$, is given as follows:

$$\bar{b} = \frac{dq_2}{dp_2} = \frac{\hat{\varphi}_1}{\bar{p}_2} - \frac{\bar{q}_2}{\bar{p}_2} = \frac{\hat{\varphi}_1}{\bar{p}_2} - \frac{\bar{p}_2\bar{q}_2}{\bar{p}_2^2} = \frac{-0.11}{884.16} - \frac{973.33}{884.16^2} = -0.00137,$$

where Tk973.33 is the average monthly household expenditure on insulin and Tk884.16 is the average of monthly price of insulin. Now, the elasticity of insulin demand at the average price and quantity of insulin is given as follows:

$$E_{22} = \bar{b}\,\frac{\bar{p}}{\bar{q}} = \bar{b}\,\frac{\bar{p}^2}{\bar{p}\bar{q}} = -0.00137 \times \frac{884.16^2}{973.33} = -1.10.$$

Using this elasticity of insulin demand measured approximately at the midpoint of the insulin demand curve, we can find the maximum markups:

$$\left(\frac{1}{1 + \frac{1}{|E_{22}|}}\right) = \frac{|E_{22}|}{1 + |E_{22}|} = 11.01.$$

This markup shows that under an unregulated monopoly, the insulin price could be more than 11 times higher than current insulin prices, where the current markup of insulin in Bangladesh is about 1.1. Using the estimated markup under an unregulated monopoly and the upper and lower bounds of MC as reported in Table 2, we estimate maximum possible counterfactual prices of insulin, which are reported in Table 3. These counterfactual prices show the most extreme situations of an increase in insulin prices in Bangladesh following its graduation from LDC status and the enforcement of strong IP laws. Thus, these provide some bounds on the prices of insulin in a worst-case scenario.

For the Pakistan price counterfactual, we use the average insulin prices reported in Ewen et al. (2019), where the insulin prices for several low- and middle-income countries including Pakistan were surveyed in 2016. Since our sample is from the

Table 3. **Counterfactual Markups and Prices of Insulin in Bangladesh under an Unregulated Monopoly (Tk)**

	Not Corrected		Corrected	
	Lower Bound	**Upper Bound**	**Lower Bound**	**Upper Bound**
Marginal costs	393.24	1,740.73	393.97	1,743.94
Counterfactual markups	11.01	11.01	11.01	11.01
Counterfactual prices	4,329.59	19,165.43	4,337.59	19,200.78
Change in prices	3,893.59	17,235.43	3,901.59	17,270.78

Tk = Bangladesh taka.
Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh; and Directorate General of Drug Administration. "Registered Products." Government of Bangladesh. http://www.dgda.gov.bd/index.php/manufacturers/allopathic (accessed 14 October 2019).

Table 4. **Insulin Prices in Pakistan in 2016 ($ per 1,000 IU)**

	Cartridge				**Vial**	
	Private Retail Pharmacies		**Private Hospitals and Clinics**		**Private Retail Pharmacies**	
	Original Brand	**Bio-similar**	**Original Brand**	**Bio-similar**	**Original Brand**	**Bio-similar**
Short-acting human	5.81	4.50	5.81	4.72		
Intermediate-acting human	5.81	4.67				
30/70 human	5.15	4.48			5.82	7.89
Glargine analogue	28.60	20.65				

IU = international unit.
Source: Authors' calculations using data from Table 2 in Ewen, Margaret, Huibert-Jan Joosse, David Beran, and Richard Laing. 2019. "Insulin Prices, Availability and Affordability in 13 Low-Income and Middle-Income Countries." *BMJ Global Health* 4 (3): e001410.

2016 HIES, we use the insulin prices in Pakistan as reported in Ewen et al. (2019). These prices are shown in Table 4, where we only show the average insulin prices in the private sector (private pharmacies, hospitals, and clinics), as reported in Ewen et al. (2019), since the public sector insulin price is very similar to the private sector price for any specific type of insulin. However, the glargine analogue insulins are only available in the private sector, particularly at private retail pharmacies.

The average insulin price per 1,000 international unit (IU) in Pakistan in 2016 ranged from about $4.50 to $7.89, except for the glargine analogue. Using the Tk–$ exchange rate in June 2016 from Bangladesh Bank, the central bank of Bangladesh, these average prices correspond to Tk352.80–Tk618.58 per 1,000 IU, whereas the average monthly cost of insulin per person in Bangladesh is about Tk884.16.[4] Since 1,000 IU of insulin is approximately the monthly supply of insulin for an individual, the average monthly insulin cost for most types of insulin is significantly higher in Bangladesh than in Pakistan. However, average prices for long-acting insulins such as glargine analogues range from $20.65 to $28.60, which corresponds to Tk1,618.18–Tk2,246.16, higher than the average monthly insulin costs in Bangladesh. Here, we use the price of the original brand of glargine analogues in Pakistan as the counterfactual price of insulin in Bangladesh under stricter IP laws. To estimate the upper bound of price gain and loss in welfare, we take the difference between this price, Tk2,246.16, and the current monthly average cost of insulin per person in Bangladesh, Tk8,84.16, which implies a potential 154% increase in the average monthly cost of insulin in Bangladesh.

D. Welfare Analysis

The welfare estimates are reported in Table 5. The welfare loss estimates in this table are aggregate national-level estimates. The welfare losses in the "Upper bound" column correspond to upper bound price changes in columns 2 and 4 of Table 4. Similarly, the welfare losses in columns 3 and 4 in Table 5 correspond to lower bound price changes in columns 1 and 3 of Table 4. The welfare estimates in column 5 of Table 5 are calculated for the counterfactual price increase from the average price of Tk884.16. The welfare loss estimates in column 6 of Table 5 are calculated by using the originator's price of long-acting insulin glargine analogues in Pakistan. All these estimates of welfare loss show the worst-case scenario, which entails maximum welfare losses under an unregulated monopoly because of stronger IP laws after Bangladesh's graduation from LDC status.

The first row of Table 5 is the measure of aggregate increases in household expenditures due to an increase in insulin prices following Bangladesh's graduation from LDC status. Here LV and PV measures are the same, as we use the same composition of goods before and after changes in insulin prices. The upper bound of the aggregate increase in household expenditure under an unregulated monopoly is about $656 million per year, whereas the lower bound is about $148 million per year. The aggregate increase in household expenditure would be significantly lower, about

[4]The Tk–$ exchange rate in June 2016 was 78.4. https://www.bb.org.bd/econdata/exchangerate.php.

Table 5. **Annual Aggregate Welfare Losses in Bangladesh under an Unregulated Monopoly and Pakistan Price Counterfactual**

		Upper Bound		Lower Bound			
		Not Corrected	**Corrected**	**Not Corrected**	**Corrected**	**Average Price Counterfactual**	**Pakistan Price Counterfactual**
LV = PV	Tk million	51,347.49	51,450.48	11,599.73	11,623.54	26,367.08	4,057.65
	$ million	654.94	656.27	147.96	148.26	336.31	51.76
CS	Tk million	25,675.23	25,726.73	5,801.35	5,813.26	13,185.03	2,030.31
	$ million	327.49	328.15	74.00	74.15	168.18	25.90
CV	Tk million	31,883.49	31,962.69	6,071.70	6,084.74	14,662.37	2,062.52
	$ million	406.68	407.69	77.45	77.61	187.02	26.31
EV	Tk million	21,385.61	21,421.22	5,552.47	5,563.38	11,961.42	1,999.02
	$ million	272.78	273.23	70.82	70.96	152.57	25.50

CS = consumer surplus, CV = compensating variation, EV = equivalent variation, LV = Laspeyres Variation, PV = Paasche Variation, Tk = Bangladesh taka.

Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

\$52 million per year if the insulin prices in Bangladesh stayed at a similar level to insulin prices in Pakistan.

For an increase in the price of insulin, the relationship among losses in CS, CV, and EV are as follows: CV > CS > EV. From Table 5, we can see that these relationships are satisfied. From the figures in third (CV) and fourth (EV) rows in Table 5, the annual aggregate loss in welfare under an unregulated monopoly will range from \$71 million to \$407 million. However, under the Pakistan price counterfactual, the annual loss in welfare would be around \$26 million.

The welfare effect of an increase in insulin prices at the household level is in Table 6, which reports the increase in household expenditure and the increase in expenditure as a percentage of household average income per year for three counterfactual scenarios: largest upper bound estimate (upper bound IV), smallest lower bound estimate (lower bound OLS), and the Pakistan price counterfactual.

The annual welfare impacts of stronger IP laws could be from \$51.8 million across impacted households (Pakistan price counterfactual) to an upper bound of \$656.3 million under an unregulated monopoly (Table 6). According to a review of the literature (Biswas et al. 2016), the incidence of people with diabetes in Bangladesh is estimated to be between 4.5% and 35.0%, with the "pooled preference" being 7.4%. The average number of people in a household in Bangladesh is 4.06 (BBS 2019). The cost per impacted household per year would therefore range from \$17.6 to \$223.1, which implies a 0.7% to about a 9.1% decline in affected household incomes.

E. Poverty Impact

An increase in the price of insulin because of stricter IP laws would also have a significant impact on the poverty incidence for households that require access to lifesaving insulin for the members of those households with diabetes. To show the effect of a price rise in insulin on household poverty, we estimate the rate of poverty for the households with members with diabetes, especially with members needing insulin. Table 7 shows the absolute number of people and households and rates of poverty under the upper and lower poverty lines at the national level, households with persons having diabetes, and households with members requiring insulin.

Table 7 shows there are about 39.33 million households in Bangladesh, and out of them, 12.89% fall below the lower poverty line and 24.28% fall below upper poverty line.[5] The corresponding poverty rates for households with at least one

[5]Lower and upper poverty line incomes are defined in BBS (2019).

Table 6. **Household-Level Welfare Analysis of Insulin Price Increases in Bangladesh**

Incidence of Diabetes (Range of Estimates)				
	Total	**4.5%**	**7.4%**	**35%**
Population (2016)	161,356,000	7,261,020	11,940,344	56,474,600
Households		1,788,429	2,940,971	13,910,000
Increase in Expenditure and Welfare Loss per Household				
	Aggregate Welfare Loss ($)	**Dollars per Household per Year**		
Pakistan price counterfactual	51,760,000	28.9	17.6	3.7
Lower bound OLS	147,960,000	82.7	50.3	10.6
Upper bound IV	656,270,000	337.0	223.1	47.2
Impact per Affected Household (Average annual income per household: $2,447[a])				
		Welfare as % of Household Average Income		
Pakistan price counterfactual		1.18%	0.72%	0.15%
Lower bound OLS		3.38%	2.06%	0.43%
Upper bound IV		15.00%	9.12%	1.93%
Welfare as % of GDP (2016 Bangladesh GDP: $221 billion)				
Pakistan price counterfactual	0.02%			
Lower bound OLS	0.06%			
Upper bound IV	0.27%			

GDP = gross domestic product, IV = instrumental variable, OLS = ordinary least squares.

[a]Average annual income per household is calculated by multiplying average monthly family income of Tk15,988 (2016 HIES) by 12 and then converting into the United States dollars by dividing by 78.4 (Tk–$ exchange rate in June 2016) with the average household size, i.e., 4.06 members per household (2016 HIES).

Note: Ranges of estimates according to Mohiuddin, Abu Kholdun. 2018. "An A–Z of Pharma Industry Review: Bangladesh Perspectives." *PahrmaTutal* 6 (12): 64–78.

Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016*. Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh; and World Bank. "World Development Indicators." https://databank.worldbank.org/source/world-development-indicators (accessed 1 June 2020).

member living with diabetes are 25.36% and 33.54%, respectively, and for households needing insulin they are 20.99% and 27.44%, respectively. The absolute number of households that would fall below the lower and upper poverty lines as a result of an increased price in insulin along with the percentage increase from the initial level are reported in Table 8.

Table 7. **Initial Level of Poverty in Bangladesh**

		Lower Poverty Line		Upper Poverty Line	
	Total Households (million)	**Households in Poverty (million)**	**Poverty Rate (%)**	**Households in Poverty (million)**	**Poverty Rate (%)**
1. National	39.33	5.07	12.89	9.55	24.28
2. Households with diabetes	1.05	0.27	25.36	0.35	33.54
3. Households needing insulin	0.38	0.08	20.99	0.10	27.44

Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

Poverty estimates in Table 8 are reported only for the upper bound and lower bound of price change under an unregulated monopoly scenario, estimated using IVs for prices with correction for sample selection bias and the price change under the Pakistan counterfactual policy regime. The numbers of households that fall below the lower poverty line are 5.2 million and 5.1 million for the upper and lower bounds of an unregulated monopoly counterfactual scenario, respectively, which are about 3.0% and 0.8% higher than the initial level. For the Pakistan price counterfactual, the increase is much smaller, with only about a 0.24% increase from the initial level of poverty.

Among all households with at least one member with diabetes, 0.27 million households are estimated to be below the lower poverty line, which increases to 0.42 million, 0.30 million, and 0.28 million under each of the three counterfactual scenarios, respectively. These increases represent a rise in poverty rates ranging from 4.61% to 58.27% from the current level of poverty for these households. Out of all households that require insulin for one or more members, 0.08 million fall below the lower poverty line, which increases by 194.51% to 0.23 million under the upper bound and 49.06% to 0.12 million under the lower bound of an unregulated monopoly counterfactual scenario. Under the Pakistan price counterfactual scenario, the number of households that fall below the lower poverty line is 0.09 million, which is 15.40% higher than the initial level. The pattern of increases in the poverty rates are similar under the upper poverty line.

Table 9 reports the numbers of households that are below the lower and upper poverty lines, and the percentage increase in poverty from the initial level of poverty under the various counterfactual price increase scenarios. We also estimated the poverty rates as a fraction of total households for three different aggregate levels.

After an increase in the insulin price under a stricter IPR regime, the fraction of total households that fall below the lower poverty line ranges from 12.92% to 13.28%

Table 8. **Poverty Rates in Bangladesh after an Increase in Insulin Prices**

	Households in Poverty before a Price Increase (million)	Households in Poverty after a Price Increase (million):			Increase in Household Poverty Rates (%):		
		Upper Bound	Lower Bound	Pakistan Price	Upper Bound	Lower Bound	Pakistan Price
		Lower Poverty Line					
1. National	5.07	5.22	5.11	5.08	3.05	0.77	0.24
2. Households with diabetes	0.27	0.42	0.30	0.28	58.27	14.69	4.61
3. Households needing insulin	0.08	0.23	0.12	0.09	194.51	49.06	15.40
		Upper Poverty Line					
1. National	9.55	9.69	9.58	9.57	1.45	0.36	0.18
2. Households with diabetes	0.35	0.49	0.39	0.37	39.45	9.80	4.92
3. Households needing insulin	0.10	0.24	0.14	0.12	133.23	33.11	16.62

Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016*. Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

Table 9. **Poverty Rates in Bangladesh before and after an Increase in Insulin Prices and Percentage Change**

	Household Poverty Rate before Price Increase	Household Poverty Rates after Price Increase			Percentage Point Increase in Household Poverty Rates		
		Upper Bound	Lower Bound	Pakistan Price	Upper Bound	Lower Bound	Pakistan Price
		Lower Poverty Line					
1. National	12.89	13.28	12.99	12.92	0.39	0.10	0.03
2. Households with diabetes	25.36	40.14	29.09	26.53	14.78	3.73	1.17
3. Households needing insulin	20.99	61.81	31.28	24.22	40.82	10.30	3.23
		Upper Poverty Line					
1. National	24.28	24.63	24.37	24.33	0.35	0.09	0.04
2. Households with diabetes	33.54	46.78	36.83	35.20	13.23	3.29	1.65
3. Households needing insulin	27.44	64.01	36.53	32.01	36.56	9.09	4.56

Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

under these three counterfactual scenarios, with an increase in poverty rates ranging from 0.03 percentage points to 0.39 percentage points. Similarly, among all the households with at least one person with diabetes, the share of households that will be under the lower poverty line increases from an initial 25.36% to 26.53%–40.14%, with the increase in poverty rates ranging from 1.17 percentage points to 14.78 percentage points. We can see a very substantial increase in household poverty among the households needing insulin. Here, under the three different counterfactual scenarios, the share of households that fall below the lower poverty line among all households needing insulin range from 24.22% to 61.81% from an initial poverty rate of 20.99%, which indicates an increase in poverty rates ranging from 3.23 percentage points to 40.82 percentage points for those households. We see a very similar pattern in increased poverty rates when we use the upper poverty line instead of the lower poverty line.

VI. Discussion and Conclusion

This paper is built on the previous theoretical and empirical insights to estimate the potential impact of Bangladesh's LDC graduation on its population living with diabetes in general and insulin users in particular. To date, few if any studies deploy an ex ante partial equilibrium framework that estimates price changes due to trade policy change and then links those results to household behavior models and data. We model and then estimate the potential impact of LDC graduation on the price of insulin in Bangladesh and then link those price changes. Following those estimates, we calculate demand elasticities and relate them to Bangladeshi household data to determine the impacts of those potential price changes in household wealth.

Our findings have significant policy ramifications as well. Bangladesh has a high incidence of diabetes and insulin users, as well as a fairly thriving domestic industry that supplies those treatments to patients in need. We find that prices of insulin would increase significantly in Bangladesh due to LDC graduation and the subsequent requirement to comply with the IPR provisions of the WTO. What is more, such price changes would also have significant welfare impacts for the population. LDC graduation would trigger a significant jump in insulin prices that could cause a 1%–15% decline in the welfare (i.e., an increase in expenditure) of households with diabetes, increasing the poverty rate of households with diabetes by 54%–58% and of those needing insulin by 15%–195% unless policy adjustments were carried out.

Our estimates of the impact of an increase in insulin price under a stronger IPR regime on household welfare and poverty has some important data limitations. These limitations emanated from the lack of detailed expenditure information on medicines by individuals with diabetes. The 2016 HIES of Bangladesh does not provide disaggregated data on types of diabetic medicines, i.e., whether an individual with diabetes needs insulin or noninsulin medicines, and it contains no information on the quantity of medicines needed per day or per month. To construct the sample for our analysis, we needed to infer the households needing insulin from the expenditure on medicines for chronic disease reported in the 2016 HIES and compare this expenditure to an interval constructed using administrative data on monthly insulin costs. It was likely that there would be some households needing insulin but not included in our sample if the household's monthly expenditure on medicines fell below the lower bound of the cost of insulin constructed using administrative data. Similarly, there would be some households that do not need insulin but expenditure on medicines by those households fell within the interval. In the prior scenario, our household welfare and poverty estimates would be underestimated, and in the latter scenario, these would be overestimated. Hence, without additional information on medicine expenditure by the households with members living with diabetes, we could not determine the direction of bias that our constructed sample may induce.

Another data limitation in the 2016 HIES is that it seems to underrepresent the fraction of the population suffering from diabetes. In the final report, 186,078 individuals were included in the survey, but only 2,238 individuals were reported to be living with diabetes, which is about 1.2% of the sample. However, it has been estimated that about 10% of the population of Bangladesh are suffering from diabetes, with half of them going undiagnosed (WHO 2016). Hence, we would expect about 5% of the individuals in our sample to report a diagnosis of diabetes. The underrepresentation of individuals with diabetes in the 2016 HIES would also cause a downward bias in estimation. Thus, in this case, our estimated effects of an increase in insulin price on households' welfare and poverty are conservative estimates, which signifies that the true welfare cost of a stricter IPR regime in Bangladesh after its graduation from LDC status would be significantly higher.

That said, this paper should not be the last word on this subject for Bangladesh, but rather it should start a discussion. As noted earlier, this analysis suffers from a lack of data availability in a transparent manner. Better data collection and dissemination will be paramount in achieving a better understanding of these issues in economics in general and in Bangladesh in particular.

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Appendix 1. Summary Statistics

Table A1. **Summary Statistics: Mean and Standard Deviation of Household and Household Head's Characteristics**

	All Households with at Least One Member with Diabetes			Households Needing Insulin		
	Obs.	Mean	SD	Obs.	Mean	SD
Household size	1,124	6.38	3.34	424	6.44	3.35
Average age	1,124	35.03	12.24	424	35.15	11.59
Head age	1,124	51.48	13.17	424	51.49	12.80
Monthly income (Tk)	1,125	28,716.56	27,074.13	424	30,936.63	30,831.34
Monthly food expenditure (Tk)	1,124	9,210.79	66,10.99	424	9,368.45	4,855.21
Monthly medicine expenditure (Tk)	1,125	1,128.66	26,80.49	424	973.33	545.03
Monthly education expenditure (Tk)	1,015	1,562.88	2,673.55	383	1,786.54	3,034.72

Obs. = observations, SD = standard deviation, Tk = Bangladesh taka.
Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

Table A2. **Summary Statistics: Proportions of Household and Household Head's Characteristics**

		All with at Least One Member with Diabetes		Households Needing Insulin	
		Obs.	Proportion (%)	Obs.	Proportion (%)
Location	Rural	618	51.07	202	47.64
	Urban	592	48.93	222	52.36
House ownership	Does not own	104	8.60	32	7.55
	Owns a house	1,106	91.40	392	92.45
Religion	Non-Muslim	143	11.82	48	11.32
	Muslim	1,067	88.18	376	88.68
Members attending school	0	392	32.37	134	31.60
	1	389	32.12	139	32.78
	2	297	24.53	106	25.00
	3	98	8.09	35	8.25
	More than 3	35	2.90	10	2.36

Continued.

Table A2. *Continued.*

		All with at Least One Member with Diabetes		Households Needing Insulin	
		Obs.	**Proportion (%)**	**Obs.**	**Proportion (%)**
Members older than 60 years	0	661	54.63	231	54.48
	1	418	34.55	146	34.43
	2	129	10.66	46	10.85
	3	2	0.17	1	0.24
Members with noncommunicable diseases	1	643	53.41	217	51.30
	2	449	37.29	168	39.72
	3	83	6.89	32	7.57
	More than 3	29	2.41	6	1.42
Household head's employment status	Unemployed	269	22.25	96	22.64
	Employed	940	77.75	328	77.36
Household head's employment sector	Agriculture	252	20.83	87	20.52
	Industry	129	10.66	51	12.03
	Service	829	69.00	286	67.00

Obs. = observations.
Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

Appendix 2. Additional Tables

Table B1. **Coefficients of QUAIDS Model**

	Not Corrected		Corrected	
	OLS	**IV**	**OLS**	**IV**
α				
α_1	0.736***	0.884***	0.704***	0.917***
α_2	0.124***	0.259***	0.147***	0.240***
α_3	0.141***	−0.143	0.149***	−0.157*
β				
β_1	0.164***	0.224***	0.111*	0.174
β_2	−0.097***	0.184***	−0.098***	−0.245**
β_3	−0.067***	−0.040	−0.013	0.072

Continued.

Table B1. *Continued*.

	Not Corrected		**Corrected**	
	OLS	**IV**	**OLS**	**IV**
γ				
γ_{11}	0.064***	0.034	0.062***	0.040
γ_{21}	−0.041***	0.012	−0.040***	0.010
γ_{31}	−0.023***	−0.046*	−0.022***	−0.050**
γ_{22}	0.055***	−0.023*	0.055***	−0.022*
γ_{32}	−0.014***	0.012*	−0.015***	0.011*
γ_{33}	0.036***	0.034	0.036***	0.039
λ				
λ_1	0.005***	−0.030***	0.006***	−0.030***
λ_2	−0.003***	0.029***	−0.003***	0.030***
λ_3	−0.003*	0.002	−0.003**	0.001
η				
$\eta_{\_Hsize\_1}$	0.001	0.018***	0.003	0.021**
$\eta_{\_Hsize\_2}$	0.001	−0.007**	0.000	−0.006*
$\eta_{\_Hsize\_3}$	−0.003	−0.011**	−0.003*	−0.015**
$\eta_{\_AvgAge\_1}$	−0.001**	0.001	−0.001*	0.002
$\eta_{\_AvgAge\_2}$	0.000	−0.001	0.000	−0.001
$\eta_{\_AvgAge\_3}$	0.001*	−0.000	0.000**	−0.001
$\eta_{\_NumSch\_1}$	−0.011***	−0.050***	−0.012***	−0.047***
$\eta_{\_NumSch\_2}$	−0.003**	0.011**	−0.002	0.011***
$\eta_{\_NumSch\_3}$	0.014***	0.039***	0.013***	0.036***
$\eta_{\_old60\_1}$	−0.002	−0.20**	−0.004	−0.023**
$\eta_{\_old60\_2}$	−0.001	0.007*	0.000	0.006
$\eta_{\_old60\_3}$	0.003	0.012**	0.003	0.017**
$\eta_{\_NumNCD\_1}$	0.018***	−0.002	0.017***	−0.003
$\eta_{\_NumNCD\_2}$	−0.009***	0.005	−0.008***	0.006
$\eta_{\_NumNCD\_3}$	−0.009***	−0.003	−0.008**	−0.003
$\eta_{\_HeadAge\_1}$	−0.000	−0.001	0.000	−0.001
$\eta_{\_HeadAge\_2}$	−0.000	0.000	−0.000	0.000
$\eta_{\_HeadAge\_3}$	0.000	0.001	0.000	0.001
$\eta_{\_HeadEmpl\_1}$	−0.007	−0.050***	−0.004	−0.055***
$\eta_{\_HeadEmpl\_2}$	0.004	0.026***	0.002	0.029***
$\eta_{\_HeadEmpl\_3}$	0.004	0.024*	0.003	0.027**
$\eta_{\_HeadSector\_1}$	−0.008	−0.017*	−0.009	−0.019
$\eta_{\_HeadSector\_2}$	0.005	0.010*	0.005	0.013**
$\eta_{\_HeadSector\_3}$	0.003	0.007	0.004	0.006
$\eta_{\_HeadMuslim\_1}$	−0.014	0.003	−0.012	0.010
$\eta_{\_HeadMuslim\_2}$	0.012**	−0.008	0.011**	−0.008
$\eta_{\_HeadMuslim\_3}$	0.002	0.005	0.001	−0.002
$\eta_{\_House\_1}$	−0.035***	−0.019	−0.032***	−0.016

Continued.

Table B1. *Continued.*

	Not Corrected		Corrected	
	OLS	IV	OLS	IV
η_House_2	0.017**	−0.000	0.017**	0.005
η_House_3	0.018***	0.019	0.015***	0.011
η_Urban_1	−0.016***	−0.035**	−0.015***	−0.031
η_Urban_2	0.002	−0.002	0.003	0.000
η_Urban_3	0.015***	0.037***	0.012***	0.031*
η_IMR_1			0.027	0.019
η_IMR_2			0.008	0.028
η_IMR_3			−0.036	−0.047
ρ				
ρ_Hsize	−0.019	1.230	0.001	0.290
ρ_AvgAge	−0.006	0.298	−0.003	0.177
ρ_NumSch	0.035	−1.266*	0.011	−1.752
ρ_old60	0.018	−1.491	−0.006	−0.271
ρ_NumNCD	0.190**	−0.531	0.126**	−0.613
ρ_HeadAge	−0.001	−0.056	0.000	−0.099
ρ_HeadEmpl	−0.052	−0.393	−0.016	−1.958
ρ_HeadSector	−0.069	−0.090	−0.047	−2.001
ρ_HeadMulim	−0.163	7.168*	−0.107	7.748*
ρ_house	−0.321**	0.220	−0.233**	−1.473
ρ_Urban	−0.037	−1.653	−0.052	−1.832
ρ_IMR			−0.310*	16.22*

IV = instrumental variable, OLS = ordinary least squares.
Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016.* Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.

Table B2. **Suppliers of Insulin in Bangladesh**

Suppliers of Insulin in Bangladesh	
Domestic Producers (50 products)	**Import (65 products)**
1. Advanced Chemical Industries Limited	1. Eli Lilly & Company, USA (License expired as of 2016)
2. Aristopharma Limited	2. Lilly France S.A.S
3. Beximco Pharmaceuticals Ltd.	3. Novo Nordisk A/S
4. Drug International Ltd.	4. Novo Noris Producao Pharmaceutica do Brasil Ltd. Brazil.
5. Incepta Pharmaceuticals Ltd.	5. Novo Nordisk Production SAS (License expired as of 2018)
6. Popular Pharmaceuticals Ltd.	6. Sanofi Aventis Deutschland
7. Square Pharmaceuticals Ltd.	

Source: Government of Bangladesh, Directorate General of Drug Administration.

Table B3. **Estimates of Insulin Demand Equation**

Dependent Variable is Total Expenditure on Insulin				
	Not Corrected		**Corrected**	
	Coefficient	**SE**	**Coefficient**	**SE**
p2IV	−0.11	0.22	−0.112	0.22
$\bar{\omega}$	0.03	0.02	0.027	0.02
AvgAge	7.85*	4.29	7.803*	4.38
NumSch	−52.94*	32.05	−53.19	32.45
old60	−48.42	36.22	−47.94	37.36
NumNCD	74.04*	38.54	74.45*	39.34
HeadAge	0.65	3.01	0.490	4.32
HeadGender	−172.700	109.90	−169.0	130.00
HeadEduc	12.35	33.64	14.95	59.41
HeadEmpl	186.90**	80.60	184.6**	91.51
HeadSector	36.74	46.47	33.27	80.14
Urban	106.30	78.48	106.5	78.65
HeadMuslim	92.49	86.32	95.46	102.90
House	−28.37	102.40	−23.91	132.50
IMR			76.30	1,436.70
N	421		421	
Adjusted R^2	0.066		0.066	

N = number of observations, SE = standard error.
Source: Authors' calculations based on data from the Bangladesh Bureau of Statistics. 2019. *Report on the Household Income and Expenditure Survey 2016*. Dhaka: Statistics and Information Division, Ministry of Planning, Government of Bangladesh.