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The Economic Burden of Noncommunicable Diseases and Mental Health
Conditions: Results for Costa Rica, Jamaica, and Peru

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Original research

The economic burden of noncommunicable diseases and mental health conditions: results for Costa Rica, Jamaica, and Peru

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ABSTRACT

Objective. We extend the World Health Organization's (WHO) EPIC model and apply it to analyze the macroeconomic impact of noncommunicable diseases (NCDs) and mental health conditions in Costa Rica, Jamaica, and Peru.

Methods. The EPIC model quantifies the impact of NCDs and mental health conditions on aggregate output solely through the effect of chronic conditions on labor supply due to mortality. In contrast, the expanded EPIC-H Plus framework also incorporates reductions in effective labor supply due to morbidity and negative effects of health expenditure on output via the diversion of productive savings and reduced capital accumulation. We apply this methodology to Costa Rica, Jamaica, and Peru and estimate gross domestic product (GDP) output lost due to four leading noncommunicable diseases (NCDs) (i.e. cardiovascular disease, cancer, chronic respiratory disease, and diabetes) and mental health conditions in these countries from 2015–2030. We also estimate losses from all NCDs and mental health conditions combined.

Results. Overall, our results show total losses associated with all NCDs and mental health conditions over the period 2015–2030 of US\$81.96 billion (2015 US\$) for Costa Rica, US\$18.45 billion for Jamaica, and US \$477.33 billion for Peru. Moderate variation exists in the magnitude of the burdens of diseases for the three countries. In Costa Rica and Peru, respiratory disease and mental health conditions are two leading contributors to lost output, while in Jamaica, cardiovascular disease alone accounts for 20.8% of the total loss, followed by cancer.

Conclusions. These results indicate that the economic impact of NCDs and mental health conditions is substantial and that interventions to reduce the prevalence of chronic conditions in countries in Latin American and the Caribbean are likely to be highly cost-beneficial.

Keywords

Chronic diseases, mental health, macroeconomic factors, ageing, economic burden of disease, Latin America, Caribbean, West Indies.

A strong interplay exists between population health and economic growth (1). First, high-income populations tend to have better health because they have access to more and better nutrition; safe water and sanitation; readily available and quality health care; and psychosocial resources such as social capital and recreation facilities. Second, healthy populations develop faster economically because healthy work forces tend to be more productive and because healthy children have higher test scores, better school attendance records, and higher levels of educational attainment. In addition, healthy populations maintain higher rates of saving, investment, and physical capital accumulation because they expend fewer resources on health care. This process may lead to a virtuous cycle that results in further investment from abroad, increasing workers' access to more-productive machines, technology, and infrastructure. Healthy populations also tend to control their fertility, allowing them to escape the burden of youth dependency and enjoy a demographic dividend (2). Therefore, understanding patterns in population health is likely to be important, at least in part, for understanding patterns in economic growth.

Noncommunicable diseases (NCDs) and mental health conditions represent a huge disease burden and have a substantial impact on individuals, communities, and societies around the globe. In total, these conditions are responsible for roughly half of healthy life years lost as measured in disability-adjusted life years (DALYs) and roughly two-thirds of deaths worldwide (3, 4). In the Region of the Americas, NCDs are the leading cause of morbidity and mortality and are responsible for 80% of all deaths (5). Of particular relevance, 35% of NCD-related deaths occur prematurely (between the ages of 30 and 70), when individuals are in their most economically productive period of life (5).

As worrying as current rates of NCDs and mental health conditions are, trends in the relevant risk factors for these conditions indicate that their global burden is only likely to grow. For example, while smoking has declined in some high-income countries, the overall rates of the main modifiable risk factors for NCDs and mental health conditions—such as tobacco use, alcohol use, and obesity—have risen globally, suggesting that an increase in the rates of chronic conditions worldwide is likely to follow (6, 7). In addition, more sedentary

occupations and unhealthy diets are becoming more common.

Demographic trends also point toward an increased future burden from NCDs and mental health conditions. In particular, the dual phenomena of urbanization and rapid population aging have significant implications. Although urbanization has many benefits in terms of efficiency and convenience, it can also facilitate dispersion of certain risk factors for NCDs, such as pollution and second-hand smoking. Given that age constitutes the main risk factor for NCDs and mental health conditions, global population aging is likely to have a major effect on overall levels of population health. While a thorough discussion of the prevalence of these conditions is beyond the scope of this paper, these details have been provided elsewhere. For more detail on NCDs in the Americas and the capacity of countries to respond, see (8).

In spite of the high burden of ill health and premature death caused by NCDs and mental conditions, the availability of data capturing their economic impact is limited (9). This paper focuses on Costa Rica, Jamaica, and Peru (see Table 1 for summary statistics) and is the result of a collaboration between the Harvard T.H. Chan School of Public Health and the Department of Noncommunicable Diseases and Mental Health of the Pan American Health Organization (PAHO). This department is responsible for providing technical cooperation in the Region of the Americas to prevent and control NCDs, as well as mental conditions, and related risk factors in accordance with global and regional mandates (10).

This paper has two goals. The first is to estimate the economic impact of NCDs and mental conditions on gross domestic product (GDP). The second is to raise awareness among policymakers and other decision makers of these conditions' economic costs and their implications for national economic progress. Finance ministers and others in charge of resource allocation are more likely to fund programs and interventions that are evidence based, and persons seeking to influence financial decisions (such as by health ministers) can use the results presented in this paper to identify and promote the adoption of cost-effective policies, such as the "best buy" NCD interventions identified by the World Health Organization (WHO) (11, 12).

TABLE 1. Summary statistics for Costa Rica, Jamaica, and Peru

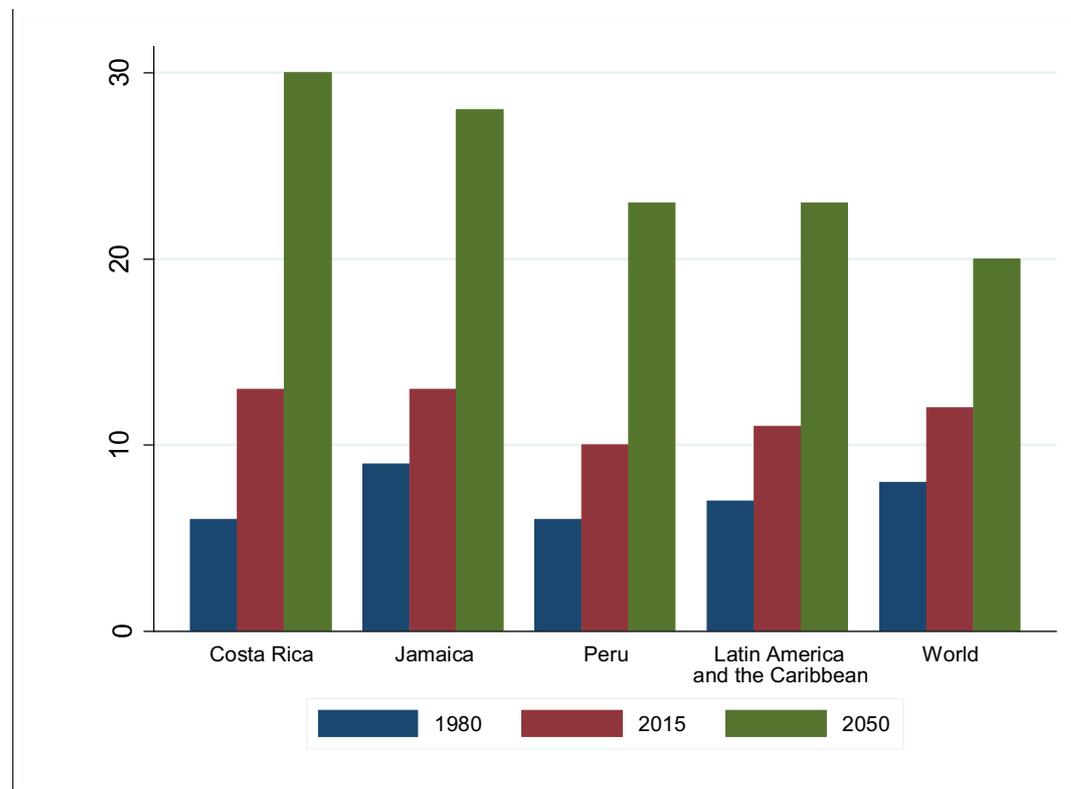
Statistic	Costa Rica	Jamaica	Peru
Population (millions, 2014)	4.8	2.7	31
2014 gross domestic product (billions, 2005 constant US\$)	29.4	11.2	127.7
2014 gross domestic product per capita (2005 constant US\$)	6 188	4 112	4 124
Savings rate (%) ^a	17	15	21
Life expectancy (years, 2013)	79.2	73.4	74.3
Percentage of persons 60+ (2015)	12.8	12.8	10.0

Source: Data from the World Bank (<http://data.worldbank.org/>).

^a The savings rate is the average rate between 2011 and 2014.

Although Costa Rica, Jamaica, and Peru represent different geographic areas in Latin America and the Caribbean and have different levels of economic development, they face similar demographic challenges, including recent steady increases in the proportions of their populations aged 60 and above (Figure 1). In 1980, the proportion of the population aged 60 and above was 9.3% for Jamaica, 6.1% for Costa Rica and 5.6% for Peru. Now, this age group accounts for 13% of the Jamaican and Costa Rican populations and 10% of the Peruvian population. According to United Nations Population Division (UNPD) projections, those aged 60 and above will account for 30% of the population in Costa Rica, 28% in Jamaica and 23% in Peru by 2050 (<https://esa.un.org/unpd/wpp/Download/Standard/Population/>).

FIGURE 1. Percent of total population aged 60+ in Costa Rica, Jamaica, and Peru, Latin America and the Caribbean, and the world, in 1980, 2015, and 2050



Source: Data from the United Nations Population Division.

Even though NCDs and mental health conditions have a significant and growing impact on the health and well-being of populations, policymakers and the public may not be aware of their full consequences. Public spending on large-scale intervention programs aimed at reducing the risk factors for these diseases (such as obesity) may therefore need to be justified by comparing the expected return on investment from these programs with expected returns from other potential uses of public funds. This can only be achieved if robust estimates of the economic costs of NCDs and mental health conditions are available.

Unfortunately, assessing the economic impact of NCDs and mental health conditions is complex. Several approaches to evaluating the economic effects of chronic conditions exist, including cost-of-illness and value-of-a-statistical-life (VSL) methods, which aggregate estimates from individual data. The cost-of-illness method sums up direct medical costs,

while VSL infers the monetary value of mortality reductions from willingness-to-pay studies or wage premia for risky occupations. However, these approaches do not capture the ways in which society's health status affects determinants of economic growth, such as labor markets and capital accumulation.

We expect such macro-level spillover effects to be important—a hypothesis that the literature supports (13). For example, NCDs and mental health conditions increase mortality and reduce productivity, thus reducing labor supply (14). Likewise, health care expenditures increase in response to chronic conditions, diverting savings away from productive investments and thus reducing capital accumulation.

One approach to estimating the impact of these spillover effects uses cross-country economic growth regressions (15, 16); however, identifying the parameters of interest can be difficult. An alternative is to build a working model of the economy, which can then be calibrated using observed data on chronic conditions and other country-specific characteristics. We can use such production function approaches to simulate different scenarios with different prevalence levels of NCDs and mental health conditions. Comparing levels of GDP and GDP growth in various scenarios provides an economic estimate of the impact of these health conditions.

It should be acknowledged that this methodology also has limitations. For example, we do not consider the behavioral change of individuals and firms. One potential alternative is to use a general equilibrium approach. However, building such a model would be complex and could ultimately require too many restrictive assumptions to be tractable.

Despite these limitations, our methodology has two distinct benefits. First, it is an economically founded approach to estimating the cost of chronic conditions that captures the aggregate impact on society rather than on individuals. Second, it enables us to describe how the labor market and capital stock—key determinants of economic growth—respond to NCDs and mental health conditions and therefore incorporate adjustment mechanisms. In this paper, we describe how we apply this production function approach to Costa Rica, Jamaica, and Peru.

METHODS

We analyzed the economic burden of NCDs and mental health conditions using the EPIC-H Plus model. EPIC-H Plus is an updated version of two models: 1) the original WHO EPIC model; and 2) our previous EPIC-H model (17). The original WHO EPIC model estimates the impact of NCDs and mental health conditions on aggregate output by quantifying reductions in the labor supply due to mortality from chronic conditions. As in the original WHO EPIC model, GDP is modeled as a function of aggregate labor supply, the aggregate capital stock, and technological progress. Health is incorporated into this framework because chronic conditions, including NCDs and mental health conditions, affect the quantity of labor supplied in the model. A higher prevalence of NCDs and mental health conditions reduces GDP because the number of working-age individuals, and therefore the size of the labor force, decreases.

For accuracy of predictions, modeling and coding adjustments were made to the original WHO EPIC model to produce an updated model, which we refer to as EPIC-H. We subsequently developed and amended this model to produce the augmented EPIC-H Plus extension, which additionally incorporates labor supply reductions due to morbidity and the negative effects of health expenditures on output, which result from the diversion of productive savings and from reduced capital accumulation. (See Appendix B for a detailed description of data sources for the parameters used in this framework.)

The projections for national income in this framework are based on the Solow model production function, which is given by

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha} \quad (1)$$

where economic output in each year (Y_t) is modeled as a function of technological progress (A_t), the capital stock (K_t), and the stock of labor in the economy (L_t). Alpha (α) describes how labor and capital combine to produce output. The production function is calibrated based on data obtained for each country, which include forecasts of population structure and the prevalence of NCDs and mental health conditions. To obtain the aggregate cost of NCDs and

mental health conditions, we simulate aggregate income for each country over the period of interest in two scenarios: status quo and counterfactual.

Status quo scenario

GDP gives economic output in each year as forecasted, assuming the prevalence of NCDs and mental health conditions evolves as expected over the period of interest. We assume that no interventions that would reduce the mortality rate of a disease have been implemented.

Counterfactual scenario

This scenario models the complete elimination of the specified disease (i.e., the prevalence of NCDs and mental health conditions is set to zero), and this reduction in disease prevalence occurs without cost. When considered alongside the status quo scenario, the counterfactual scenario can be used to calculate the total output loss attributable to NCDs and mental health conditions, and this will be the focus of this article's analysis.

The model can also be extended to examine a proposed intervention scenario. In such an intervention scenario, GDP is calculated assuming the elimination of a designated percentage of mortality for the specified disease. For example, this could be used to evaluate an intervention that reduces the prevalence of NCDs and mental health conditions by 10%. In this piece, we do not consider an intervention scenario as part of the analysis as we focus on estimating the aggregate cost of NCDs and mental health conditions.

After constructing the GDP projections for these two scenarios, the difference between GDP values in the counterfactual scenario and in the status quo scenario gives the aggregate cost of NCDs and mental health conditions. The sum of these differences in each year over the period of interest gives the total burden. Appendix A has a detailed description of the modeling methodology. Further details of model functionality and derivations are given in Bloom et al. (18).

RESULTS

Tables A2, A3, and A4 (see Appendix C) present baseline-case estimates of the economic burden of NCDs and mental health conditions for Costa Rica, Jamaica, and Peru, during the period of 2015–2030. The estimates, which are given in 2015 US\$, draw on WHO mortality data and assume that the same mortality rates observed from 2005 through 2013 will hold for 2015–2030. In addition to separate economic burden estimates for each of four leading noncommunicable diseases (diabetes, cardiovascular disease (CVD), chronic respiratory disease, and cancer), and mental health conditions, estimates of the aggregate cost of all NCDs and mental health conditions is presented in each table. These aggregate estimates were obtained by scaling the figure for the five domains using the procedure based on disability-adjusted life years (DALYs) that is described by Bloom et al. (17).

The costs associated with NCDs and mental health conditions in the three countries are substantial

According to the model, all NCDs and mental health conditions will cost Costa Rica, Jamaica, and Peru, respectively, US\$81.96 billion (US\$16 143 per capita), US\$18.45 billion (US\$6 306 per capita), and US\$477.33 billion (US\$15 010 per capita), in 2015 US\$, from 2015 through 2030. Considering these countries' income per capita and the size of their economies, these figures represent huge costs. For Costa Rica, Jamaica, and Peru, estimates of the value of lost output are, respectively, 142%, 105%, and 255% of the countries' 2013 GDP. Furthermore, these estimates amount to more than 48 times Peru's total health spending in 2013, and more than 18 and 15 times that of Jamaica and Costa Rica, respectively.

Moderate variation exists in the magnitude of the burdens of diseases for the three countries

In Costa Rica, respiratory disease alone accounts for 20.1% of the total loss, followed by mental health conditions (18.6%), and cardiovascular disease (9.4%); diabetes accounts for only 6%. Peru faces a similar situation: respiratory disease (19.7%), mental health conditions

(20.9%), and cardiovascular disease (8.4%) are the three leading contributors to lost output, while diabetes accounts for only 4.2%. In Jamaica, the magnitude of the burden associated with specific diseases varies somewhat less than in the other two countries: CVD contributes 20.8% to the total loss, followed by cancer (13.7%) and diabetes (13.5%).

The burden of NCDs and mental health conditions in Peru is greater than the burden in Costa Rica and Jamaica

Figures 2, 3, and 4 compare the output losses due to NCDs and mental health conditions in Costa Rica, Jamaica, and Peru. We present the output losses due to four leading noncommunicable diseases (i.e. cardiovascular disease, cancer, chronic respiratory disease, diabetes), mental health conditions, and total NCDs. Here total NCDs (all NCDs plus mental health conditions) include cardiovascular diseases, cancer, chronic respiratory diseases, cirrhosis, digestive diseases, diabetes, urogenital diseases, blood diseases, endocrine diseases, musculoskeletal disorders and other non-communicable diseases including congenital anomalies, skin and subcutaneous diseases, sense organ diseases and oral disorders and mental health conditions. Between 2015 and 2030, Peru will suffer a larger total output loss than either Costa Rica or Jamaica (US\$477.33 billion versus US\$81.96 billion and US\$18.45 billion, respectively). This higher aggregate output loss may be due to Peru's larger population and initially higher level of economic output. Peru has 6 times the population of Costa Rica and almost 11 times that of Jamaica, with 4 times the GDP of Costa Rica and almost 10 times that of Jamaica.

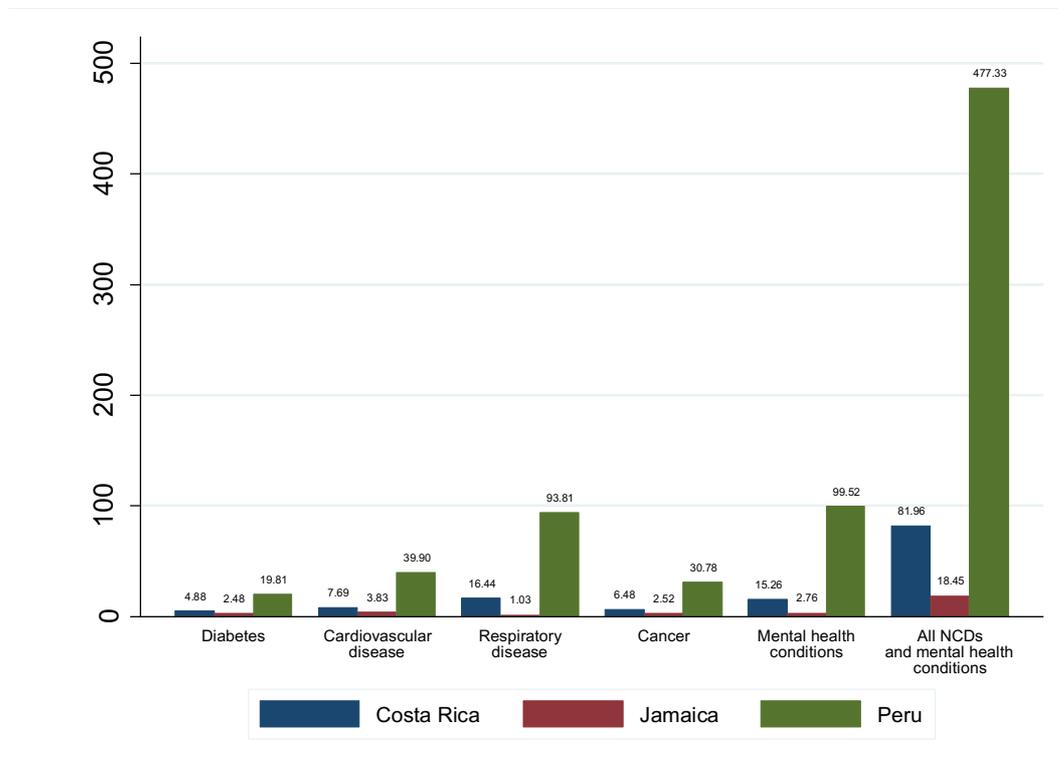
Peru not only has the highest output loss among the countries studied at the aggregate level, but also the largest at the per capita level (US\$16 143). Furthermore, Peru's burden of NCDs and mental health conditions is much larger when compared with its baseline GDP. In 2015–2030, total losses related to NCDs and mental health conditions for Costa Rica and Jamaica, respectively, are estimated at 142% and 105% of the countries' 2013 GDPs, while the corresponding loss for Peru over the same time period is 255% of its 2013 GDP. NCDs and mental health conditions therefore pose a larger burden for Peru's economy in both

absolute and relative terms. Among chronic conditions, respiratory diseases and mental health conditions are the leading causes of lost output in Peru.

The lower per capita loss in Jamaica does not necessarily mean that the burden of NCDs is small. It is mostly a result of the low GDP per capita in Jamaica at the beginning of the projection period. In addition, Jamaica's GDP is expected to grow more slowly than that of Peru and of Costa Rica (according to economic data from the World Bank); as a result, the expected per capita loss will be smaller.

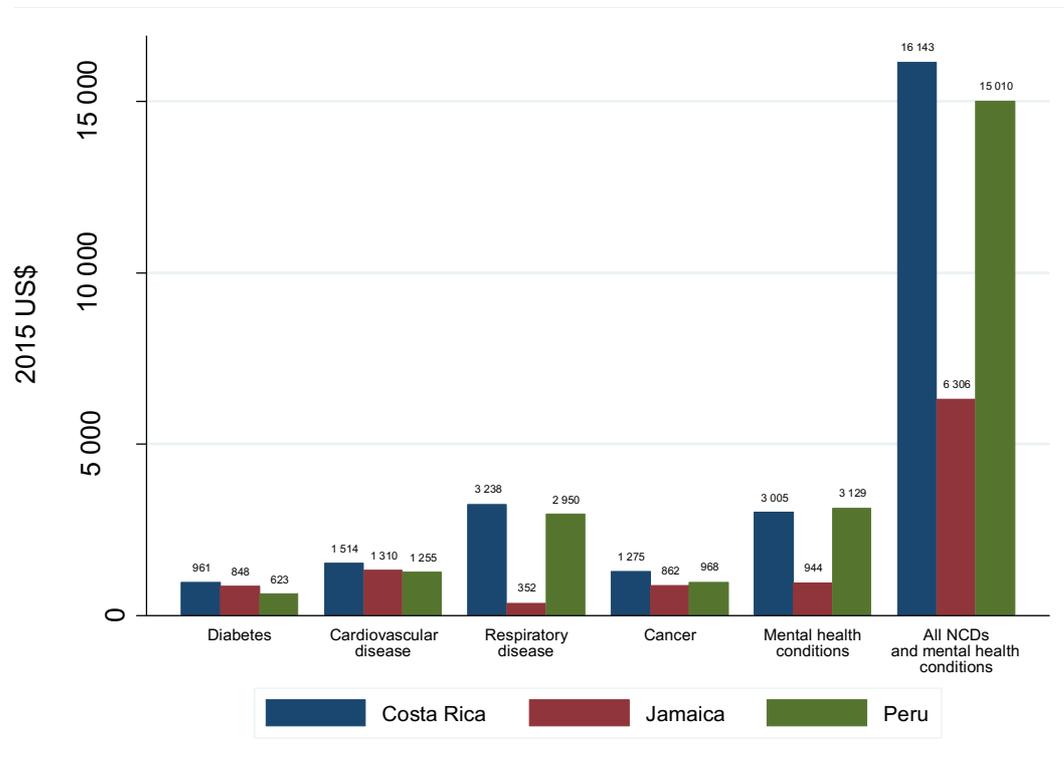
We also conducted sensitivity analyses by varying data sources and assumptions (Appendix D). As it is not possible to validate our estimates directly, it is important to provide evidence that our results are robust to a variety of mortality scenarios. From the sensitivity analysis, we conclude that the results are similar and robust across different projection methods and data sources, and that the impact of treatment cost and morbidity is quite significant.

FIGURE 2. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions in Costa Rica, Jamaica, and Peru, 2015–2030



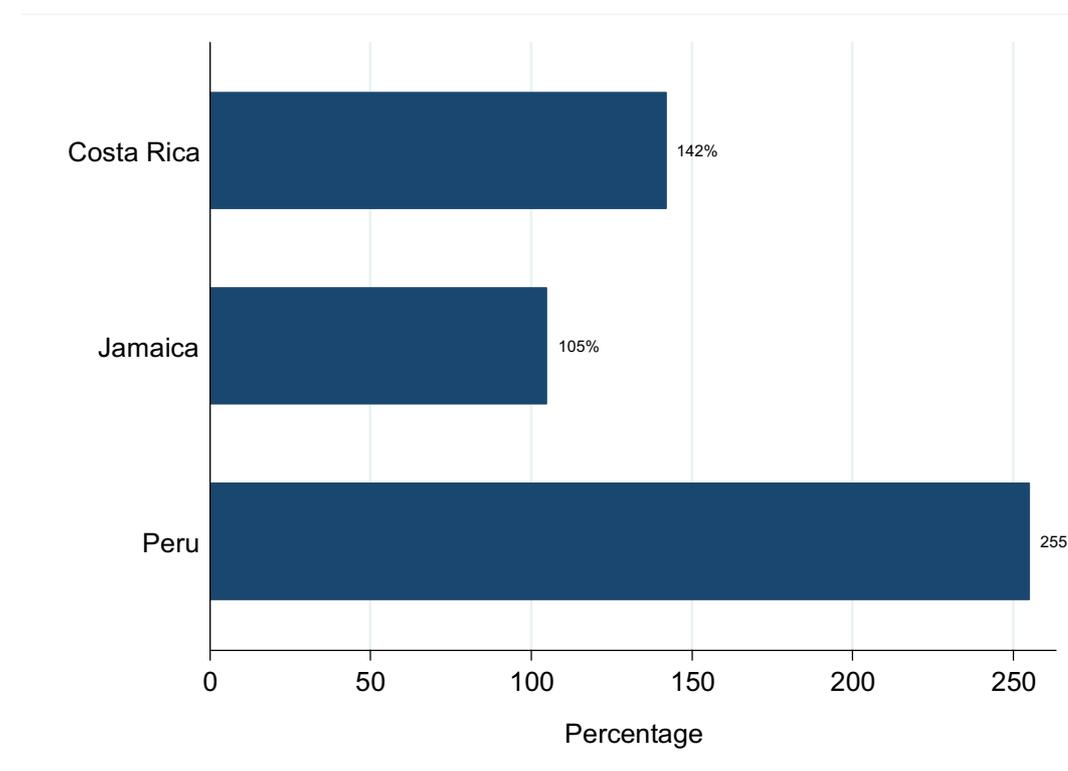
Source: Prepared by the authors based on the results of the study.

FIGURE 3. Estimates of lost gross domestic product (GDP) per capita output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions in Costa Rica, Jamaica, and Peru, 2015–2030



Source: Prepared by the authors based on the results of the study.

FIGURE 4. Estimates of lost gross domestic product (GDP) output due to noncommunicable diseases and mental health conditions for 2015-2030 as a percentage of 2013 GDP (in constant 2015 US\$)



Source: Prepared by the authors based on the results of the study.

DISCUSSION

Our study has several implications. The first is that substantial costs are associated with NCDs and mental health conditions in these three countries of Latin America and the Caribbean. Unless the prevalence of chronic conditions can be reduced, the impact on economic growth is likely to be substantial due to consequent reductions in effective labor supply and capital accumulation. Correspondingly, the estimates imply that cost-effective interventions targeted at reducing the prevalence of chronic conditions are likely to be cost-beneficial because of the substantial economic burden that NCDs and mental health conditions impose. Furthermore, implementing interventions designed to reduce risk factors for NCDs are likely to lead to a 25% reduction in premature mortality from NCDs by 2025 (a

goal set forth by the WHO Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-2020 (10)). Finally, these interventions could serve as a strategy to promote economic development, given the expected impact on labor supply and capital accumulation, and therefore on economic activity and output.

Caveats

The results we present here are based on a set of assumptions about how economies grow and how various inputs, including health, affect economic output. We assume that there is no excess labor available to replace the labor (or rather, effective labor) lost due to NCD-related mortality or morbidity. This assumption may be less valid in countries in which unemployment is high or in which there are large shadow economies. However, it is difficult to assess the magnitude of these effects on real output (as opposed to measured GDP). These assumptions should be borne in mind when interpreting the estimates, and this is an important topic for future research.

Our results are also based on data that were available and accessible at the time of writing. We have attempted to assess the sensitivity of these estimates to different information sources and assumptions; however, in pursuing this analysis we found the dearth of quality data to be a major impediment to estimating the economic impact of NCDs and mental health conditions. Estimates using alternative mortality sources were found to differ, albeit not substantially in most cases. More importantly, obtaining comprehensive information on the treatment costs associated with each disease was difficult. For example, due to a lack of country-specific data, we were forced to rely on several different sources to estimate treatment costs for Costa Rica. By contrast, the availability of country-specific treatment cost data for Jamaica and Peru allowed us to provide estimates for these countries that are likely more accurate.

As another example of a data limitation, we determined that we should use DALY estimates to approximate the morbidity impact of different conditions. Alternative ways of quantifying this impact rely on survey data and have the merit of providing a direct measure of the effect of morbidity (e.g., the association between having a condition and hours

worked). However, these alternative methods may require strong assumptions about how costs are measured (e.g., that the relationship is causal).

Moving forward, we recommend that evaluations of the impact of NCDs and mental health conditions begin by encouraging the collection of comprehensive data to better measure the pathways linking NCDs and mental health conditions to economic outcomes. For example, expenditure surveys based on nationally representative samples of patients in each country could help to determine the actual costs associated with each disease of interest. Then, these estimates would not have to be inferred either indirectly from other sources or from cost data in other countries, as is currently necessary. Finally, although we focus on projecting future scenarios in this paper, it would be interesting to evaluate the historical impact of NCDs on economic growth in a different analysis.

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Conflicts of Interest. None declared.

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APPENDIX A. Mathematical formulation

Modeling the mortality and morbidity impact of NCDs and mental health conditions on labor supply

In our model, age-specific disease mortality and morbidity affect labor supply. The impact of mortality is straightforward: it directly reduces the size of the working-age population. However, the impact of morbidity is more complicated: it can lower labor supply through early retirement, reduced productivity, and reduced working hours. The effect of morbidity is theoretically substantial but because of a lack of data and the difficulties associated with determining causality from survey-based information, it is hard to quantify in practice.

There are very few, if any, systematic studies that provide a comprehensive assessment of the disability impact of having a given condition on labor market productivity. Therefore, we cannot calibrate this effect directly from the literature. There are two alternative approaches we could adopt: first, estimate the productivity effect ourselves using survey data; second, model the productivity effect with certain assumptions. For the former, we require estimates of the causal effect of having a given health condition (e.g., diabetes) on, say, working hours. The causal effect is required because simple associations could either under- or over-estimate the economic impact of interest. Conducting survey analysis for multiple conditions, let alone in multiple countries, would be a major undertaking that is beyond the scope of this paper. In this paper, we therefore adopted the latter approach. More specifically, we assume the following relationship holds:

$$\frac{\text{loss of labor due to morbidity}}{\text{loss of labor due to mortality}} = \frac{\text{YLD}}{\text{YLL}}$$

where YLD is years lost due to living with disability and YLL is years of life lost due to mortality. The sum of YLD and YLL make up the total DALYs associated with a given condition, which is widely used as a measure of disease burden (Lim et al., 2013). We assume that the loss of effective labor supply due to morbidity can be derived from the proportion of total DALYs (DALYs=YLD + YLL) due to years lived with a disability (YLD). In other

words, we assume that the ratio of effective labor lost due to morbidity relative to labor lost due to mortality is proportional to the ratio of YLD relative to YLL. If this assumption holds, we can weight the value of effective labor lost due to mortality (which we can estimate) by the contribution of YLL to total DALYs lost to obtain the sum of the value of labor lost to mortality and labor lost to morbidity. For example, if YLD constitute 50% of DALYs lost due to cancer, and our estimate of the value of labor lost due to cancer mortality is US\$10 billion, then our weighted estimate of the value of labor lost due to cancer morbidity and mortality combined is: $\frac{1}{50\%} * US\$10 \text{ billion} = US\20 billion .

While this assumption that the contribution of mortality and morbidity to total economic costs occurs in the same proportion as the contribution of mortality and morbidity to the total health impact (as measured by DALYs) has its limitations, we believe it represents a good first step at attempting to estimate the approximate magnitude of the quantity of interest, especially considering the limitations of alternative approaches to quantify the morbidity impact. As an example of how this assumption impacts the future supply of labor, the mortality associated with diabetes in the year 2030 would reduce the effective labor supply in Peru by 0.46%, while the morbidity associated with diabetes would further reduce effective labor by another 0.27%.

Real data and official projections provide the labor supply in the status quo scenario. Simulating the evolution of labor supply over time after eliminating the mortality and morbidity effects of NCDs and mental health conditions provides the labor supply in the counterfactual scenario.

Modeling the impact of NCDS and mental health conditions on physical capital

Health expenditure aimed at treating NCDs and mental health conditions diverts savings away from productive investments that are otherwise assumed to create physical capital. The impact of NCDs and mental health conditions on physical capital is therefore modeled explicitly through the relevant accumulation process:

1) For the status quo scenario, the accumulation of physical capital simply follows the usual Solow form:

$$K_{t+1} = sY_t + (1 - \delta)K_t \quad (2)$$

2) For the counterfactual and intervention scenarios, the treatment and intervention costs modify the accumulation of physical capital:

$$K_{t+1} = sY_t + (1 - \delta)K_t + \chi TC_t \quad (3)$$

where s is the savings rate, δ is the depreciation rate of physical capital, χ is the proportion of savings that goes to either treatment or intervention costs, and TC_t is treatment cost.

Specifically, TC_t refers to the costs of undergoing treatment (or, potentially, alternative prevention strategies). Note that in the counterfactual scenario where diseases are eliminated, these resources can otherwise be used as savings/investment or consumption, and are thus included (i.e., are added back in).

Unfortunately, there is a relative paucity of comprehensive data on treatment costs, and even fewer sources that can be compared across countries. For example, in order to calibrate the model for TC_t , we were obliged to adopt cost data on cancer from South Korea (19), COPD data from Europe (20), regional data on CVD (11), and diabetes data from Zhang et al. (2010) (21), as these were the only sources available. We were, however, able to locate country-specific estimates for CVD and diabetes in Peru from PAHO and for Jamaica from national accounts. This lack of data poses a significant hindrance to assessing the reliability of our estimates because it prevents comparison of cost information used in our study with other analyses. Collecting more treatment cost data is therefore an important item for future research.

Projecting counterfactual GDP

The economic projection for the counterfactual scenario is implemented as follows:

1) We use the status quo GDP projection to calculate physical capital in each year and then apply the Solow model to obtain the residual, A_t . We assume this total factor productivity remains the same in different scenarios.

2) For the counterfactual, the GDP projection is calculated on a yearly basis using the projected labor supply, total factor productivity (A_t), and other economic parameters, such as the savings rate.

The economic burden of a particular disease is then calculated as the difference in projected annual GDP between the status quo scenario and the counterfactual scenario in each year, summed over the period of interest.

APPENDIX B. Data sources

TABLE A1. Data sources

Inputs	Data source
Mortality	WHO ^a , PAHO ^b , IHME ^c
Morbidity	YLL ^d , YLD ^e data are from WHO GHE ^f 2012
Economic projection	World Bank
DALYs ^g	WHO GHE 2012
Treatment cost (Costa Rica)	
Cancer	Adjusted data from Kim et al. (19)
CVD ^h	Regional treatment cost data from Bloom et al. (11)
COPD ⁱ	BOLD ^j study (20)
Diabetes	International Diabetes Federation Diabetes Atlas 2010 (21)
Treatment cost (Peru)	
Cancer	Adjusted data from Kim et al. (19)
CVD	PAHO
COPD	BOLD study (20)
Diabetes	PAHO
Treatment cost (Jamaica)	Final report of the development of NCD ^k national health subaccounts (2012)
Scaling factors	Calculated using DALY data
Population	ILO ^l
Labor	ILO
χ^m	Assumed to be 10% for each country

^a WHO = World Health Organization.

^b PAHO = Pan American Health Organization.

^c IHME = Institute for Health Metrics and Evaluation

^d YLL = years of life lost

^e YLD = years of life lived with disability

^f GHE = global health estimates

^g DALY = disability-adjusted life years

^h CVD = cardiovascular disease

ⁱ COPD = chronic obstructive pulmonary disease

^j BOLD = burden of obstructive lung disease

^k NCD = noncommunicable diseases

^l ILO = international labor organization

^m χ = the proportion of savings that goes towards either treatment or intervention costs. Note: following the WHO EPIC model, we assume χ is 10% (i.e. 10% of treatment cost is diverted to savings when diseases are eliminated (in the counterfactual scenario)).

APPENDIX C. Supplemental tables for key results

TABLE A2. EPIC-H plus output for Costa Rica 2015–2030^a

Disease	Economic burden (billions of 2015 US\$)
Diabetes	4.88
Cardiovascular disease	7.69
Respiratory disease	16.44
Cancer	6.48
Mental health conditions	15.26
Total NCDs and mental health conditions ^b	81.96

^a Estimates are from the baseline case, which uses WHO mortality data and assumes exponential mortality rate growth.

^b Total NCDs include cardiovascular diseases, cancer, chronic respiratory diseases, cirrhosis, digestive diseases, diabetes, urogenital diseases, blood diseases, endocrine diseases, musculoskeletal disorders and other non-communicable diseases including congenital anomalies, skin and subcutaneous diseases, sense organ diseases and oral disorders.

TABLE A3. EPIC-H plus output for Jamaica 2015–2030^a

Disease	Economic burden (billions of 2015 US\$)
Diabetes	2.48
Cardiovascular disease	3.83
Respiratory disease	1.03
Cancer	2.52
Mental health conditions	2.76
Total NCDs and mental health conditions ^b	18.45

^a Estimates are from the baseline case, which uses WHO mortality data and assumes exponential mortality rate growth.

^b Total NCDs include cardiovascular diseases, cancer, chronic respiratory diseases, cirrhosis, digestive diseases, diabetes, urogenital diseases, blood diseases, endocrine diseases, musculoskeletal disorders and other non-communicable diseases including congenital anomalies, skin and subcutaneous diseases, sense organ diseases and oral disorders.

TABLE A4. EPIC-H plus output for Peru 2015–2030^a

Disease	Economic burden (billions of 2015 US\$)
Diabetes	19.81
Cardiovascular disease	39.90
Respiratory disease	93.81
Cancer	30.78
Mental health conditions	99.52
Total NCDs and mental health conditions ^b	477.33

^a Estimates are from the baseline case, which uses WHO mortality data and assumes exponential mortality rate growth.

^b Total NCDs include cardiovascular diseases, cancer, chronic respiratory diseases, cirrhosis, digestive diseases, diabetes, urogenital diseases, blood diseases, endocrine diseases, musculoskeletal disorders and other non-communicable diseases including congenital anomalies, skin and subcutaneous diseases, sense organ diseases and oral disorders.

APPENDIX D. Sensitivity analysis

For data on the mortality rate associated with each disease, we have three sources: the WHO, the Institute for Health Metrics and Evaluation (IHME), and PAHO.

For each data source, we consider three cases for forecasting the mortality rate:

- 1) the exponential case, which assumes the mortality rate growth trend is exponential and that the mortality rate in 2014–2030² follows the same growth rate as the mortality rate in 2005–2013
- 2) the constant case, which assumes the mortality rate in 2014–2030 is the same as that in 2013
- 3) the linear case, which assumes the mortality rate growth trend is linear and that the mortality rate in 2014–2030 follows the same growth rate as the mortality rate in 2005–2013

We generate a set of four estimates for each case and for each data source:

- 1) an estimate that includes the morbidity effect of NCDs and mental health conditions and where the treatment cost for NCDs and mental health conditions is nonzero
- 2) an estimate with a morbidity effect but zero treatment cost
- 3) an estimate with no morbidity effect and a nonzero treatment cost
- 4) an estimate with neither a morbidity effect nor a treatment cost

Therefore, there are 36 sensitivity analyses for each country.

For the baseline scenario (discussed in the Results section), we use the WHO mortality data and assume an exponential mortality rate growth with a morbidity effect and a nonzero treatment cost. This choice is made for several reasons. First, the assumption that the mortality rate in 2014–2030 will follow the same growth rate as the mortality rate in 2005–2013 is more realistic than the assumption that the mortality rate will remain at the 2013 level, since it is apparent from the data that the mortality rate has changed over time in the

² Notice that our projection period for output loss is still from 2015–2030, but here we need to do data processing starting from 2014.

past. Second, treatment costs are, of course, nonzero in the real world. Finally, effective labor supply and thus output are both clearly affected by morbidity.

The results are similar and robust across different projection methods and data sources

Figures A1 through A6 compare total and per capita output losses due to NCDs and mental health conditions across different mortality rate forecasting assumptions: WHO data with the exponential mortality projection, WHO data with the constant mortality projection, and WHO data with the linear mortality projection. No substantial differences exist between cases that use different mortality projections.

Figures A7 through A12 compare total and per capita output losses due to NCDs and mental health conditions across different mortality data sources: WHO data with the exponential mortality projection, IHME data with the exponential mortality projection, and PAHO data with the exponential mortality projection. The differences between cases using different data sources are small for Costa Rica and Jamaica. For Costa Rica, the output loss using IHME mortality data is slightly higher than that using PAHO mortality data and that using WHO mortality data. For Jamaica, the output loss using PAHO mortality data is the highest. Because WHO and IHME have a higher number of deaths than the PAHO data for the initial part of the study period but not throughout the period as a whole, the growth rate under an exponential mortality projection is likely to be higher when using PAHO mortality data than when using the WHO or IHME data. This might explain why PAHO data give higher output losses than the other two data sources. For Peru, the output loss using IHME mortality data is substantially higher than that obtained using PAHO and WHO mortality data. That is because IHME data differ more substantially from PAHO and WHO data for Peru than they do for the other countries.

The impact of treatment cost and morbidity is quite substantial

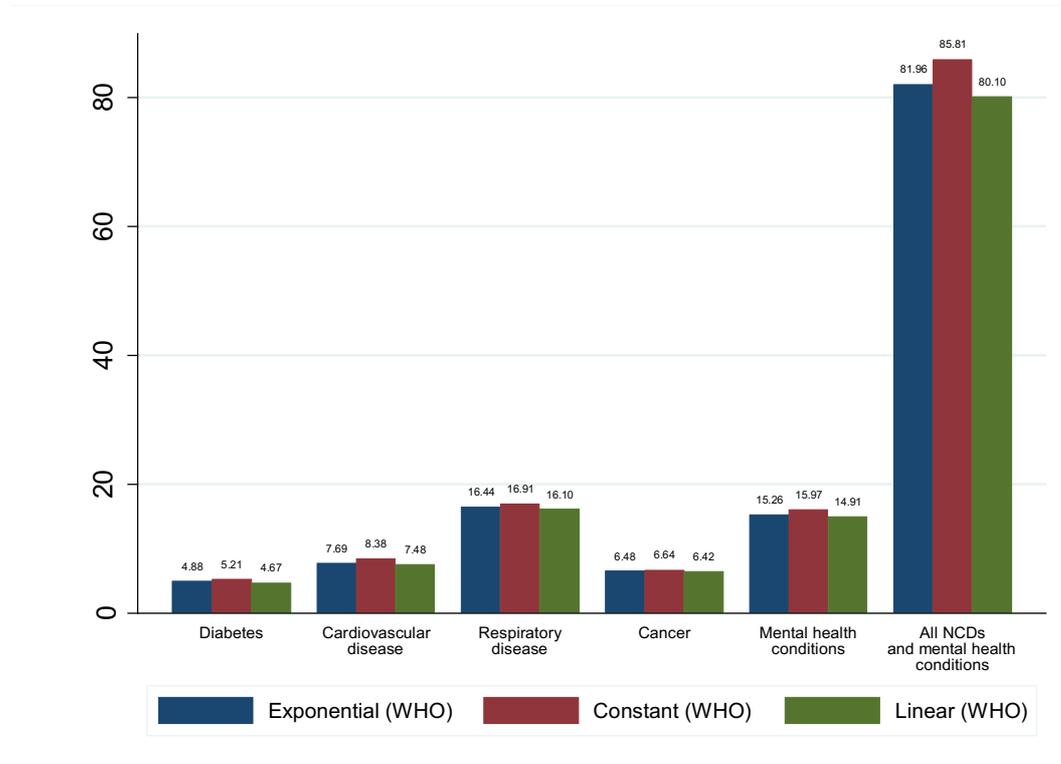
In the EPIC-H Plus model, we consider the impact of both treatment cost and

morbidity in addition to the impact of mortality, while EPIC considers only the impact of mortality. To illustrate the difference, we provide results for these cases:

- 1) both treatment cost and morbidity effects are considered
- 2) only the morbidity effect is considered
- 3) only the treatment cost is considered
- 4) neither treatment cost nor morbidity is considered

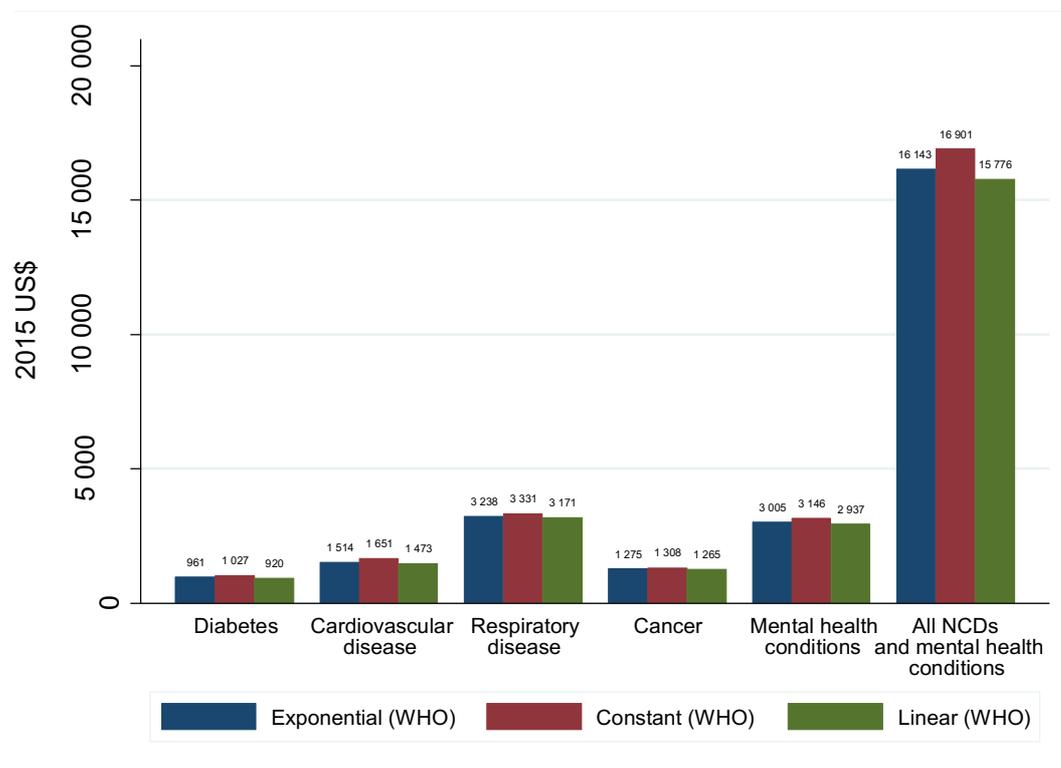
Figures A13 through A15 provide comparisons among these four cases. The output loss differences between Case 1 and Case 4 are US\$63 billion for Costa Rica, US\$8 billion for Jamaica, and US\$364 billion for Peru. These differences account for 76% of the total loss for Costa Rica, 45% for Jamaica, and 76% for Peru. This shows that treatment cost and morbidity substantially affect our estimates of the economic burden of NCDs and mental health conditions. Furthermore, we also conducted a decomposition, and, as Figures A16 and A17 indicate, we found that the total effect on output is larger when considering both morbidity and treatment costs than the sum of their separate effects. This is because the morbidity effect reduces the labor supply (L_t) at the same time that treatment cost reduces the stock of physical capital (K_t). From equation (1) we can see that these two effects are not additive, because output is a function of the product of $L_t^{1-\alpha}$ and K_t^α . This nonlinearity gives rise to the interaction effect that makes the combination of the two effects larger than their simple sum. We can also conclude that the effect of including morbidity in the model is greater than the effect of including treatment cost for Jamaica and Peru, while the reverse is true for Costa Rica.

FIGURE A1. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate assumptions in Costa Rica, 2015–2030



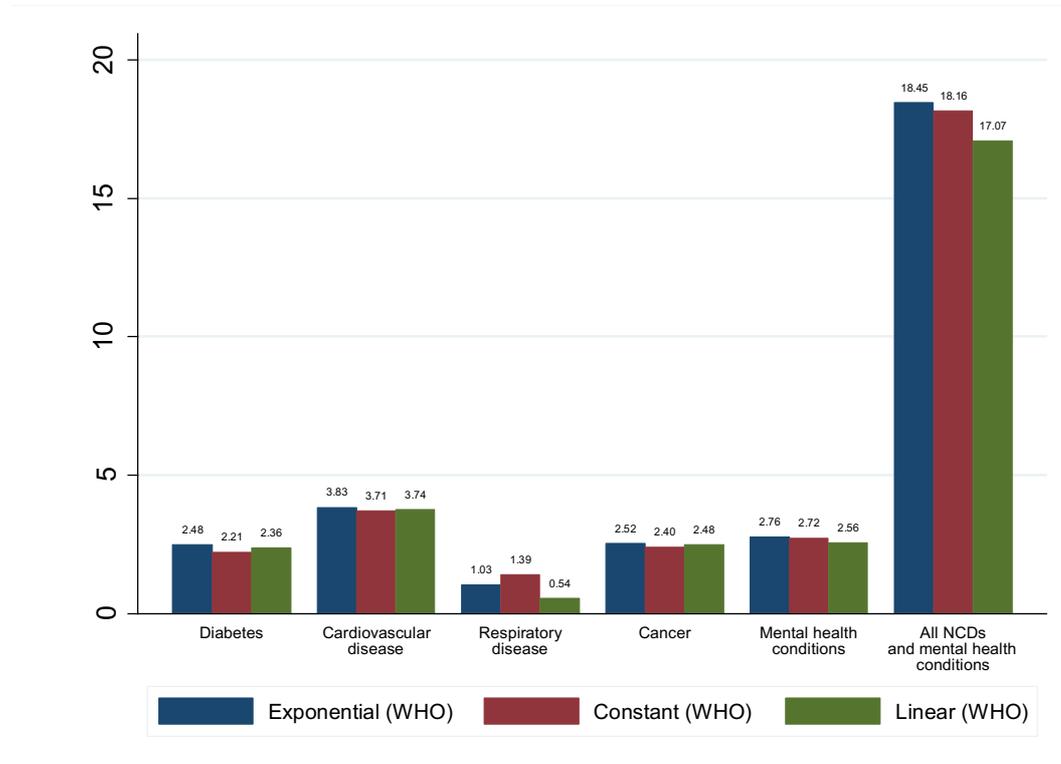
Source: Prepared by the authors based on the results of the study.

FIGURE A2. Estimates of lost gross domestic product (GDP) output per capita due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate assumptions in Costa Rica, 2015–2030



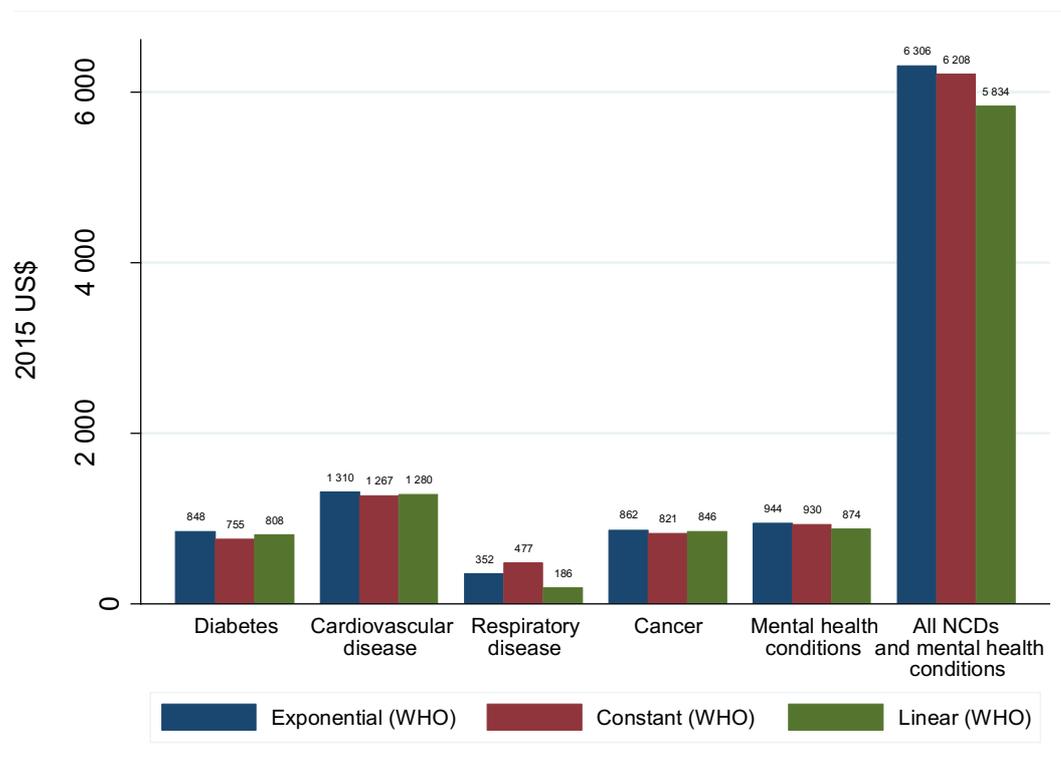
Source: Prepared by the authors based on the results of the study.

FIGURE A3. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate assumptions in Jamaica, 2015–2030



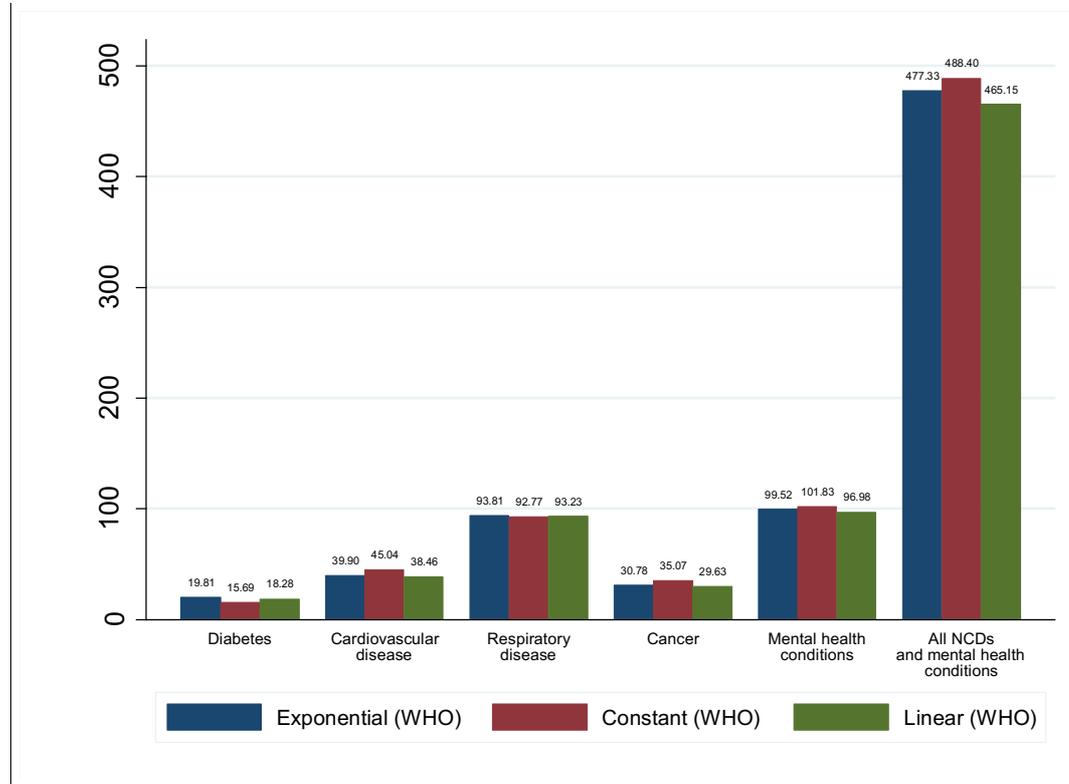
Source: Prepared by the authors based on the results of the study.

FIGURE A4. Estimates of lost gross domestic product (GDP) output per capita due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate assumptions in Jamaica, 2015–2030



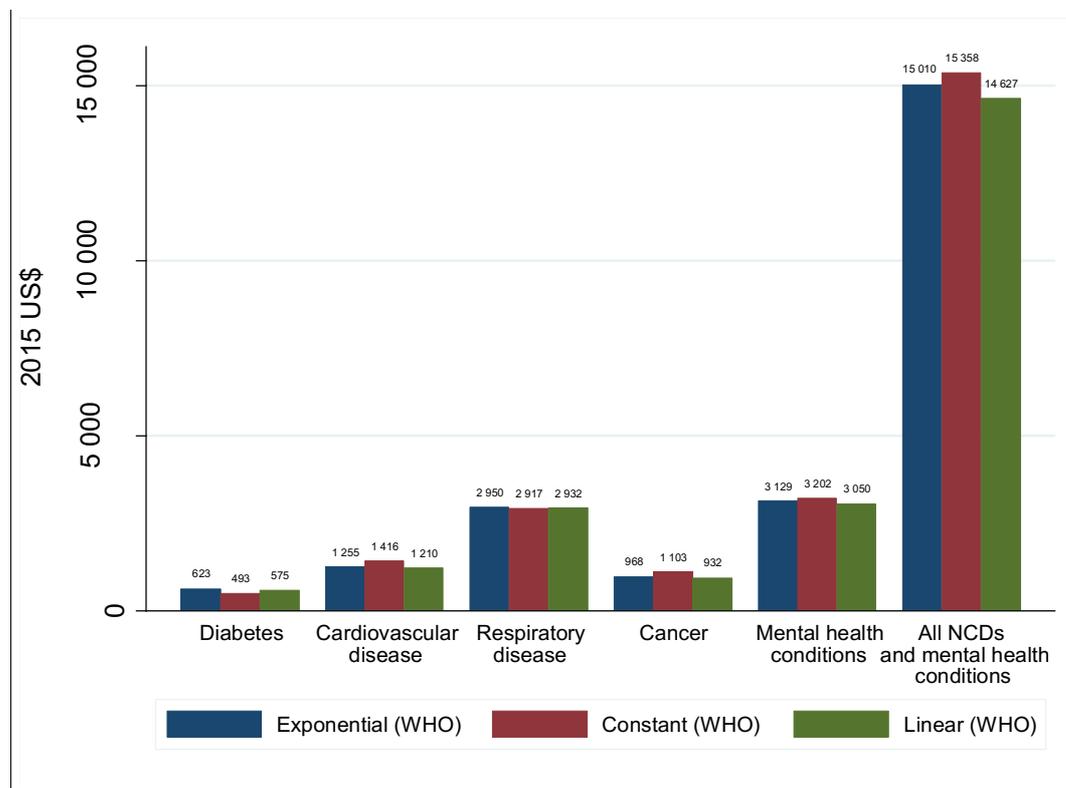
Source: Prepared by the authors based on the results of the study.

FIGURE A5. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate assumptions in Peru, 2015–2030



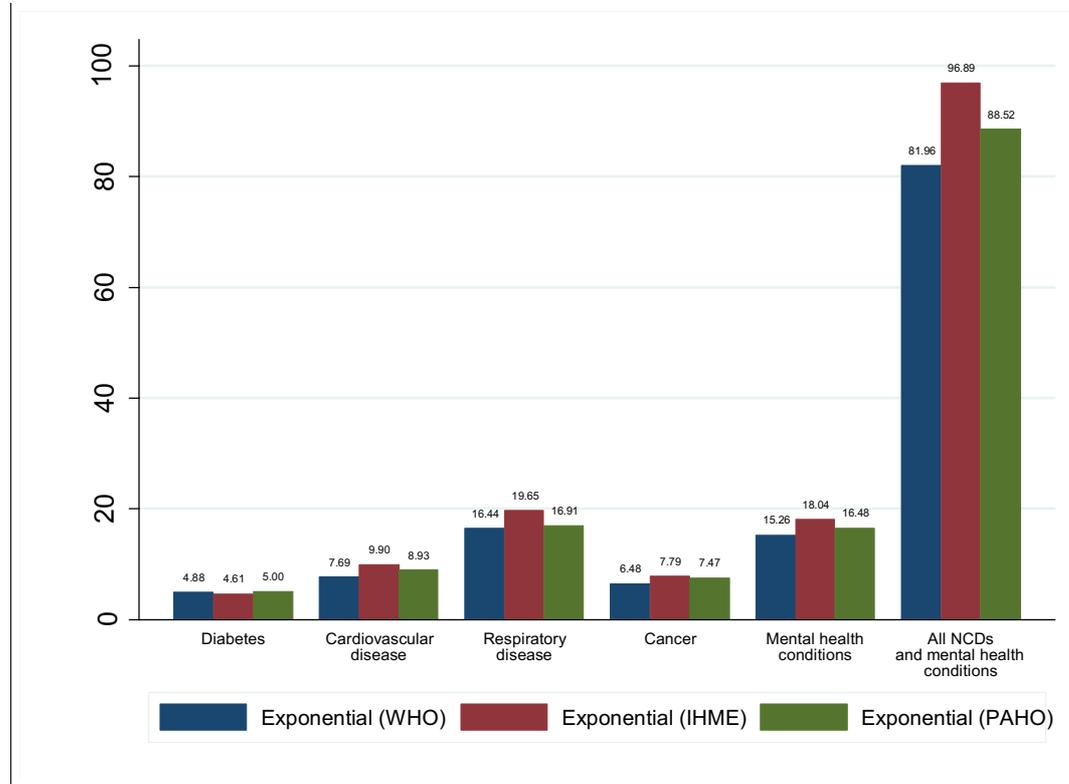
Source: Prepared by the authors based on the results of the study.

FIGURE A6. Estimates of lost gross domestic product (GDP) output per capita due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate assumptions in Peru, 2015–2030



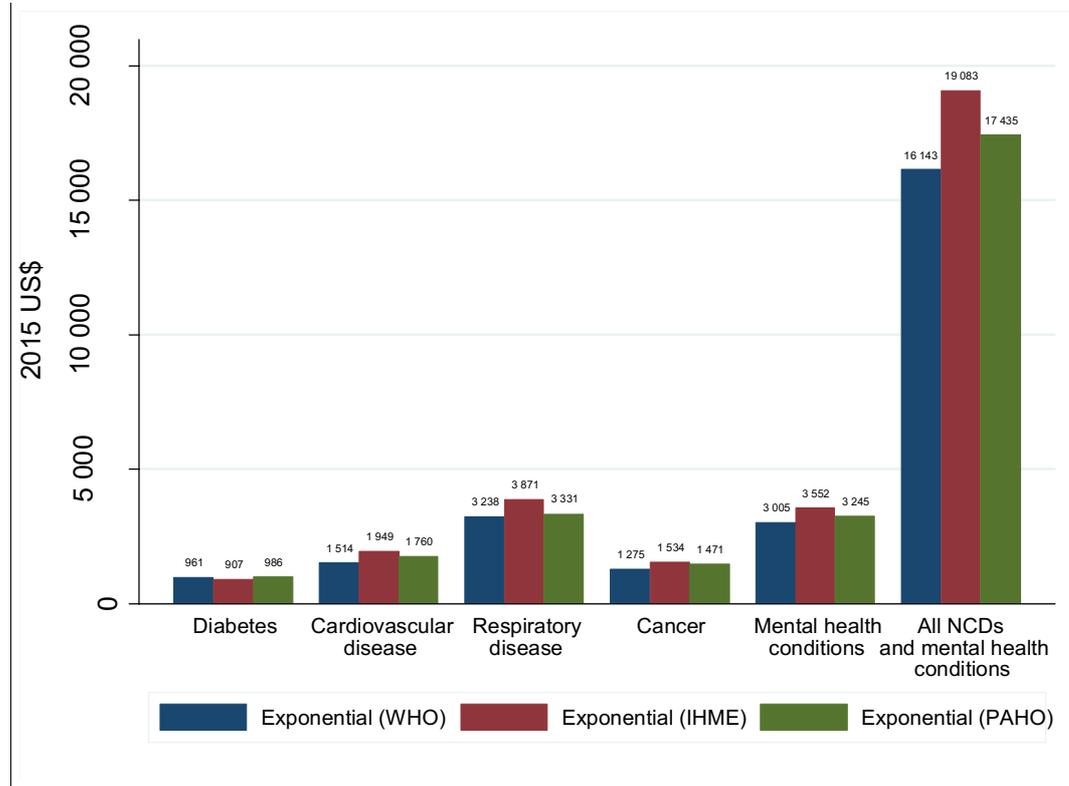
Source: Prepared by the authors based on the results of the study.

FIGURE A7. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate data sources in Costa Rica, 2015–2030



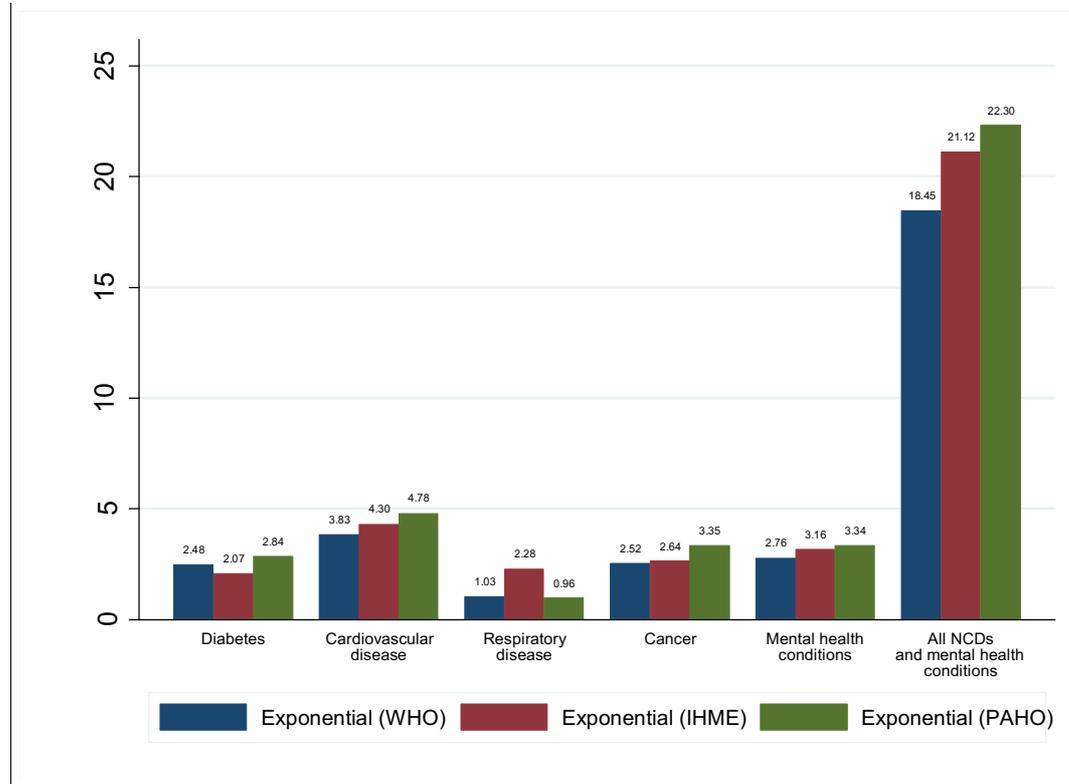
Source: Prepared by the authors based on the results of the study.

FIGURE A8. Estimates of lost gross domestic product (GDP) output per capita due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate data sources in Costa Rica, 2015–2030



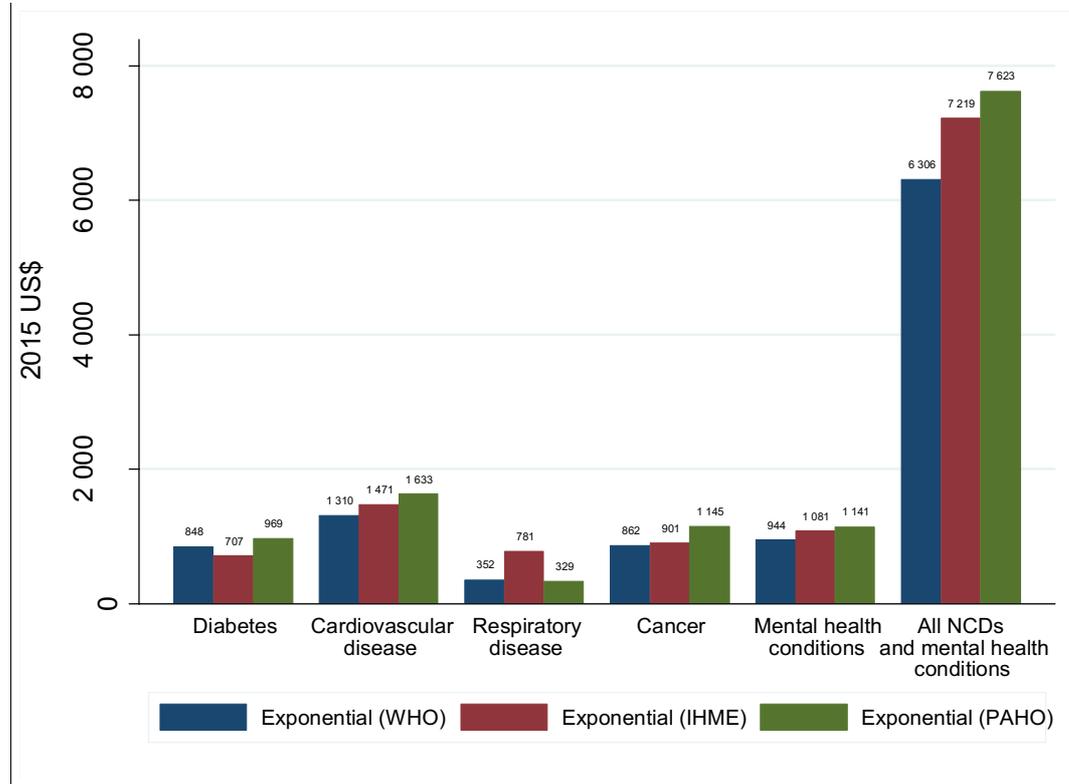
Source: Prepared by the authors based on the results of the study.

FIGURE A9. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate data sources in Jamaica, 2015–2030



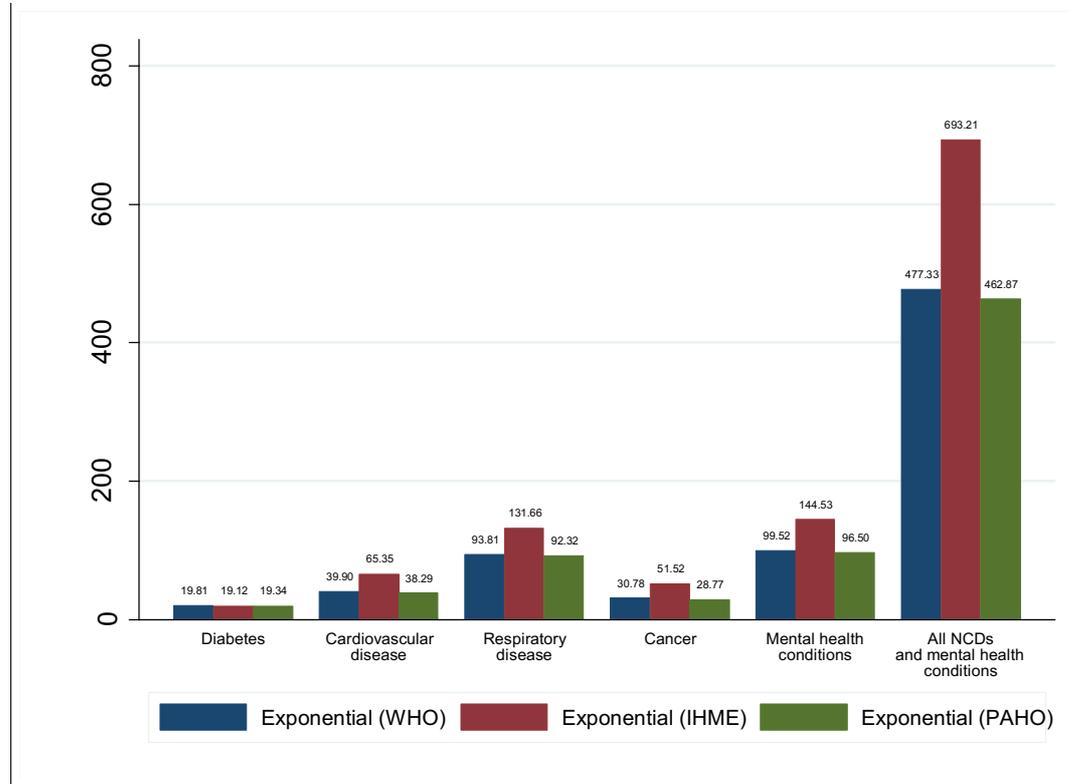
Source: Prepared by the authors based on the results of the study.

FIGURE A10. Estimates of lost gross domestic product (GDP) output per capita due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate data sources in Jamaica, 2015–2030



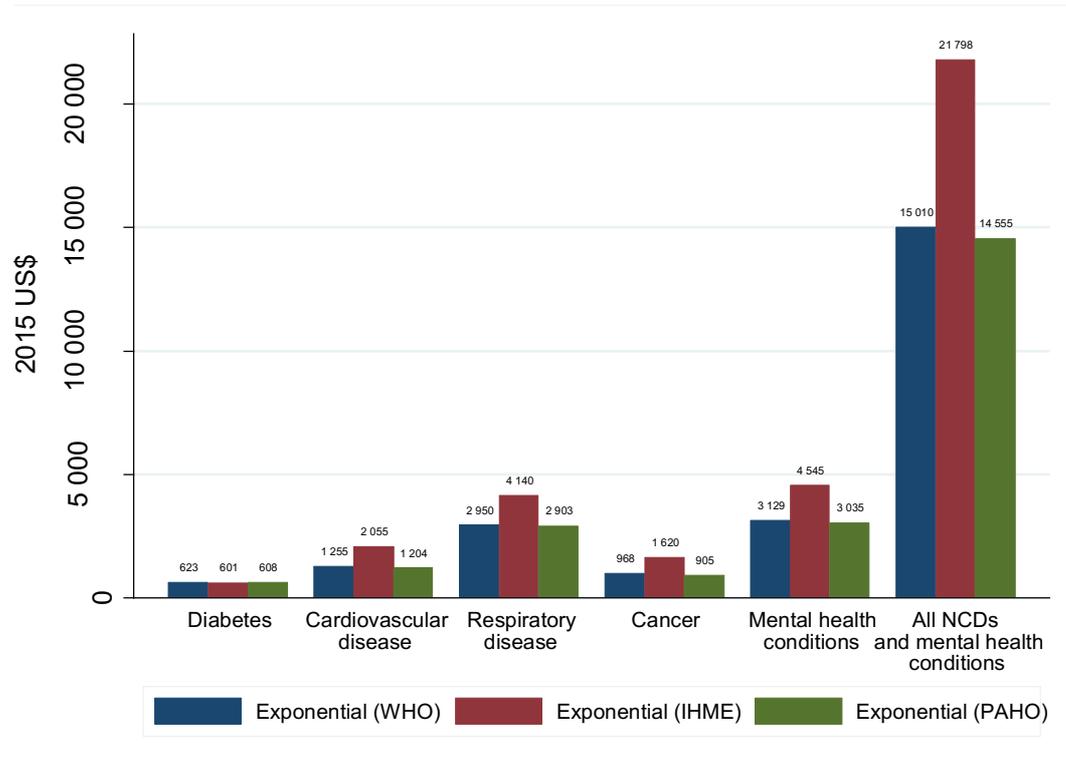
Source: Prepared by the authors based on the results of the study.

FIGURE A11. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate data sources in Peru, 2015–2030



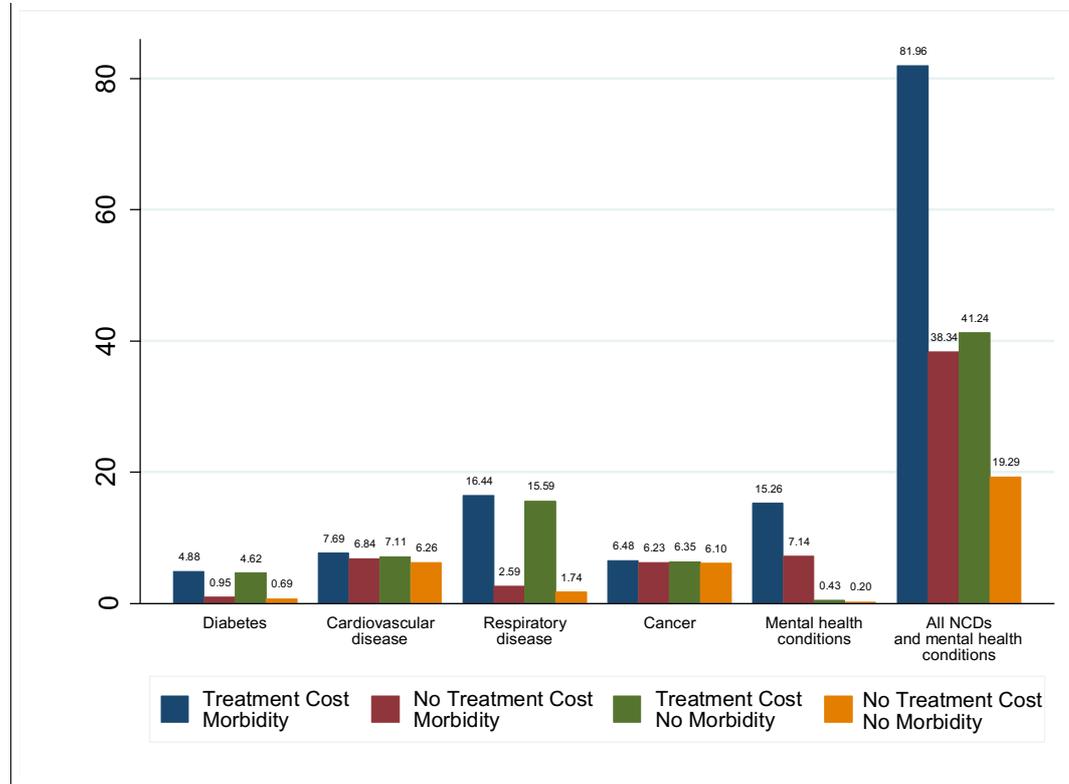
Source: Prepared by the authors based on the results of the study.

FIGURE A12. Estimates of lost gross domestic product (GDP) output per capita due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different mortality rate data sources in Peru, 2015–2030



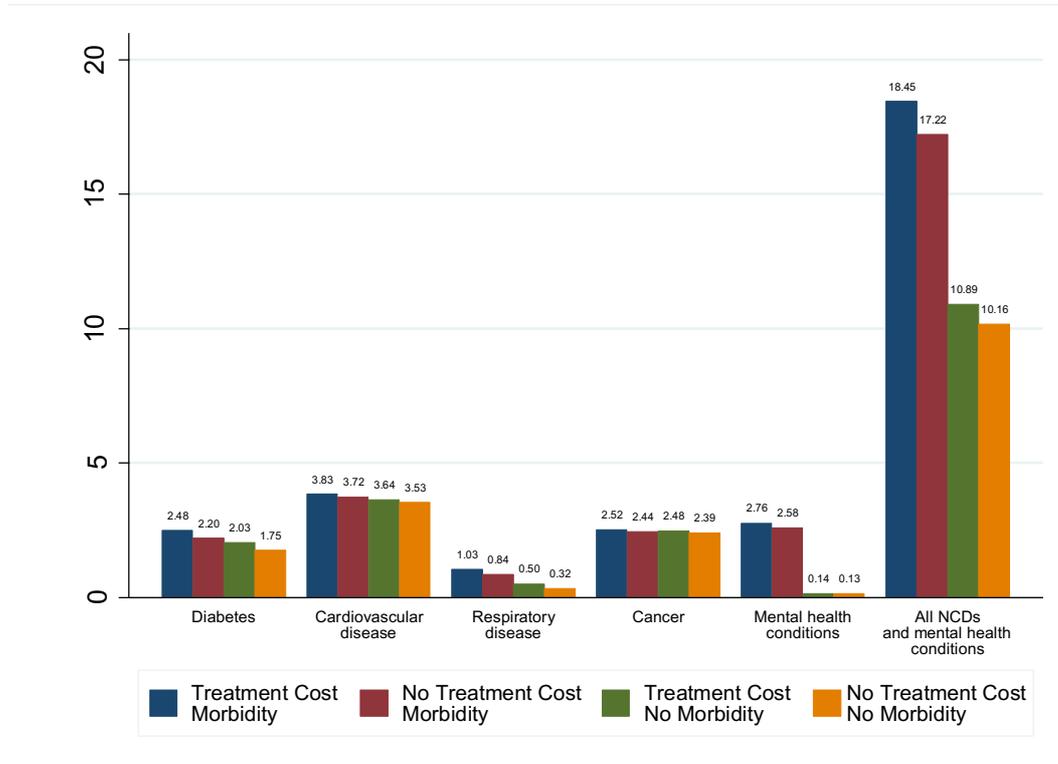
Source: Prepared by the authors based on the results of the study.

FIGURE A13. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different cases in Costa Rica, 2015–2030



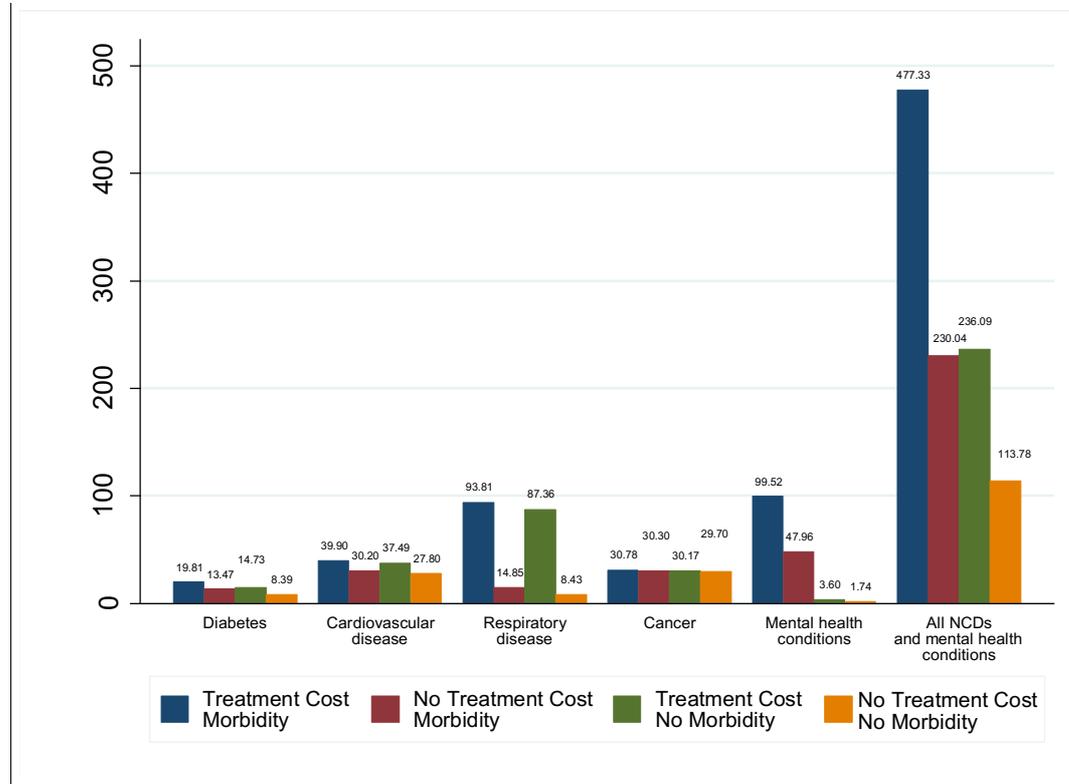
Source: Prepared by the authors based on the results of the study.

FIGURE A14. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different cases in Jamaica, 2015–2030



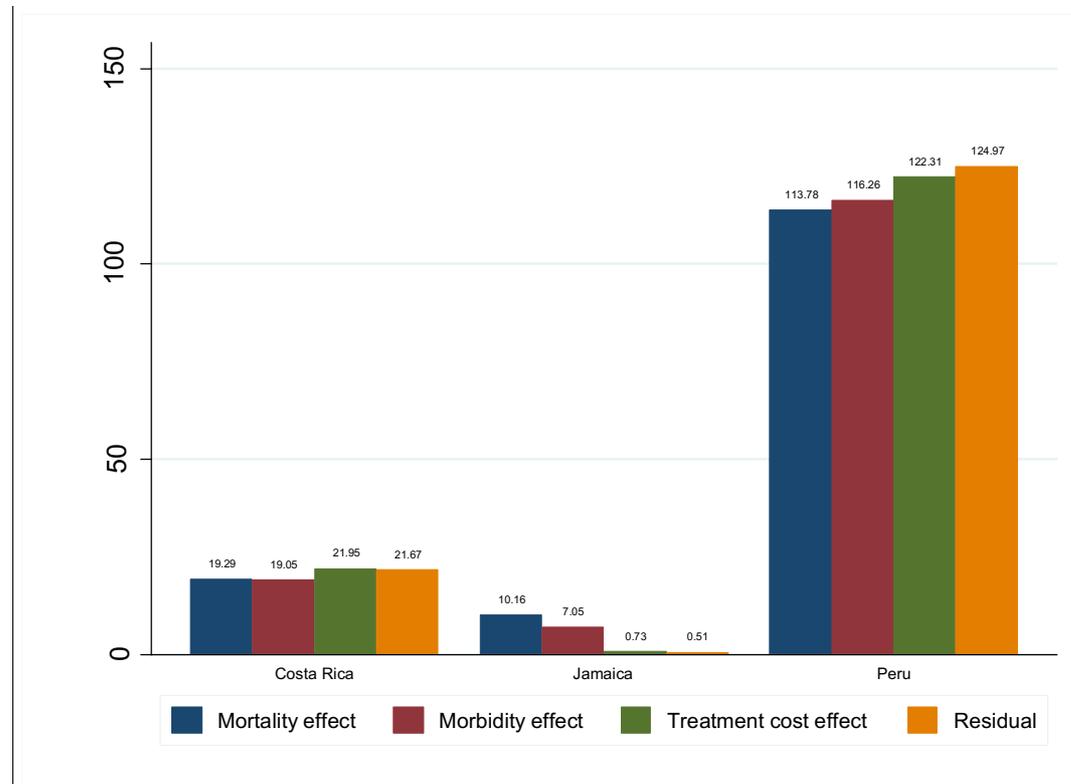
Source: Prepared by the authors based on the results of the study.

FIGURE A15. Estimates of lost gross domestic product (GDP) output due to four leading noncommunicable diseases (NCDs), mental health conditions, and all NCDs and mental health conditions across different cases in Peru, 2015–2030



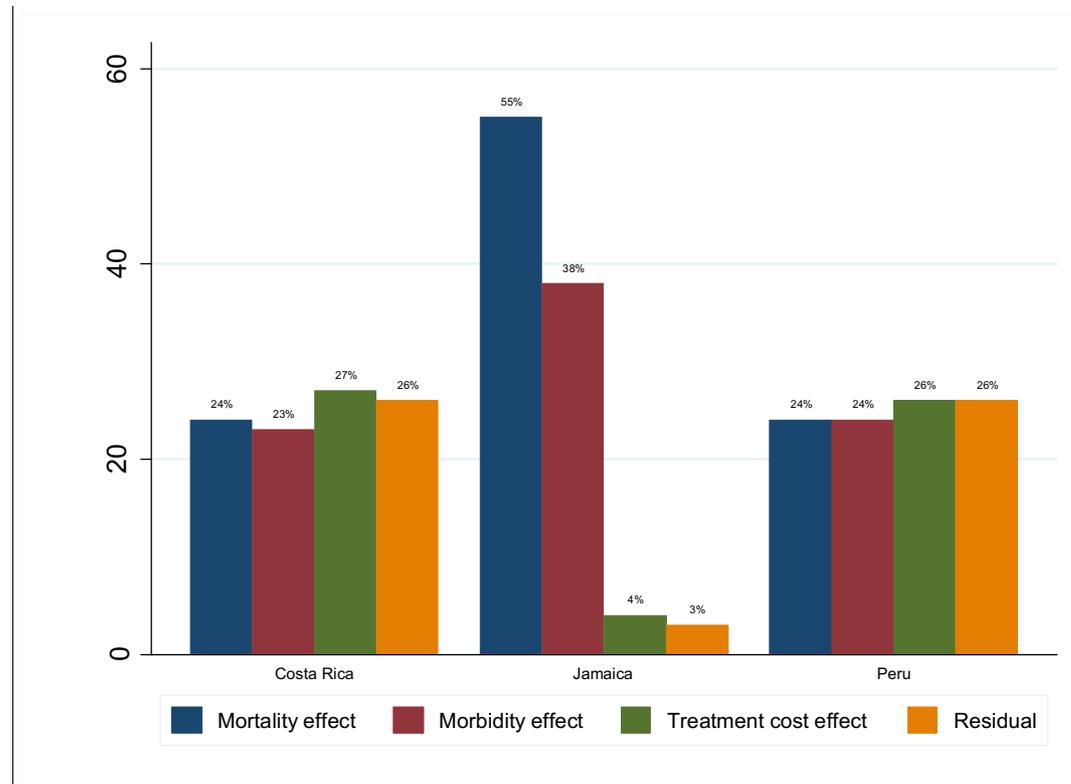
Source: Prepared by the authors based on the results of the study.

FIGURE A16. Decomposition of lost gross domestic product (GDP) output due to all NCDs and mental health conditions for three countries caused by various effects in absolute value, 2015–2030



Source: Prepared by the authors based on the results of the study.

FIGURE A17. Decomposition of lost gross domestic product (GDP) output due to all NCDs and mental health conditions for three countries caused by various effects as a percentage of total burden of disease, 2015–2030



Source: Prepared by the authors based on the results of the study.