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CAN THE WORLD'S POOR PROTECT THEMSELVES FROM THE NEW CORONAVIRUS?

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ABSTRACT

We propose an index of the adequacy of home environments for protection (HEP) from COVID-19, and we compare our index across developing countries using data for one million sampled households from the latest Demographic and Health Surveys. We find that prevailing WHO recommendations for protection posit unrealistic home environments. 90% of households have inadequate HEP by one or more dimensions considered. 40% do not have a formal health-care facility within 5km. A strong wealth effect is indicated within and between countries. Only 6% of the poorest 40% have an adequate HEP, and the proportion is virtually zero in sub-Saharan Africa.

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1. Introduction

In the absence of a vaccine or antiviral treatments, much emphasis has been given to the role of protective measures to reduce personal exposure to the new coronavirus (SARS-CoV-2) that leads to the life-threatening illness COVID-19.[2] In rich countries, the messages have got out reasonably well on how best to protect oneself from exposure to the virus. The World Health Organization's (WHO) detailed recommendations built on prior literature and experience, including from when the virus first appeared in Wuhan, China.[3] The WHO recommendations have been ratified by numerous national and provincial governments.

The prevailing recommendations have four main elements:

1. Learning: A fundamental requirement is to be able to receive reliable information on local disease incidence and protection measures.[4] Compliance with this recommendation requires some sort of access to communication tools: radio, TV, phone, the internet.
2. Isolating: Social distancing (maintaining at least one-meter separation) and lockdown (shelter-in-place) are now widely recommended. The idea is to lower the reproduction rate of the virus by reducing contacts per day. This requires both a personal behavioral response and suitable home-infrastructure. A dwelling with walls, a roof and closures is clearly desirable. In settings with large (often extended) families, intra-household transmission becomes more important. This points to the advantage of a sufficiently low density of people in the dwelling. And there must be certain facilities; you can't isolate as effectively if you have to leave the dwelling or yard to go to the toilet, for example.
3. Washing: Regular hand washing with soap and water is strongly recommended by the WHO and national health authorities for protection from the virus. This too requires suitable facilities within the residence.
4. Treatment: If key symptoms (fever, difficulty breathing) develop, seeking medical help is recommended. Of course, this requires physical access to health-care facilities.

[2] A comprehensive review of current knowledge on the epidemiological and clinical aspects of the disease can be found in Huilan et al. (2020).
[3] A review of the lessons learnt in this period with bearing on protection can be found in Adhikari et al. (2020).
[4] For example, the WHO website lists as one of its recommendations: "Keep up to date on the latest information from trusted sources, such as WHO or your local and national health authorities." Also see the discussion in Huilan et al. (2020). The communication channel can also help assure community-level cooperation and tracking; for further discussion see Ravallion (2020).

The belief that these nonpharmaceutical measures can help contain the spread of illness is consistent with the available evidence.[5] We are seeing stabilization and even decline in the daily counts of confirmed new cases and deaths attributed to COVID-19 in a number of relatively rich countries.

Virtually all of these recommendations require that a household environment supports the capacity to protect from the virus—what we call the "home environment for protection" (HEP). The HEP is the result of past wealth-constrained choices, and these are unlikely to change quickly. Dwelling attributes such as its size, construction and location (determining access to treatment) cannot be easily adjusted in response to the immediate virus threat, and nor is health all that people care about when allocating their resources. Importantly, all of the aspects of the HEP mentioned above are likely to have a wealth effect, meaning that poorer households will have less capacity to follow WHO recommendations. This is to be expected between countries as well as within them.

Anecdotal observations and some empirical evidence from household surveys suggest that the world's poorest may well have little or no capacity to protect themselves from the virus. For example, it appears likely that a majority of the population of sub-Saharan Africa still do not have access to water on their own premises, and this tends to be higher in poorer countries and regions within countries, especially rural areas.[6] By contrast, in the US (say) over 99% of the population have piped water within their homes, though with concerns about water quality (McGraw and Fox, 2019).

These and other observations have led some to question whether the current policies used to address the new pandemic are transferable to developing countries, and particularly to poor people (Andrew et al., 2020; Jones et al., 2020; Ravallion, 2020). Furthermore, the new virus is known to be quite infectious in the absence of the protective measures summarized above.[7] Thus,

[5] For further discussion see Prem et al. (2020) for China and Flaxman et al. (2020) for Europe. A useful compilation of the available evidence on the incidence and death rates from COVID-19 can be found in Roser et al. (2020).
[6] JMP (2019) provides evidence for selected countries consistent with this claim. Also see the map of the global incidence of facilities for handwashing at home in Andrew et al. (2020).
[7] In the absence of interventions for social distancing, estimates of the number of people in a population without immunity that are expected to catch the virus from one infected person have been in the region of 2-3 (Huilan et al. 2020). Anderson et al. (2020) point to the long transmission period for COVID-19 (around 10 days) and the high proportion of mild or asymptomatic cases (approximately 80%), both of which contribute to the spread of the disease.

the virus could spread even more rapidly among poor people in the world than we have seen in the rich world. This is a broad concern for the population as a whole, as with any contagious disease. Poor people living in circumstances that provide little or no HEP may well become the incubators for spreading the virus to the rest of the population. Data from COVID-19 tests are more scarce for developing countries, but we are seeing rising incidence and deaths in many of those countries.[8]

Exacerbating matters are the likely behavioral responses to the WHO recommendations. Even if full compliance is feasible given the dwelling and possessions, being poor in terms of income or wealth can be expected to reduce the capacity to survive in isolation for anything more than a short period (as discussed further in Ravallion, 2020). For informal-sector workers in countries with limited social protection, staying home is likely to entail a potentially devastating loss of income.[9] Poverty itself diminishes the capacity to isolate and hence protect one's family from the virus.

So, there is both a direct wealth effect on the capacity to protect and an indirect effect via the attributes of the home environment relevant to implementing the prevailing recommendations for protection. Social protection policies in response to the pandemic focus primarily on the direct effect, by aiming to support consumption (especially of food) while in isolation. Many developing countries are doing this, or gearing up for that task, although based on past evidence on the effectiveness of social protection policies in reaching the poorest, one might be justifiably skeptical about how well this will work in the pandemic.[10]

The task of this paper is to systematically assess the adequacy of the home environments for protection from the virus in the developing world. We provide a definition of the HEP concept, and we propose an index of HEP adequacy, which we implement for as many developing countries as possible, with the required data since 2010. Our index allows for either partial or full compliance with a set of attributes of the home environment that we identify as

[8] Roser et al (2020) provide data compilations consistent with this claim, with suitable caveats, especially on testing.
[9] Early reports from India, which imposed a lockdown across the country in late March, suggest that tens of millions of migrant workers have lost their incomes.
[10] At the time of writing, about two-thirds of the world's countries have implemented some form of cash transfers in response to the pandemic (Gentilini et al. 2020). Of course, many of these are existing programs (maybe with re-labelling) and coverage may quite limited, with large exclusion errors. For evidence on past effectiveness in reaching the poorest through social protection spending see Margitic and Ravallion (2019).

being desirable for implementing the WHO recommendations. A specific focus of the paper is the strength of the wealth effect on HEP adequacy between and within countries. A positive wealth effect is to be expected; greater household wealth is very likely to support a home environment that is better able to protect someone from the virus. But how strong is this effect? In particular, how effectively can the wealth poor protect themselves, and how does this differ between countries? Our approach allows us to assess to what extent the dwelling-related circumstances of the home environment reinforce the direct wealth effect on capacity to protect from the virus.

This provides a new window on how the context of global poverty is likely to interact with the pandemic. It also carries an important policy implication: if poor families have low HEP, then complementary policies will be needed to try to assure protection from the virus. The challenges in supporting the food system and the command over food of poor people has been emphasized in recent policy-oriented discussions, as reviewed in Ravallion (2020). Cash and food transfers are now being used by many countries as part of their policy responses to the pandemic (Gentilini et al. 2020). However, if inadequate HEP is a major concern, then this points to new policy challenges.

Using the Demographic and Health Surveys (DHS) done over the last 10 years across 54 countries, we demonstrate that there is a significant wealth effect on HEP in the developing world. Among the poorest, the HEP is so deficient as to raise a serious doubt that there is any credible prospect of comprehensive compliance with current recommendations for protection from the virus. A strong wealth effect is also evident across developing countries, with households living in lower-income countries showing a diminished capacity to protect themselves from the disease.

In response to this, it might be conjectured that once infected, currently known risk factors for developing extreme symptoms and death from COVID-19 are low for the poor, thus attenuating concerns about the need for pro-poor protection from the virus. Older individuals have been found to be more susceptible to death from the virus.[11] The youthful demographic

[11] Wu et al. (2020) estimate that the symptomatic case-fatality rate in Wuhan, China, is five times higher for those aged 60 years and older relative to those aged between 30-59 years. Onder et al. (2020) find similar case-fatality rates by age for Italy, particularly for adults over 70 years of age.

profile of the developing world may reduce death rates (though not COVID mortality counts, noting that two-thirds of those living over 65, say, live in non-high-income countries). To address this issue, we also provide evidence on the wealth effects on identifiable COVID-19 risk factors, such as age and incidence of obesity. Our findings do not suggest that the poor are less likely to bear the full brunt of COVID-19.

The following section outlines our economic model for interpreting HEP. Section 3 describes our data and methods, while Section 4 presents our results; an online Appendix provides more detail. Section 5 concludes.

2. An economic interpretation of HEP

To help motivate the empirics we provide a simple economic interpretation of HEP and draw out some implications for its wealth effect. This is a straightforward application of consumer theory, modified to allow for the potentially nonlinear cost function for the key dwelling attributes relevant to HEP.

Let $\boldsymbol{Z} = (Z_1, .., Z_\mathrm{K})$ denote a K-vector of non-negative housing attributes that describe the relevant aspects of the home environment, as required for the trilogy of learning, isolating and washing, in response to the threat posed by the new coronavirus. The cost of a bundle of these attributes is denoted $C(\boldsymbol{Z})$, with $C(\boldsymbol{0}) = 0$ and the function C is strictly increasing in all arguments. We can interpret an adequate HEP as the attainment of a specific bundle of these home environment attributes, namely $\boldsymbol{Z}^{\min} = (Z_1^{\min}, .., Z_K^{\min})$ with $Z_i^{\min} \geq 0$ for all *i*. Full compliance with the WHO recommendations requires that $Z_i \geq Z_i^{\min}$ for all *i*. We can also consider partial compliance for some subset of the elements of $\boldsymbol{Z}$.

By the "wealth gradient of HEP," we refer to how the relevant elements of $\boldsymbol{Z}$ vary with household wealth W. Consider the wealth gradient for HEP that one would observe when $\boldsymbol{Z}$ is optimal given W, assuming that this is the case at the outset of the pandemic. People clearly do not maximize their health, though it obviously matters a lot to them. We can expect that the household derives utility from its health status, H, but also from $\boldsymbol{Z}$ directly as well as household consumption of other goods, represented by the vector $\boldsymbol{X}$. Utility is increasing in all arguments. Health status depends (positively) on both $\boldsymbol{Z}$ and $\boldsymbol{X}$; given our focus on COVID-19 we can also assume that health gain from $\boldsymbol{Z}$ depends on its value relative to $\boldsymbol{Z}^{\min}$. The elements of $\boldsymbol{X}$ have prices $\boldsymbol{P}$. The available wealth, W, is to be allocated between $\boldsymbol{Z}$ and $\boldsymbol{X}$, taking account of the effects on H. Standard continuity and curvature assumptions about the utility and health production functions imply interior solutions, though we also consider corner solutions.[12] We can write the solutions for the HEP goods in the generic form:

$$\boldsymbol{Z} = \boldsymbol{Z}(W, \boldsymbol{P}, \boldsymbol{Z}^{\min}) \qquad (1)$$

Compliance with the recommendations requires that $Z_i(W, \boldsymbol{P}, \boldsymbol{Z}^{\min}) \geq Z_i^{\min}$ for $i = 1, .., \mathrm{K}$.

As usual, the comparative statics will depend on the properties of preferences (represented by a utility function), the health production function, the cost function and the prices. It would clearly be a restrictive special case to have no wealth effect; rather, it would be more reasonable to assume that $\boldsymbol{Z}$ varies positively with W, though (as usual), nothing we have assumed above precludes the possibility that $\boldsymbol{Z}$ includes inferior goods. Little more can be said in general. A special case would be Cobb-Douglas utility and health production functions and a linear cost function. Then the share of wealth devoted to $\boldsymbol{Z}$ would be a constant for given parameter values of the underlying Cobb-Douglas functions. With constant parameters, expenditure on $\boldsymbol{Z}$ is linear in wealth, and the wealth gradient for $\boldsymbol{Z}$ would be positive for all elements of $\boldsymbol{Z}$ with the size of the gradient depending on the Cobb-Douglas parameters.

Some households will be able to comply with the recommendations for protection, some not. Non-compliers include corner solutions for the HEP goods, namely that $\boldsymbol{Z} = \boldsymbol{0}$. Here the cost function for household infrastructure is likely to play an important role. Many of the things recommended for protection against the virus entail sizeable fixed costs, such as in creating solid walls and ceilings, and plumbing or some other form of water system. As a result, large fixed costs imply that there is some positive minimum level of wealth below which none of the goods required will be present. In more formal terms, we can imagine that the cost function has a discontinuity at zero (with $C(\boldsymbol{\varepsilon}) > 0$ for a vector $\boldsymbol{\varepsilon}$ comprising infinitely small values). Then at sufficiently low levels of wealth, the household will be better off choosing $\boldsymbol{Z} = \boldsymbol{0}$. We can think of this as "homelessness," although it is also consistent with the existence of a home but one that is missing some or all of the dwelling attributes required for an adequate HEP. Of course, non-

[12] Interior solutions are implied by strict quasi-concavity of utility in $\boldsymbol{X}$ and $\boldsymbol{Z}$ (allowing H to vary) and that $C(\boldsymbol{Z})$ is continuously weakly quasi-convex in $\boldsymbol{Z}$.

compliers could also be found among interior solutions. If $W < C(\boldsymbol{Z}^{\min})$ then that household will not be able to follow the recommendations fully, and so will be more exposed to the virus.

In taking these concepts to the data, we define the HEP-adequacy index (I^k) as the proportion of the relevant population of size N that satisfy any $k \leq$ K of the identified categories of HEP attributes:

$$I^k = \frac{1}{N}\sum_{j=1}^{N} \mathbb{I}(Z_{ij} \geq Z_i^{\min} \text{ for at least } k \leq \text{K values of } i) \ (k = 1, .., \text{K}) \quad (2)$$

We also provide the shares of the population satisfying each element separately ($\frac{1}{N}\sum_{j=1}^{N} \mathbb{I}(Z_{kj} \geq Z_k^{\min})$) and the corresponding mean share.

The rest of the paper studies HEP empirically for the developing world, subject (of course) to the limitations of our data.

3. Data and methods

We draw on data from the Demographic and Health Surveys (DHS) and the Service Provision Assessment (SPA) surveys, both administered by USAID. This discussion focuses first on the DHS. We only use DHSs conducted in the last 10 years, which gives us data on 1.05 million sampled households spanning 54 countries over 2010-2018, with half the surveys completed since 2014.[13] DHS comprehensively covers sub-Saharan Africa (SSA, with 31 surveys), with surveys also from Central and South America (6 surveys), Asia (9 surveys), and the Middle East, Eastern Europe, and North Africa (8 surveys). (The Appendix gives further details by country.)

The DHS focuses on the health and demographic characteristics of households, but also has detailed data on the household's infrastructure, as relevant to assessing the quality of the HEP. A limitation of the DHS (in common with many surveys) is that questions needed to measure wealth directly are not included. However, the DHS does include a household wealth index based on a household's assets and living conditions (following methods proposed by Filmer and Pritchett 2001). A number of studies have found that the DHS wealth index is a good

[13] In countries with older surveys, our results may well understate home environment capabilities, although for others, such as Yemen, where wars have since ravaged infrastructure, they may well overstate them.

predictor of various human capital and other household outcomes (Filmer and Pritchett 1999, 2001; Filmer and Scott 2012; Sahn and Stifel 2003; Petrou and Kupek 2010).

The DHS wealth index is constructed separately for each country, but using the same method. Following common practice, we group households into quintiles of the wealth index. However, it should be noted that since the index is country-specific, the same quintile does not imply the same absolute level of wealth across countries; rather it is a relative measure. We provide country-specific results as well. We use GDP per capita at Purchasing Power Parity for absolute inter-country wealth comparisons.

We identified six conditions to assess the ability to comply with prevailing recommendations for household protection from the virus, namely:

1. The household has at least one of the following: internet, a phone (land or mobile), TV, or radio. This is not strictly a recommendation for protection, but (as noted in the Introduction) it is implicit in the requirements for learning by receiving recommendations and related health and social protection announcements.
2. No more than two people per sleeping room. More than this, we assume that it would be difficult to implement the social distancing recommendations within the household. This is a judgement call on our part, though drawing the line at two people seems reasonable.
3. The household has a toilet and doesn't have to share it with other households. Without its own toilet it will clearly be harder for the household to implement social distancing.
4. The dwelling can be adequately closed, which we can interpret as the presence of walls and a ceiling.
5. The household has water piped into the dwelling or the yard, or some other private water source. This too reflects the potential for compliance with social distancing. Water is also required for hand washing.
6. The household has a place for handwashing with soap. This is a much-emphasized recommendation for protection from infection.

Data availability both across and within countries prevent us from measuring all of these conditions for all households. We use all the information available to us. For 40 of the 54 countries the HEP index uses all six conditions. For the rest we use the maximum number available.[14] When we come to the country-specific HEP indices we confine attention to the 40 countries in the main text, though we provide results using incomplete data for the other countries in the Appendix.

Given that our purpose is descriptive rather than causal, we do not make an effort to isolate the impact of exogeneous variation in wealth on HEP. We acknowledge, however, that the data generation processes are likely to impart a positive correlation, stemming from the fact that there is some overlap between the variables used in measuring the HEP and those used in the DHS wealth index. For example, the communication assets listed under Category 1 are often included in the DHS wealth index, as are water and toilet facilities.

We can make two observations in this regard. First, the overlap is far from complete. The DHS wealth index includes roughly 100 other variables that have no direct bearing on HEP, including ownership of the dwelling, having a kitchen, cooking fuel, electricity, livestock, ownership of a bank account and consumer durables such as a fridge, iron, watch, bicycle, motorbike and car.[15] These "non-HEP" variables account for almost 90% of the variance in the wealth index across the sample.[16] Second, we shall only use the quintile rankings by the wealth index, not their cardinal values. This will help attenuate any spurious correlation, as well as the usual concerns about measurement errors.

For the locational aspect of HEP we focus on proximity to a formal health-care facility.[17] The SPA covers formal health facilities, not including pharmacies and individual doctors' offices. It is a random sample and not representative at the cluster level, and in some cases, GIS coordinates in DHS have been displaced slightly for confidentiality.[18] Nor are survey year matchings exact (though as close as possible). So measurement error is expected. Furthermore, we only have nine countries with GPS coordinates as required to link up with the household

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[14] There are also missing values within countries for some households. As a result, there is minor heterogeneity within countries with respect to the number of conditions that can be measured.
[15] The DHS website provides details for the construction for the wealth index for each variable.
[16] The R^2 of the wealth index on the HEP index is 0.11.
[17] We considered including population density (people per square km) as a location attribute but chose not to do so. Our expectation is that the role of this variable is highly contingent on wealth and HEP adequacy. (Living in a Mumbai slum has different implications for vulnerability to infection to living in a Manhattan high-rise apartment, even though population densities are similar.)
[18] USAID's SPA website provides further details on this survey. Also see the discussion in Skiles et al. (2013). We followed Burgert and Prosnitz (2014) in linking the DHS and SPA data sets.

locations in the DHS.[19] For those countries, we ask whether the household's cluster (as used in the sample design) is within 5km (straight-line distance) of any sample facility in the SPA. (The Appendix also gives results for 10km.)

4. Results

We start with the index for the proximity of formal health-care facilities. The top panel of Table 1 provides the proportion of households within five km of a formal health-care facility by wealth quintile. We give results for both rural and urban areas and separately for "public-only" facilities since these are likely to matter more to poor people. 59% of households have a facility within 5km, and this drops to 50% for public health-care. In rural areas, the corresponding proportions are 46% and 36%. We see a marked wealth gradient here too, which is found in both urban and rural areas, though the difference is greater for poorer quintiles. The majority of the poorest 40% do not have a facility within 5km. The wealth effect remains when one controls for population density (Appendix).

The rest of this discussion focuses on the HEP index for dwelling attributes. Table 1 provides the average values of the six component variables going into the HEP index by country-specific wealth quintile (poorest=1) using the DHS data for 54 countries. In the developing world as a whole, fulfillment is greatest for the presence of a wall and roof and least for having a private water source. Coverage for the "learning" aspects of HEP is good, with almost 90% of households having at least one of the identified items.

A marked wealth gradient is evident for all six component variables, though with a stronger gradient for some than others. Half of those in the poorest quintile in SSA do not have any of the identified items for receiving health messages relevant to protection from the virus; in comparison, about one quarter of the poorest quintile in the rest of the developing world do not have that capability.

A number of the findings in Table 1 point to the difficulties of ensuring social distancing across the developing world. A majority of those in the poorest two quintiles have more than two people per room, do not have their own toilet (indeed, this is the case for the majority in SSA

[19] The countries are Bangladesh, DRC, Haiti, Kenya, Malawi, Namibia, Nepal, Senegal and Tanzania.

except for the richest quintile), and the vast majority across all wealth groups would have to leave their residence and yard for water.

Focusing on hand washing with soap (for which there is seemingly universal agreement on its importance among public health specialists, and is not included in the wealth index) we find that less than half (44%) the sampled households can comply across the developing world as a whole, and only 19% in SSA. Focusing on the poorest 40%, only 29% can comply for the developing world as a whole, falling to 10% in SSA (Table 1).

Turning to the HEP index, Table 1 provides its values for complete compliance by wealth quintiles and region. The overall HEP index is 14%. The index falls to 4% in sub-Saharan Africa; for the rest of the developing world the HEP index is 21%. As noted, some variables are missing for 14 countries (often the handwashing variable). For those, the HEP index is based on fewer variables, which tends to give a higher value. If we confine the calculation to the 40 countries for which we have all six categories, the HEP index falls to just 10%.

We find a strong wealth effect in the HEP index. For the poorest quintile in the developing world, the HEP index is only 4%, rising to 30% for the richest quintile (Table 1). Strikingly, among the poorest few quintiles in SSA, the HEP index is virtually zero. The index is also lower for poorer households in the rest of the developing world, though higher than for the same quintile in SSA.

This wealth effect in HEP is especially pronounced for SSA. The Appendix provides a full set of concentration curves (graphing the cumulative share of households who are able to attain full HEP by wealth percentile) by region. SSA and Asia show substantially higher inequality in the HEP index by wealth than other regions. For SSA, the bottom 80% of households represent less than 20% of all households that can comply with the recommendations for protection from the virus.

As in Equation (2), we also calculate the HEP index for partial compliance. Tables 2 and 3 provide I^k for $k < 6$ for countries which have non-missing values for all six variables (40 out of 54 countries). Table 2 gives the aggregate quintile values of the HEP index, while Table 3 gives the country-level results. (The online Appendix also shows the component variables by country.) Even if we only require that a household passes any four of the six conditions, this only occurs for about one half of the countries.

There is a large variance in the HEP index across countries. If we pool all wealth quintiles across all countries (n=310), we find that 70% of the variance in the HEP index is between countries. (The share accountable to the wealth quintile alone is 23%.) The HEP index for full compliance ($k = 6$) ranges from 0.003 in Liberia and the DRC to 0.746 in Armenia. Strikingly, only in Armenia does a majority of the population pass all six conditions for HEP; the Kyrgyz Republic is second, with 41% satisfying all six. (Where only five of the six variables are available, a majority of the population is also considered to have full HEP in Colombia and Egypt.[20]) For most countries, we find that households can protect themselves for any two of the six categories, which are typically the presence of a closed dwelling (with walls and a ceiling) and the media access variable. However, even for these (rather basic) variables, there are some countries with weak protection; for example, only 56% of the households in Liberia and 66% of those in Yemen have a dwelling with walls and ceiling (see Table A3 in the Appendix). At $k = 4$, we find that about half of the population as a whole pass (54%), but only 15 out of the 40 countries see a majority of their population satisfy 4 or more of the recommendations. When we switch from $k = 3$ to $k = 4$ we see a sharp decline in the HEP index for most countries and this drop off is very pronounced for the poorest two quintiles in SSA. Only 7% of the poorest quintile achieve 5 or 6 of the recommendations overall, and only 1% in SSA.

There is also a wealth effect on the HEP index across countries. Figure 1 plots the log HEP index (for $k = 6$) against log GDP per capita (at Purchasing Power Parity). The regression coefficient (interpretable as the cross-country income elasticity of the HEP index) is 0.93 (with a Huber-White standard error of 0.22 and R^2=0.33). The elasticity is significantly different from zero, but it is not significantly different from unity. Comparing the R^2 for a household-level regression of the HEP index on a complete set of country dummy variables with the R^2 for the regression on (log) GDP per capita alone, we find that 45% of the cross-country variance in mean HEP is attributable to differences in GDP.[21]

[20] See Table A3 in the Appendix for further details.
[21] The R^2 for the regressions are 0.288 and 0.131 respectively; n > 1 million. The regression coefficient on log GDP is 0.10 (t=399).

Figure 1 also gives the plot for $k = 4$. The income elasticity is appreciably lower at 0.43 (s.e.=0.09; R^2=0.30); it is now significantly less than unity, though still significantly positive. (Naturally the income elasticity goes to virtually zero for $k = 1$.)

One possible response to these findings is to question whether poorer households face the same risks once infected with the virus.[22] While they clearly have less capacity for protection, this would be less of an issue if they have appreciably fewer risk factors. There is only so far we can go in assessing this individual level attribute from these data. The DHS do identify some key variables at the individual level—age, obesity, HIV-positive or pregnant, heavy smoking—that are likely to be relevant although this is an incomplete accounting; for example, we do not know from the surveys if there is hypertension or diabetes. To be consistent, we only include countries for which there are both men's and women's surveys available.[23]

Table 4 provides summary statistics by wealth quintile for SSA on the variables for men and women 15 and older in the DHS that are likely to result in worse symptoms and often death from COVID-19. (The online Appendix provides the same table for the countries for which the data are available in other regions.) Some risk factors (obesity and being HIV positive) are less common among poorer households, but others (including age) show the opposite pattern. We find little to suggest that the poorest quintiles will be less vulnerable if they catch COVID-19.

5. Conclusions

The WHO and governmental recommendations for protection from the new coronavirus have been developed in relatively rich countries, where most people (though certainly not all) live in homes with the facilities—the attributes of a dwelling and its infrastructure—required for implementing the recommendations. A wealth effect is likely even within rich countries. However, the relevance of these recommendations is questionable in the context of many developing countries. Global poverty may well create a worrying degree of exposure to the virus.

The limited scope for poor people to be able to isolate without starving has been noted by a number of observers. Here we have focused on the limitations posed by the home environment.

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[22] Huilan et al. (2020) provide a review of what we currently know about the risk factors.
[23] Every DHS surveys women 15 to 49 years of age; however, fewer surveys also include a men's survey that has the variables relevant for our purposes.

Using the Demographic and Health Surveys done over the last 10 years, the paper has proposed and implemented an index for measuring the extent to which households in the developing world have home environments that provide the capacity to protect themselves from the virus by following the WHO-type recommendations. The DHS does not include everything one might like to have in our index, but it is clearly the best data source for our purpose, including for cross-country comparisons. Using the DHS wealth index and national accounts data, we have been able to explore the wealth effects on capacity to comply with these recommendations both between and within developing countries.

Our assessment indicates that 90% of households in the developing world cannot comply fully with the six conditions we have identified as being required for compliance with the WHO recommendations for protection from the virus. A majority can only achieve quite partial compliance. There is a strong wealth effect on our index, and the wealth effect is evident both within and between countries. When we focus on the poorest two quintiles of the wealth distribution, virtually no households in sub-Saharan Africa can comply fully, by our assessment, and the majority can only comply with a few very minimal requirements, such as the existence of a dwelling with walls and a ceiling, and the ability to at least receive relevant messages under isolation at home. Strikingly, the recommendation of having a place to wash hands with soap is not satisfied by the majority of households in the developing world overall, and only satisfied by one-in-five households in sub-Saharan Africa. Nor is it the case that Africa's poor are likely to be less vulnerable; the risk factors we can identify suggest that in some respects the poor are more likely to face serious illness if they catch the virus. The scope for protection among the poor looks better in the rest of the developing world, but even then, less than 10% can fully comply.

This analysis leads us to conclude that the developing world, and especially its poorest half, is ill-prepared to protect itself from this virus. For most households, the recommendations that have been implemented on a massive scale in the rich world must be considered near fiction for the world's poor. Given the contagion rate of this virus, the likely degree of exposure to be expected among a large segment of the population of the developing world also points to a serious concern for the entire population.

The housing stock cannot be changed rapidly. But there are still things that can be done now. The current infrastructure for information (particularly cell-phone coverage) holds promise for getting the messages out on public health and access to consumption support. Policies such as distributing or subsidizing soap and improved water access could be feasible in the near term, and justified by both the external benefits and the equity impacts. Home-grown innovative adaptations to the realities of life in the developing world will be crucial.

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Table 1: The HEP indices by country-specific wealth quintile

	Wealth quintile					
	1	2	3	4	5	Total
HEP index for health facilities within 5km						
Any health facility	0.385	0.492	0.565	0.707	0.884	0.591
Rural	0.350	0.444	0.480	0.560	0.739	0.456
Urban	0.636	0.725	0.799	0.860	0.923	0.844
Public health facility	0.310	0.403	0.471	0.599	0.781	0.498
Rural	0.276	0.353	0.384	0.443	0.571	0.361
Urban	0.553	0.646	0.709	0.763	0.837	0.755
HEP index for dwelling attributes						
All countries						
Has internet, phone, tv, or radio	0.652	0.850	0.936	0.975	0.996	0.882
Two members or less per room	0.405	0.461	0.499	0.531	0.637	0.507
Has toilet and doesn't share	0.354	0.480	0.565	0.652	0.780	0.566
Has wall and roof of any type	0.943	0.969	0.981	0.988	0.993	0.975
Water source in dwelling or yard	0.279	0.353	0.405	0.483	0.614	0.427
Has place to wash hands and soap	0.232	0.341	0.426	0.523	0.665	0.437
Mean	0.493	0.591	0.649	0.703	0.789	0.645
HEP index	0.042	0.076	0.113	0.169	0.303	0.141
Sub-Saharan Africa						
Has internet, phone, tv, or radio	0.500	0.733	0.872	0.944	0.991	0.808
Two members or less per room	0.434	0.480	0.515	0.518	0.582	0.506
Has toilet and doesn't share	0.304	0.409	0.440	0.436	0.576	0.433
Has wall and roof of any type	0.928	0.956	0.980	0.991	0.998	0.970
Water source in dwelling or yard	0.062	0.107	0.171	0.284	0.537	0.232
Has place to wash hands and soap	0.080	0.116	0.148	0.207	0.390	0.188
Mean	0.395	0.479	0.533	0.575	0.689	0.534
HEP index	0.002	0.006	0.015	0.035	0.156	0.043
Other regions						
Has internet, phone, tv, or radio	0.762	0.934	0.983	0.996	1.000	0.935
Two members or less per room	0.385	0.446	0.487	0.540	0.677	0.508
Has toilet and doesn't share	0.393	0.535	0.661	0.820	0.938	0.669
Has wall and roof of any type	0.954	0.978	0.981	0.986	0.990	0.978
Water source in dwelling or yard	0.444	0.541	0.583	0.634	0.673	0.575
Has place to wash hands and soap	0.350	0.516	0.642	0.768	0.879	0.631
Mean	0.563	0.671	0.732	0.795	0.860	0.724
HEP index	0.071	0.127	0.184	0.266	0.409	0.211

Note: The top panel shows the proportion of households with any health facility and any public health facility within 5km for the nine countries for which GIS coordinates are available for the sampled clusters in the DHS. We also provide the same statistics for urban and rural areas separately. The rest of the table uses DHS data for 54 countries. The mean is formed by taking a simple average of the six indicator values. If a variable is missing, it is not included in that country's index. "Has internet, phone, tv, or radio" equals 1 if the household has an internet connection, a landline or mobile phone, a TV, or a radio, and zero otherwise. "Two members or less per room" is equal to 1 if household size divided by the dwelling's total number of rooms is 2 or less. "Has toilet and doesn't share" is equal to 1 if the household has any type of toilet and does not share it with other households. "Has any wall or roof" is equal to 1 if the household reports having some type of wall and roof. "Water source in dwelling or yard" is equal to 1 if the household has a water source in either the dwelling or its surrounding private area. "Has place to wash hands and soap" is equal to 1 if the household has both a place to wash hands and soap in that place. Statistics are country population weighted.

Table 2: The HEP index for all *k* by country-specific wealth quintile

	Wealth Quintile					
	1	2	3	4	5	Total
All countries						
Mean	0.454	0.551	0.614	0.673	0.768	0.612
HEP index						
k = 1	0.993	0.998	1.000	1.000	1.000	0.998
k = 2	0.870	0.954	0.981	0.993	0.999	0.959
k = 3	0.546	0.739	0.836	0.891	0.950	0.793
k = 4	0.231	0.415	0.547	0.666	0.816	0.535
k = 5	0.070	0.161	0.251	0.370	0.587	0.288
k = 6	0.016	0.037	0.068	0.116	0.255	0.098
Sub-Saharan Africa						
Mean	0.384	0.465	0.521	0.563	0.678	0.522
HEP index						
k = 1	0.988	0.996	0.999	1.000	1.000	0.996
k = 2	0.796	0.916	0.963	0.985	0.998	0.932
k = 3	0.394	0.605	0.731	0.799	0.901	0.686
k = 4	0.109	0.227	0.343	0.437	0.661	0.355
k = 5	0.014	0.041	0.081	0.134	0.369	0.128
k = 6	0.001	0.003	0.009	0.023	0.136	0.035
Other regions						
Mean	0.521	0.632	0.701	0.775	0.852	0.696
HEP index						
k = 1	0.998	1.000	1.000	1.000	1.000	1.000
k = 2	0.939	0.990	0.998	1.000	1.000	0.985
k = 3	0.689	0.865	0.935	0.978	0.995	0.893
k = 4	0.346	0.592	0.738	0.880	0.962	0.704
k = 5	0.123	0.275	0.411	0.591	0.792	0.439
k = 6	0.030	0.068	0.123	0.203	0.365	0.158

Note: Mean is formed by taking a simple average of the 6 variables. Only countries (40 out of 54 countries) and households within these countries are included if they have non-missing values for all 6 categories. See Table 3 for the full list of countries. The compliance k indicator is equal to 1 if the households satisfy k categories and zero otherwise. Statistics are country population weighted.

Table 3: HEP index for all *k* by country

		***k* =**					
	Mean	1	2	3	4	5	6
Afghanistan	0.604	0.997	0.972	0.840	0.546	0.226	0.041
Angola	0.524	0.999	0.912	0.658	0.362	0.160	0.050
Armenia	0.953	1.000	1.000	1.000	0.998	0.977	0.746
Benin	0.476	1.000	0.952	0.584	0.226	0.077	0.019
Burkina Faso	0.448	0.998	0.906	0.518	0.183	0.064	0.018
Burundi	0.504	0.999	0.960	0.717	0.292	0.046	0.011
Chad	0.383	0.989	0.797	0.358	0.114	0.034	0.005
Comoros	0.633	0.998	0.983	0.881	0.611	0.264	0.060
Cote d'Ivoire	0.526	1.000	0.953	0.700	0.342	0.126	0.033
DRC	0.421	0.999	0.857	0.484	0.159	0.024	0.003
Gambia	0.582	1.000	0.993	0.838	0.468	0.157	0.038
Ghana	0.566	1.000	0.982	0.819	0.442	0.131	0.022
Guatemala	0.763	1.000	0.995	0.966	0.867	0.592	0.160
Guinea	0.552	1.000	0.977	0.760	0.406	0.139	0.029
Haiti	0.510	1.000	0.944	0.680	0.327	0.099	0.009
Honduras	0.696	1.000	0.995	0.953	0.794	0.388	0.043
India	0.683	1.000	0.984	0.871	0.662	0.417	0.163
Kenya	0.564	1.000	0.965	0.776	0.439	0.166	0.039
Kyrgyz Republic	0.855	1.000	1.000	1.000	0.962	0.757	0.413
Lesotho	0.507	0.982	0.877	0.679	0.387	0.099	0.018
Liberia	0.341	0.924	0.684	0.330	0.094	0.014	0.003
Malawi	0.490	1.000	0.915	0.644	0.282	0.079	0.021
Mali	0.555	0.996	0.957	0.760	0.432	0.154	0.031
Mozambique	0.487	0.999	0.891	0.599	0.301	0.107	0.029
Myanmar	0.697	1.000	0.983	0.918	0.750	0.429	0.103
Namibia	0.681	0.999	0.991	0.891	0.623	0.389	0.190
Nepal	0.722	1.000	0.995	0.935	0.743	0.468	0.193
Nigeria	0.590	0.999	0.976	0.818	0.490	0.202	0.056
Pakistan	0.701	0.998	0.980	0.918	0.765	0.457	0.089
Philippines	0.750	1.000	0.996	0.969	0.856	0.533	0.144
Rwanda	0.536	1.000	0.966	0.785	0.383	0.064	0.015
Senegal	0.608	1.000	0.981	0.838	0.556	0.220	0.051
Sierra Leone	0.405	0.996	0.855	0.426	0.114	0.030	0.007
Tajikistan	0.809	1.000	1.000	0.995	0.916	0.688	0.255
Tanzania	0.598	1.000	0.972	0.827	0.523	0.219	0.049
Timor-Leste	0.708	1.000	0.990	0.906	0.719	0.463	0.170
Togo	0.461	1.000	0.934	0.558	0.193	0.063	0.016
Uganda	0.542	1.000	0.956	0.750	0.393	0.126	0.026
Zambia	0.542	0.999	0.950	0.723	0.385	0.149	0.046
Zimbabwe	0.616	1.000	0.978	0.830	0.551	0.257	0.081
Total	0.612	0.998	0.959	0.793	0.535	0.288	0.098

Note: Mean is formed by taking a simple average of the 6 variables. Only countries (40 out of 54 countries) and households within these countries are included if they have non-missing values for all 6 categories. The compliance k indicator is equal to 1 if the households satisfy k categories and zero otherwise. Statistics are country population weighted.

Table 4: Individual-level risk factors for sub-Saharan Africa by wealth quintile

	Wealth quintile					
	1	2	3	4	5	Total
Men						
60 years or older	0.141	0.130	0.118	0.099	0.077	0.111
65 years or older	0.094	0.086	0.078	0.062	0.044	0.072
70 years or older	0.062	0.057	0.050	0.039	0.026	0.046
Underweight	0.260	0.196	0.182	0.166	0.145	0.189
Obese	0.003	0.004	0.007	0.017	0.046	0.017
HIV positive	0.026	0.036	0.037	0.042	0.042	0.037
Heavy smoker	0.014	0.013	0.012	0.011	0.012	0.013
Women						
60 years or older	0.139	0.130	0.109	0.087	0.072	0.107
65 years or older	0.097	0.089	0.073	0.057	0.047	0.072
70 years or older	0.066	0.060	0.048	0.038	0.031	0.048
Underweight	0.170	0.134	0.121	0.111	0.089	0.124
Pregnant	0.095	0.073	0.052	0.033	0.012	0.052
Obese	0.017	0.030	0.045	0.070	0.124	0.060
HIV positive	0.044	0.051	0.061	0.075	0.066	0.059
Heavy smoker	0.001	0.001	0.001	0.001	0.002	0.001

Note: All individuals between 15 years and older. Countries in SSA only. Underweight is defined as someone with a BMI of 18.5 or less; obese is defined as someone with a BMI of 30 or more. HIV positive is equal to one if the respondent was both offered and accepted a test, and tested positive for either HIV1 or HIV2. Heavy smoker is defined as someone who smokes 20 or more cigarettes per day. All variables are indicators.

Figure 1: Graph of HEP index against GDP per capita (both in logs)