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Priorities for action on the social determinants of health:

Empirical evidence on the strongest associations with life expectancy in 54 low-income countries, 1990 - 2012

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Abstract

The WHO Commission on the Social Determinants of Health set out an impressive collection of policy proposals on the social determinants of health. However, a serious weakness for securing implementation is the difficulty for policymakers in identifying priorities for action. The objective of this study is to determine a small set of the most influential determinants using existing data and an empirical approach. 45 Indicators from the World Bank's World Development Indicators are selected to measure attainment for the determinants proposed by the Commission. Panel data models of life expectancy at birth for 54 low-income countries over the years 1990 to 2012 are estimated. Each determinant is subjected to a robustness test using Extreme Bound Analysis, to determine the stability of its estimated impact on life expectancy. For 20 robust and significant determinants the magnitude of association with life expectancy is determined. The largest average increases in life expectancy at 14.5 months per capita is associated with a one standard deviation reduction in HIV prevalence among children, followed by advances in gender equality at 9.4 months. Improvements in life expectancy between 6 and 9 months are associated with agricultural production, political stability, access to clean water and sanitation, good governance, and primary school enrolment. Improvements below 6 months are associated with increases in private health expenditure and overseas development assistance, and control of armed conflict and HIV prevalence among men. There is no evidence that national income, public spending on healthcare and education, secondary schooling, terms of international trade, employment, debt service and relief, out-of-pocket expenditures, agricultural ex- or imports, lifestock production, foreign investment, urbanization or environmental degradation are robustly associated with population health. Results provide support for the relevance of some proposed policies. The findings can inform priorities for future research and policy action on the social determinants of health.

Keywords: Social determinants of health, extreme bound analysis, model averaging, life expectancy, population health, low income countries.

1 Introduction

Life expectancy at birth (LEB) varies greatly between and within countries. The Commission on the Social Determinants of Health (CSDH) was established by the World Health Organisation (WHO) to collate evidence on what can be done to reduce such health inequities (CSDH, 2008; Marmot et al., 2008). The Commission's final report presented a substantial body of evidence on the social determinants of health (CSDH, 2008). It identified over a dozen areas where government intervention could have a significant impact on population health, and supplemented its broad recommendations with an extensive body of policy proposals. These proposals ranged far and wide, reflecting the Commission's belief that 'every aspect of government and the economy has the potential to affect health and health equity – finance, education, housing, employment, transport, and health, just to name six.' (p10). However, a serious weakness for securing implementation was the difficulty for policymakers in identifying the most urgent priorities for action. Even the most accomplished of governments can attempt only a limited range of reforms in any time span, and a natural question will be: where can we make a start to secure the biggest gains from addressing social determinants of health?

The objective of our study is to find an answer to this question using an empirical approach. We subject 45 social determinants of health to a robustness test that assesses the strength of their association with population health. We use the World Bank's database of World Development Indicators (The World Bank, 2014) for 54 of the poorest countries of the world. We first compile a large set of development indicators that measure attainment in many of the social determinants identified by the CSDH, and address missing data problems with multiple imputation. We then estimate panel data models of life expectancy at birth (LEB) over the years 1990 to 2012. Multiple regression analyses can in principle test the association of LEB with specific social determinants, and indicate their importance relative to others. However, conventional multiple regression fails when there are too many determinants that need evaluating at the same time, as is the case here. It is simply infeasible to include all the determinants that have been proposed by the CSDH in a single empirical model.

To address this problem, we employ Extreme Bound Analysis (EBA). EBA requires estimating thousands of regressions to evaluate a determinant against all possible sets of other determinants, and then comparing how stable the estimate of its association with LEB is across all these regressions. If the association does not vary much across regressions, i.e. is robust, then we can have greater confidence in our finding than if the association varies a lot. EBA has originally been developed for empirical models of economic growth (Levine & Renelt, 1992; Reed, 2009; Sala-I-Martin, 1997; Sturm & De Haan, 2005), where – much like in the field of population health – a large number of potential determinants has been suggested by the literature. EBA has since spread to fields of research other than economic growth, for example politics (Dreher et al., 2009; Gassebner et al., 2013), environmental economics (Gassebner et al., 2013), national savings (Hussain & Brookins, 2001), stock markets (Durham, 2000), criminal activity (Fowles & Merva, 1996), concealed weapons legislation (Bartley & Cohen, 1998), healthcare expenditure growth (Hartwig & Sturm, 2012), and health (Carmignani et al., 2014; Hanmer et al., 2003). For this study, EBA allows us to systematically assess the comparative importance of each putative determinant that has been proposed by the CSDH against all other determinants. Our results can inform policy makers on the social determinants for which empirical evidence is strong that they have been associated with LEB in the poorest countries of the world over the past 2 decades, and the determinants for which such evidence is weak. For robust determinants, we calculate the magnitude of their association with LEB.

2 Data

We first review the CSDH report (2008), and produce an overview of all recommended policies; see the Appendix for a discussion of the CSDH's final report. We then use the 2014 edition of the World

Bank's database of World Development Indicators (WDIs) (The World Bank, 2014) to identify variables that we deem suitable to measure attainment and progress on the policies recommended by the CSDH. Table A2 gives a summary overview of the CSDH policy recommendations and matching indicators from the WDI. For some policies there are many relevant indicators in the WDI, for example, school education or early child development. Others are less well represented or indicators have many missing values, for example, indicators on rural and urban living conditions including housing, fair work arrangements, social protection, global governance, or monitoring, research, and training. The WDI are the primary World Bank collection of development indicators, compiled from officially-recognized international sources, and contain hundreds of indicators (The World Bank, 2014). Considerable effort is undertaken to achieve consistency in variable collation and definition across countries and years, and the WDI are considered the most current and accurate global development data available. We supplement the WDI with six indicators from the World Bank's Worldwide Governance Indicators project (Kaufmann et al., 2010, 2013), which rank quality of governance across several dimensions. We further include an indicator of the degree of democracy/autocracy from the Polity IV project (Marshall & Cole, 2011; Marshall & Gurr, 2013). We analyse data from 54 low-income countries (LICs) covering 22 years over the period 1990 to 2012 (table A1). LIC status is based on mode classification of World Bank lending criteria over the period. LICs that ceased to exist are not reported in the WDI, but - where appropriate - historic data on countries from which states separated are used (e.g. in the case of Sudan). We exclude indicators that have an absolute correlation higher than 0.6 with any other indicator using an iterative procedure described in Carmigiani et al. (2014), see Appendix. We also estimate an alternative specification that leaves more determinants in the model because it uses a less strict 0.8 as maximum correlation cut-off. We further exclude indicators that have more than 60% missing values. Our dependent variable *Life expectancy at birth* has no missing values. Missing values for indicators are derived via multiple imputation by chained equations, using predictive mean matching with three neighbours and 50 imputed datasets (White et al., 2011). Finally, 45 (58 for the 0.8 specification) determinants of LEB are subjected to further analysis. Table A3 provides summary statistics of the final estimation samples. See table A4 for variable descriptions of robust determinants, and the World Bank website for all other (The World Bank, 2015).

3 Methods

An empirical analysis of the CSDH recommendations could in principle shed light on the comparative importance of determinants by testing their association with life expectancy with a 'ceteris paribus' approach, evaluating each determinant while controlling for all others. Because of the large number of determinants this is not feasible, giving rise to a problem of model uncertainty on the correct specification of the empirical model. 'Extreme Bounds Analysis' (EBA) was proposed by Leamer (1985) and Leamer and Leonard (1983) as a tool for quantifying the robustness of regression estimates under high model uncertainty. EBA -and related Bayesian Model Averaging- have received considerable attention in the economic growth literature (Levine & Renelt, 1992; Moral-Benito, 2010; Sala-I-Martin, 1997), where it is now commonly used; for a review see the Appendix. However, there are not many applications in the area of health. In a recent editorial, Hodge and Jimenez-Soto (2013) called for better evidence on the reasons for cross-country differences in child mortality based on powerful statistical methods such as EBA. Hanmer et al. (2003) used EBA to analyse the World Bank's position that health spending is ineffective in reducing child mortality, and that improvements are mainly explained by a country's income per capita. However, the paper provides insufficient detail about the data and methods employed to assess the validity of the research. Carmignani et al. (2014) test for the robustness and significance of 45 potential predictors of life expectancy and infant mortality across 214 countries of all income levels. However, they use pooled cross-sectional data only for 1995.

We use EBA to narrow down the large set of determinants suggested by the CSDH to those that show the strongest association with LEB over the past 22 years. EBA estimates a population health model repeatedly, each time with a different set of control variables. Because each regression yields coefficient estimates for the variables, all the regressions together generate a distribution for the estimated coefficients. A regressor is very likely to have a significant association with life expectancy, or be 'robust', if a sufficiently large fraction of the density function lies to one side of zero (Levine & Renelt, 1992; Sala-I-Martin, 1997). We estimate a panel data fixed effects model:

$$LE_{it} = \delta + \beta y_{it} + Z_{it}\lambda + T_t\tau + u_i + e_{it} \qquad (1)$$

where LE_{it} is life expectancy in country i at time *t*, y_{it} is the social determinant of interest and the object of the robustness test, Z_{it} is a set of three determinants (control variables), and T_t are time dummies. The parameters β, λ and τ are to be estimated. The determinant y_{it} is chosen from the pool of determinants that we want to test, as are the variables in Z_{it} (after y_{it} has been excluded). The error terms u_i and e_{it} have the usual distributional assumptions.

We estimate model (1) repeatedly with the same determinant y_{it}. At each repetition a different set of 3 control variables is selected for Z_{it}, until all possible combinations are exhausted. Each model specification contains 4 regressors, time dummies and a constant. Once we have estimated all models for a particular determinant y_{it}, we choose the next variable y_{it} from the set of determinants, and re-estimate model (1) for all possible sets of control variables for Z_{it}. We re-estimate model (1) until estimates for β have been generated for every determinant. The number of model specifications to be estimated is given by $(n, r) = \frac{n!}{r!(n-r)!}$, where n is the number of determinants and r the number of regressors in each model. We separately estimate the EBA for the 45 and 58 determinants that are identified by applying 0.6 and 0.8 as the maximum allowed correlation. The number of specifications to be estimated is 148,995 (0.6 sample) and 424,270 (0.8 sample). We use STATA MP 13's.

From the coefficient estimates $\hat{\beta}$ for each determinant y_{it} we generate the cumulative distribution function (CDF) assuming normality. We then compute 1-CDF(0), the inverse of the value of the CDF when the coefficient has a value of zero. This value tells us what proportion of the density function for $\hat{\beta}$ lies to the right side of the coefficient value 0, and can be interpreted as the probability value that a determinant is robust and positively associated with LEB. For determinants with robust positive association 1-CDF(0) is close to 1, and most estimates are positive, and for determinants with a robust negative association 1-CDF(0) is close to zero, and most estimates are negative. If the value for 1-CDF(0) lies around 0.5 then the determinant switches signs frequently across specifications and cannot be considered robust. In order to assess the sensitivity of our results to the assumption of normality, figures A1 a – A1 l plot the empirical and the normal CDFs for the very robust determinants where 1-CDF(0)>0.95 or 1-CDF(0)<0.05. For some indicators there is not a perfect overlap between the CDFs. However, for this to affect our estimate there would have to be divergence in the CDFs at the coefficient value of zero, and the plots show that for the very robust determinants this value lies at the extremes of the distribution where divergence is very small.

The value for 1-CDF(0) does not directly indicate how confident we can be that the coefficient estimates are statistically significant different from zero. Therefore, for each specification, we calculate the p-value of one-tailed tests whether the coefficient is larger than zero (if the mean coefficient estimate > 0) or smaller (if the mean coefficient estimate < 0), and then average the p-values across all specifications for one determinant. Results on robustness and significance of determinants do not inform on the magnitude of their association with LEB. Even highly robust and significant determinants may have a small association. We calculate the magnitude of the impact from the estimated average coefficient values across all specifications, for robust and statistically significant determinants (1-CDF(0)<0.10 or 1-CDF(0)>0.90 and average p-value<0.1). We present estimates of impact on LEB in months in terms of both natural unit change and one standard deviation (SD) change of the determinant, to allow comparison of the relative impact of determinants that are measured in different units.

4 Results and Discussion

Figures 1 to 4 summarize the results, presented separately for robust and not robust determinants and for the 0.6 and 0.8 estimation samples. For each figure, the horizontal axis plots the value of the inverse of the cumulative density function of the estimated coefficients of the determinant evaluated at zero. The vertical axis plots the average p-value of one-tailed tests that the coefficient is larger or smaller than zero. Figures 1 and 2 display robust determinants for which 1-CDF(0) is larger than 0.9 or smaller than 0.1 and average p-values are smaller than 0.1, and figures 3 and 4 display non-robust determinants for which 1-CDF(0) is smaller than 0.9 and greater than 0.1 and p-values are greater than 0.1. For determinants located towards the bottom right/left of the graph, confidence that the determinant is robustly positive/negative and statistically significant greater than zero is high. For determinants located towards the top and middle of the figure, robustness and statistical significance are low. Table 1 presents estimates of the magnitude of the association with LEB of robust and significant determinants, ordered according to magnitude. We report the robustness confidence levels, the estimated impact on LEB in months based on a one SD and an original unit change, the average p-values and value for 1-CDF(0). The reported *per capita* gains in terms of months can lead to a large number of life years when viewed alongside the average population size of a LIC of 40 million. The results should be interpreted with the limitations of our study in mind, which we discuss in more detail in the concluding section, but in our view they nevertheless offer important new evidence on which of the CSDH policy recommendations have the greatest association with population health.

Equity from the start: The Commission emphasized the importance of early childhood interventions. A robust and significant determinant of LEB is *Children living with HIV*, according to both the 0.6 and 0.8 sample. 1-CDF(0) and the average p-value are both very close to zero, indicating that it is a highly robust and significant negative determinant of health. The indicator reflects the dramatic increase in HIV infections over the last two decades and associated reductions in LEB in high-endemic countries. It also reflects countries' efforts in providing anti-retroviral therapy (ART) and interventions to prevent transmissions, including mother-to-child, which are highly effective if well implemented (WHO, 2007). The indicator has greatest association with LEB of all determinants, a one SD increase is associated with 14 months shorter LEB (table 1). The number of AIDS related deaths in Sub-Saharan Africa was estimated at 790,000 in 2014, a marked reduction from 1.2 million in 2000. However, the number of deaths actually increased in Asia, the Pacific and Eastern Europe over the same period, from 269,000 to 328,000 (UNAIDS, 2015). Studies suggest that the mean gain in life expectancy due to ART could be up to 14 years, even in poor countries (Johansson et al., 2010). Globally, access to treatment has increased dramatically from less than 1% in 2000 to 40% in 2014, but treatment coverage is much lower in poor countries (UNAIDS, 2015). It is estimated that of the 36.9 million people living with HIV/AIDS globally, 22 million do not have access to treatment, including 1.8 million children (UNAIDS, 2015). Therefore, unfortunately, the majority of HIV positive patients in poor countries still do not receive ART. This is partly explained by unavailability of 1st and 2nd line drug regimens, but also by poor uptake of testing, linkage to care and adherence.

The 0.8 sample contains the robust determinant *Immunizations against DPT*. The DPT immunization is a combined vaccination protecting against diphtheria, pertussis (whooping cough), and tetanus. At least 3 courses are required to achieve adequate protection against diphtheria and pertussis, which proves challenging in some settings (WHO, 2006). *Immunizations against measles* is excluded from analysis during the correlation analysis in both samples. Therefore, DPT immunizations are likely to capture the impact of other immunizations, and possibly childhood interventions in general. 1-CDF(0) is close to one, indicating as expected that immunizations are positively associated with LEB. A one SD increase is associated with 7 months longer LEB. The 2013 Global Burden of Disease Study estimated that reductions in prevalence of vaccine preventable childhood infectious disease contributed greatly to decreases in the number of worldwide deaths between 1990 and 2010 (Lozano et al., 2012). Vaccinations are cost-saving public health interventions in most settings (Armstrong, 2007). *Vitamin A supplementation* is bordering robustness, in particular for the 0.8 sample, but *Newborns protected against tetanus* is not robust. Vitamin A deficiency is a major cause of blindness in children, and is estimated to increase a child's risk of dying from diarrhoea, measles and malaria by 20-24% (Ezzati et al., 2004).

Education is considered one of the most important social determinants of health. There are three possible, but not mutually exclusive, explanations for the observed association between schooling and health: (1) more education improves health, (2) better health leads to more education, and (3) there is no direct causality between health and education and the positive correlation is explained by third variables relating to the household and wider environment, such as parental education (Bolin, 2011; Cutler & Lleras-Muney, 2006; Grossman & Kaestner, 1997). We are not able to disentangle these factors with our relatively simple analysis, but we still find support for a positive association between education and LEB. In both samples, *Pupil-teacher ratio* is a positive and *Children out of school* a negative highly robust determinant of LEB. One SD changes is associated with 6 and 7 months differences in LEB, respectively. For the 0.8 sample only, additional positive robust indicators are *School enrolment, primary*, and *Primary completion rate*, with associations of 7 months and 5 months. *Private primary school enrolment* is a negative determinant of LEB, confirming the recommendation of the Commission to increase public involvement in the provision of basic services. Private schooling can be an indicator of poor public schooling and reduce overall levels of education, with associated negative impact on LEB. The association with LEB is relatively small at 2 months. *Public spending on education (% GDP)* is not robust. More direct indicators of enrolment seem better able to capture education levels of countries. Indicators of secondary education are not robust, although bordering positive robustness for the 0.8 sample. Evidence for African countries suggests that secondary schooling may exacerbate income inequalities because of monetary and non-monetary access restrictions (Schultz, 1999).

Healthy places healthy people: Our results for this chapter confirm the prediction of the Commission about the importance of urban and rural living conditions, and agricultural production. The indicators *Crop production index* from the World Bank National Accounts data and *Arable land* are robust positive determinants of LEB and associated with around 9 and 5 months longer LEB. In the 0.8 sample, *Cereal yield* is robust and a one SD increase in kg per hectare is associated with a 5 month increased LEB. The other agricultural indicators are not robust, except for *Livestock production index*. *Improved water source* and *Improved sanitation facilities* are highly robust positive determinants and a one SD increase is associated with increases in LEB of about 8 months. That poor sanitation and water quality are breeding grounds for communicable diseases is one of the most salient public health messages. Many poor countries have invested in community-level water infrastructure such as wells, but maintaining this infrastructure requires continued investment (Zwane & Kremer, 2007).

The level of urbanization, as measured by *Rural population (% of total population),* is not associated with LEB. The percentage of *Paved roads (% of total roads)* is a robustly negative determinant. Its association with LEB is however relatively small; a one SD increase is associated with about 2 months shorter LEB. There is a complex causal relation between positive effects (accelerated economic development) and negative effects (traffic accidents) of road infrastructure investments, and sophisticated statistical methods are required to disentangle those (Bishai et al., 2006). *CO2 and PM10 emissions* nearly reach positive robustness. Results may be inconclusive because the positive association between particle emissions and economic development counteracts negative health impacts, for a discussion of this issue see Wilkinson et al. (2010) and Team et al. (2011)

Fair employment and decent work: None of the employment indicators are robustly associated with LEB. They are based on modelled estimates by the International Labour Organization (ILO, 2010), and it is possible that they do not accurately capture employment in the informal sector, important in many LICs. There is a debate whether informal sector employment is a result of competitive market forces or labour market segmentation. It has been argued that neither of the two theories adequately explains informal employment, but rather that the informal sector shows a heterogeneous structure which is an attractive source of employment for some and the last resort for others (Günther & Launov, 2012).

Social protection across the life-course: *Age dependency ratios*, i.e. the proportion of either young or old non-productive persons in relation to working age persons, strains social security systems and are the only indicators for the chapter 'Social Protection'. We find no robust association with LEB.

Universal health care: It is interesting to note in the context of our study that *Health expenditure, public* (both expressed per capita and % GDP) are not robust determinants of LEB. The relationship between resources devoted to health care and health outcomes is one of the most salient questions in health research, and ultimately also motivation of the CSDH report and our analysis. Nowadays, a common view is that the total contribution of healthcare is probably substantial, but its marginal contribution small (Bokhari et al., 2007; Fuchs, 1983; MacKeown, 1976; McKinlay & McKinlay, 1977). *Out-of-pocket expenditures*, both as percentages of private and total health expenditures, are not robustly associated with LEB, however, *Private health expenditure (% GDP)*, which considers private insurance contributions and out of pocket payments, is a robust positive determinant. A one SD increases is associated with about 5 months longer LEB. While the association of user fees with household income is commonly studied (see for example McIntyre et al., 2006; Xu et al., 2007), the actual association with health is less commonly a focus of empirical analyses. An exception are two papers by Moreno-Serra and Smith (2012, 2015) that present evidence that expanded health coverage, particularly through higher levels of publicly funded health spending, results in lower child and adult mortality. Private health expenditure is likely to be associated with income, and it is possible that the estimated association between private expenditure and LEB is coincidental. Our study cannot analyse within-country inequities in health that may be associated with private healthcare.

Health equity in all policies, systems and programmes and Fair financing: We cannot find direct indicators for 'Health equity in all policies'. For 'Fair financing', we use *GNI per capita* from the 0.8 sample, and the WDI Governance indicators. GNI is not robust, which is a surprising result. An immense amount of research has not left much doubt that income and various measures of health are strongly correlated across countries, as first documented by Preston with simple scatter plots (1975). However, there is less dispersion of GNI in the sample of countries analysed here as they are all low-income countries. It has also been found that the positive effect of national income on LEB is stronger for developing countries with higher levels of income. In the poorest countries of the world, instead of GDP, determinants of health including female illiteracy (Schell et al., 2007), public spending on health, ethnic fragmentation (Houweling et al., 2005), and global factors including advances in medical technology and diffusion of health technology (Asiedu et al., 2015) have strongest association with health. Furthermore, the relation is not so simple on closer inspection and likely to be affected by a complex and possibly non-monotonic relation between income per capita, health, population dynamics and other factors including education, quality of institutions, and many more; for a recent summary of the literature see Cervellati (2011) and Deaton (2006).

The six indicators from the Worldwide Governance Project are measures of the quality of political institutions as perceived by a sample of stakeholders (Kaufmann et al., 2013). Critics of the Governance Indicators question the extent to which perceptions data adequately capture the relevant reality, a concern that the authors discuss in some length (Kaufmann et al., 2013). *Political stability and absence of violence/terrorism* and *Regulatory quality* are both robust positive, confirming the Commission's recommendations. One SD increases are associated with 9 and 6 months longer LEB, respectively. *Control of corruption* is also robust positive, with a one SD impact of 8 months (0.8 sample only).

Market responsibility: The CSDH emphasises the importance of market responsibility by advocating the removal of direct market and competitive constraints. We test several indicators of trade openness and terms of trade, i.e. measures of the relation between export and import values. *Manufactured imports as % of merchandise imports* is the only robust indicator for this chapter, with a positive association with LEB. The result implies that a greater share of imported manufactured goods on overall imports is positively associated with LEB. Possibly, importing products that are used productively in the local economy rather than for mere consumption has positive impacts on development and population health. The impact of one SD change is relatively small at under 3 months. All other trade indicators are not robust. The indicators *Manufactured exports (% of merchandise exports)*, *Exports of goods and services (% of GDP), Merchandise trade (% of GDP)* and *External balance on goods and services (% of GDP)* can all be interpreted as measures of international exchange and dependency, but none of them is robust. *Agricultural raw material imports* and *exports* in relation to manufactured imports and exports are not robust either. The notion that countries that rely heavily on trade of agricultural exports (as opposed to manufactured products) are negatively affecting health of populations is not supported by our results.

Overall, there is little evidence in our results that a more restrictive trade policy is detrimental to population health. Previous studies have investigated whether a positive association between openness and health may be driven by the correlation with a third associated factor, for example political openness (Tsai, 2007) or overseas development assistance (Welander, 2012). Studies found evidence that the association is complex on closer inspection (Peneva & Ram, 2012), either because it is positive only for high-income but not low-income countries (Bergh et al., 2014), or positive only for LEB of men but not women (Bussmann, 2009). Trade openness facilitates spread of infectious diseases, for example Oster (Oster, 2012) found that a doubling of exports leads to approximately a quadrupling of new HIV infections.

Net ODA received per capita is positive robust, a one SD increase is associated with a 2 months longer LEB. This confirms the Commissions calls for greater international responsibility in development assistance to the poorest countries of the world. *Foreign direct investment, net inflows (% of GDP)* may strengthen the national economy, however, it is not robust. Studies often find a positive association but usually investigate the reverse causality, i.e. whether a healthy workforce attracts foreign direct investment (Alsan et al., 2006). There is evidence that in the absence of malaria and HIV, net FDI inflows into Sub-Saharan African countries could have been one-third higher (Azémar & Desbordes, 2009). Neither *Total debt service (% of GNI)* nor *External debt stocks (% of GNI)* are robust determinants. Chauvin & Kraay (2005) also find little evidence that debt relief has affected economic or social development in LICs, and overall evidence seems to suggest that debt is a symptom rather than a cause of development difficulties, and modest improvements in development may be due to the reforms that were required as a precondition for the granting of debt relief.

Gender equity: There is a strong human rights argument for equal treatment of men and women, although some argue that some degree of inequality may be justified to take account of biological differences (Anand & Sen, 1995; Tsuchiya & Williams, 2005). Empowering women is believed to increase investment in children (World Bank, 2001), and therefore promotion of gender equality is seen as a potent means of human development, not simply as an important end in itself (United Nations, 2005). Our results provide some support. The *Proportion of seats held by women in national parliaments* is positive robust, and in terms of magnitude, second highest after *Children living with HIV*. A one SD increase is associated with over 9 months longer LEB. The indicator may act as a proxy for societies that value gender equality more highly than others, but the literature suggest also a more direct association. It has been found that women place greater weight on child welfare and provision of public goods than men, and that historically, the success of hygiene campaigns in reducing infant mortality is linked with the rising influence and political participation of women (Duflo, 2003; Miller, 2008). *Women's share of population living with HIV* is positively robust, suggesting that an increase in the proportion of women infected (and a reduction in the share of men infected) is positively associated with LEB. This seems to counter the gender equality argument. Possibly, the detrimental impact on economic development that is associated with a reduction in the productivity and earning capacity of men is greater than a reduction in women's capacity. In most countries employment rates of men are still higher.

Political empowerment – inclusion and voice: For this area we rely on the Polity index as a measure of democracy/autocracy (Marshall & Gurr, 2013). We find that it is robust negative, a counterintuitive result. An increase in the polity index is associated with a 3 months reduction in LEB. Treier & Jackman (2008) subject the Polity index to a rigorous analysis, and recommend caution in its use because of significant measurement error.

Good global governance: As predicted by the Commission, we find evidence for the negative impact of armed conflict on LEB. *Refugee population by country or territory of origin,* refugees that left the reporting country, is robust negative. A one SD increase is associated with 3 months shorter LEB. *Refugee population by country or territory of asylum* (refugees that live in the reporting country) is not robust. A study by Salehyan (2008) found evidence that both refugee-receiving and sending states experience reductions in welfare, because refugee-receiving states are more likely to initiate militarized interstate disputes as they intervene to prevent further externalities, whereas refugee-sending states initiate disputes with the receiving country as they violate borders in pursuit of dissidents. *Military expenditure (% of GDP)* is robust negative, as predicted by the Commission, but impact is smallest of all robust indicators at under 2 months.

5 Conclusions

The WHO Commission for the Social Determinants of Health (CSDH) sets out an impressive collection of policy proposals, based on the existing substantial research evidence. This consists of an extensive but uncoordinated array of studies across many diverse topic areas. There is very little evidence that identifies priorities across areas, because of the considerable methodological complexities of such an endeavour. In the end, the CSDH could offer no information for the resource constrained policymaker as to which of the many proposed policies is likely to be the most effective. Our study does not answer that question in its entirety. To do so would require information on the costs of alternative reforms. However, our study reduces to a manageable number the types of social determinant to which population health was most sensitive. From 45 (58 for alternative specification) social determinants of health, we identify 20 (26) that exhibited strong association with LEB, using a large dataset on 53 of the world's poorest countries over the years 1990 to 2012. For the other 25 (32) determinants, the association that had been predicted by the CSDH was contradicted by the available data.

This research has limitations. Most notably, we cannot not prove causality. Some putative determinants may act as proxies for other determinants that are not included in the models, or the relationship is highly complex and influenced by other factors. Imputation of missing data may affect our results. Some policy areas of the CSDH report are poorly represented in the WDIs, and suitable indicators cannot be found. While some criticize EBA as purely agnostic (Angrist & Pischke, 2010), it is still recognized that in situations where there is no concise testable theoretical model, as in the area of population health, EBA is possibly one of the only pragmatic modelling approaches (Durlauf et al., 2005).

The CSDH identified over a dozen policy areas where government intervention could have a significant impact on health inequities. Our results provide support for the importance of some but not all. The largest increases in life expectancy at 14.5 months per capita are associated with reductions in HIV prevalence among children, followed by advances in gender equality at 9.4 months. Improvements in life expectancy between 6 and 9 months are associated with agricultural production, political stability, access to clean water and sanitation, good governance, and primary school enrolment. Improvements below 6 months are associated with increases in private health expenditure and overseas development assistance, control of armed conflict and HIV prevalence among men. There is no evidence that national income, public spending on healthcare and education, secondary schooling, terms of international trade, employment, female employment, debt service and relief, out-of-pocket expenditures, agricultural ex- or imports, lifestock production, foreign investment, urbanization or environmental degradation are robustly associated with population health.

It is difficult to envisage that overarching research on the social determinants of health can ever rely on any sort of controlled experimentation to inform policy. Therefore debates must rely on extracting as much information as possible from observational data sources. Our study seeks to do this in a systematic way, using a purely empirical approach. Despite its limitations, we can suggest determinants for which empirical evidence suggests strong association with population health over the past two decades. They should receive priority attention for further research and action on the social determinants of health.

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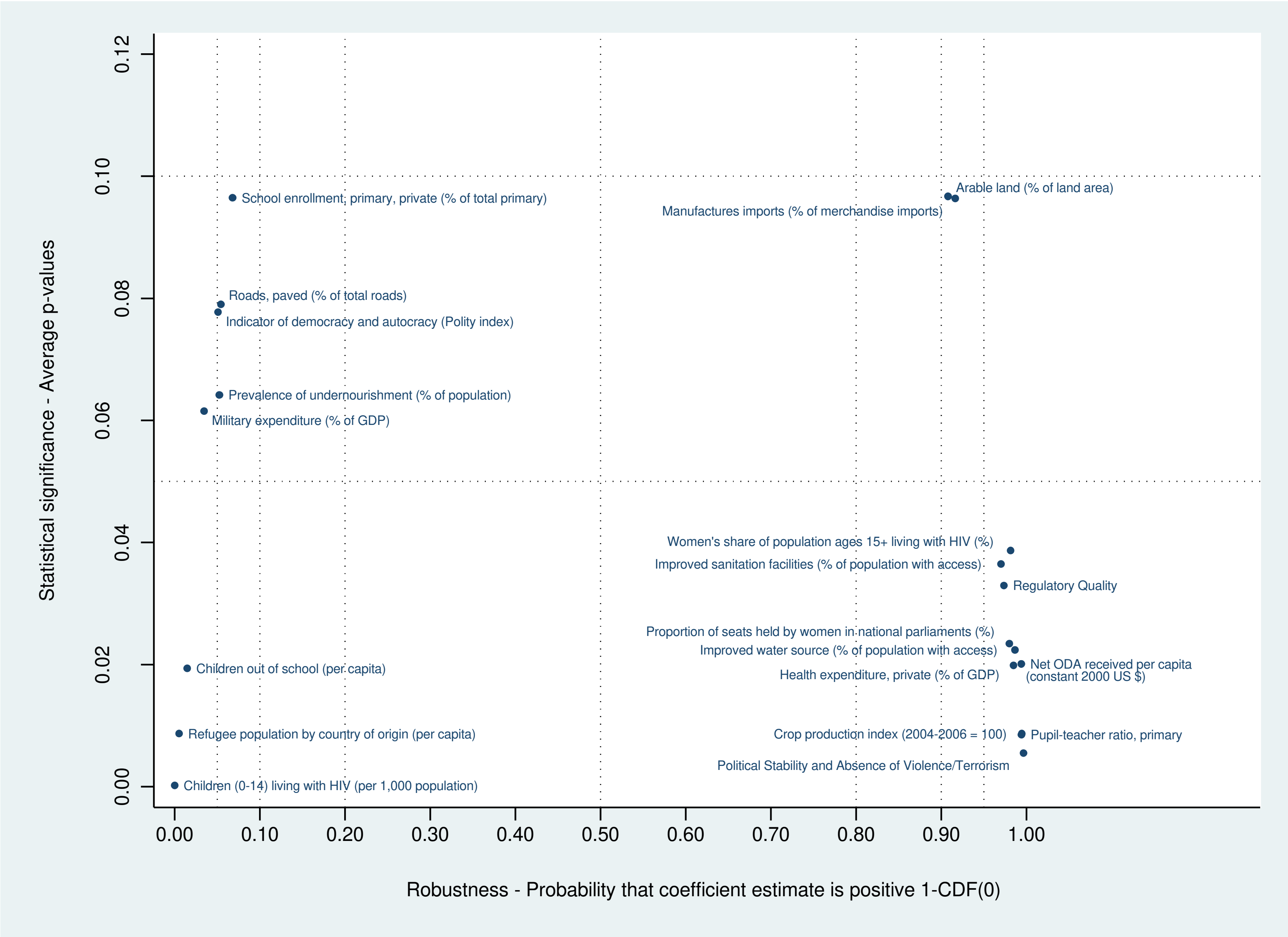
Table 1: Impact on life expectancy at birth of robust and significant determinants of health

Determinant			**Association with life expectancy at birth (in months)**							
	Confidence level		Standard deviation change		Original unit change		Average p value		CDF(0)	
Sample**:**	0.6	0.8	0.6	0.8	0.6	0.8	0.6	0.8	0.6	0.8
Children (0-14) living with HIV (per 1,000 population)	***	***	-14.05	-14.51	-9.43	-9.75	0.000	0.000	0.000	0.000
Proportion of seats held by women in national parliaments (%)	**	**	9.43	9.84	1.97	2.06	0.023	0.017	0.980	0.986
Crop production index (2004-2006 = 100)	***	***	8.97	8.87	0.38	0.37	0.009	0.010	0.994	0.993
Political Stability and Absence of Violence/Terrorism	***	***	9.24	8.60	25.55	23.76	0.006	0.006	0.996	0.996
Improved sanitation facilities (% of population with access)	**	**	8.31	8.56	2.15	2.22	0.036	0.034	0.970	0.972
Control of Corruption		***	.	8.25	.	39.31	.	0.013	.	0.991
Improved water source (% of population with access)	**	**	7.57	7.93	1.26	1.32	0.022	0.020	0.986	0.988
Immunization, DPT (% of children ages 12-23 months)		***	.	7.08	.	0.55	.	0.009	.	0.998
Children out of school (per capita)	**	**	-6.65	-6.98	-4.45	-4.67	0.019	0.026	0.015	0.019
School enrolment, primary (% gross)		**	.	6.91	.	0.46	.	0.028	.	0.989
Regulatory Quality	**	**	5.87	6.54	31.07	34.63	0.033	0.031	0.973	0.976
Pupil-teacher ratio, primary	***	***	5.92	5.70	1.11	1.07	0.009	0.010	0.994	0.993
Cereal yield (kg per hectare)		***	.	5.13	.	0.02	.	0.012	.	0.996
Prevalence of undernourishment (% of population)	*	**	-4.75	-4.87	-0.85	-0.88	0.064	0.061	0.052	0.050
Arable land (% of land area)	*	*	4.76	4.78	3.18	3.19	0.097	0.096	0.908	0.908
Primary completion rate, total (% of relevant age group)		**	.	4.75	.	0.44	.	0.065	.	0.963
Health expenditure, private (% of GDP)	**	**	4.68	4.63	8.22	8.14	0.020	0.025	0.985	0.980
Refugee population by country of origin (per capita)	**	**	-3.35	-3.31	-2.60	-2.57	0.009	0.010	0.005	0.006
Women's share of population ages 15+ living with HIV (%)	**	**	3.12	3.08	1.21	1.20	0.039	0.036	0.981	0.981
Indicator of democracy and autocracy (Polity index)	*	**	-2.63	-2.71	-0.86	-0.89	0.078	0.073	0.051	0.049
School enrolment, preprimary (% gross)		*	.	-2.47	.	-0.37	.	0.084	.	0.069
Manufactures imports (% of merchandise imports)	*	*	2.76	2.46	0.42	0.38	0.096	0.101	0.916	0.914
Roads, paved (% of total roads)	*	*	-2.04	-2.01	-0.53	-0.53	0.079	0.072	0.054	0.051
Net ODA received per capita (constant 2000 US $)	***	**	2.06	1.91	0.06	0.06	0.020	0.047	0.994	0.987
School enrolment, primary, private (% of total primary)	*	*	-2.24	-1.72	-0.72	-0.56	0.096	0.111	0.068	0.075
Military expenditure (% of GDP)	**	**	-1.50	-1.62	-1.35	-1.46	0.062	0.057	0.035	0.029

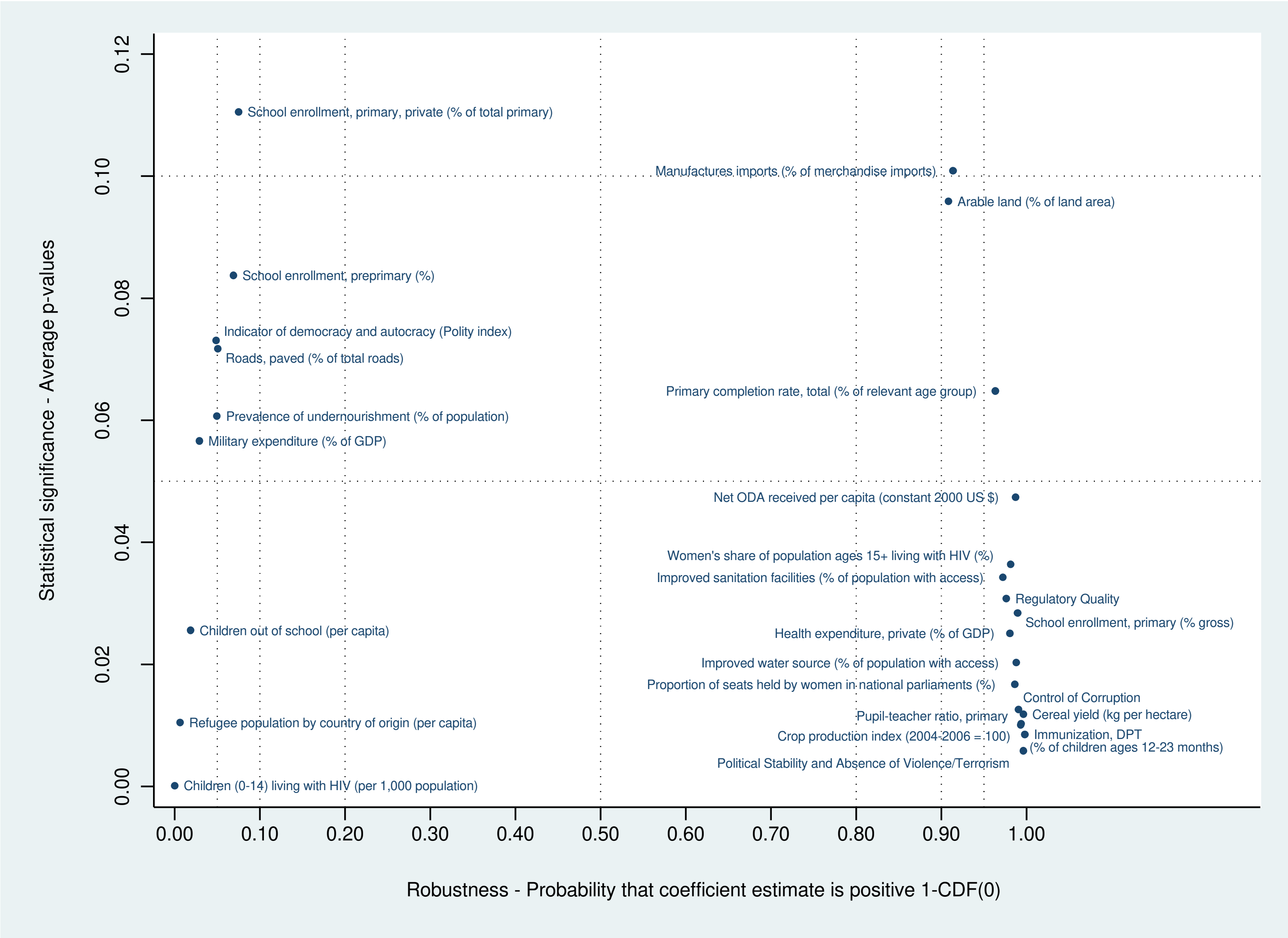
Notes: This table displays determinants that are robust and statistically significant at 90% level or above; confidence levels are based on robustness results only: *** 99%, ** 95%, * 90%; Standard deviation is calculated within-country across time. Results are from EBA carried out on 0.6 and 0.8 sample separately.

Figure 1: Robustness and significance for robust and statistically significant determinants of life expectancy at birth (0.6 sample)



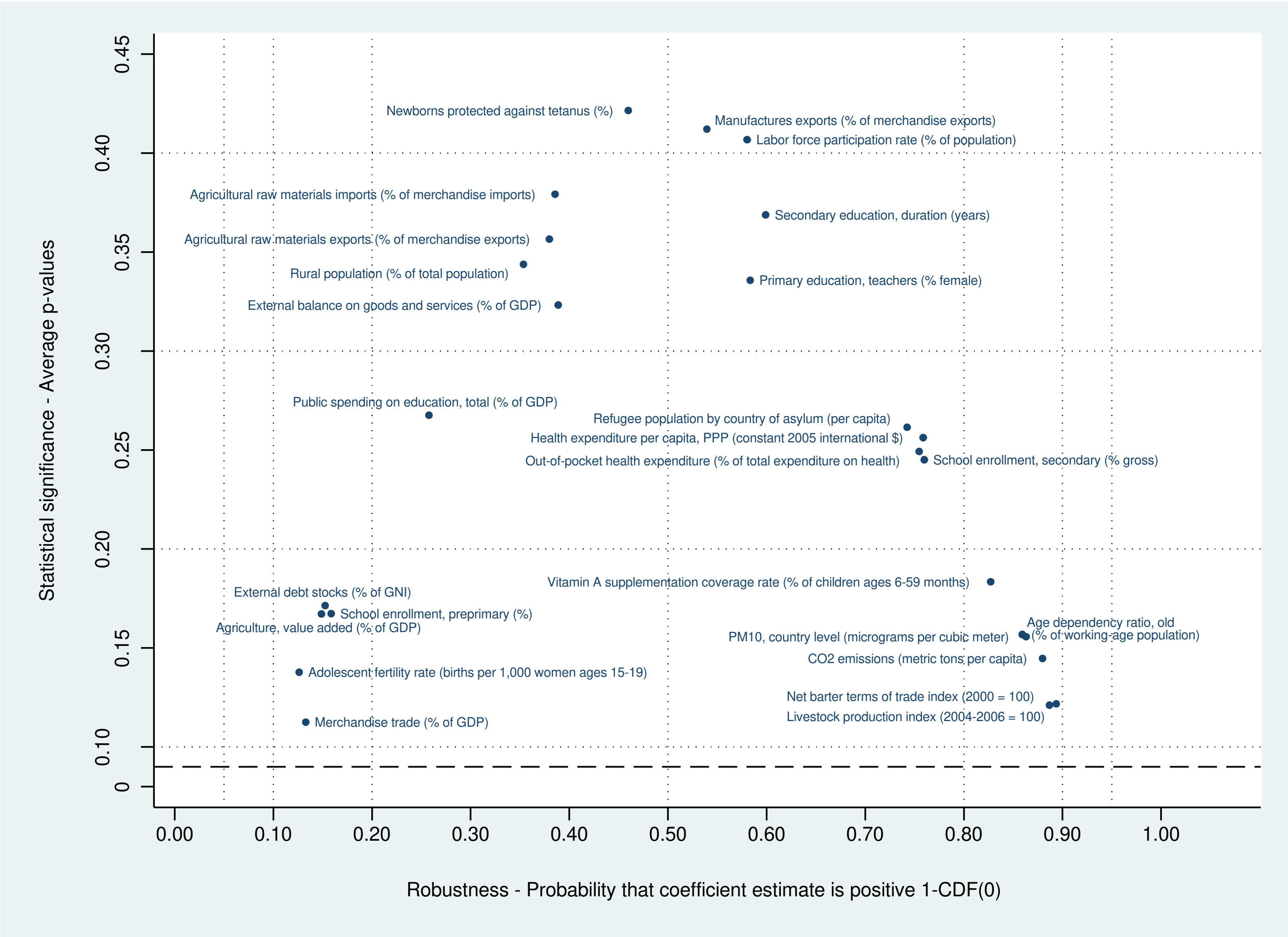
Notes: The figure only shows determinants where 1-CDF(0)>0.9 or 1-CDF(0)<0.1, and average p-value<0.1; determinants towards the right/left have positive/negative impact on LEB; statistical confidence levels of 0.95, 0.90, 0.80 and 0.50 are indicated by the vertical and horizontal dashed lines; determinants with correlation above 0.6 with all others are excluded from analysis.

Figure 2: Robustness and significance for robust and statistically significant determinants of life expectancy at birth (0.8 sample)



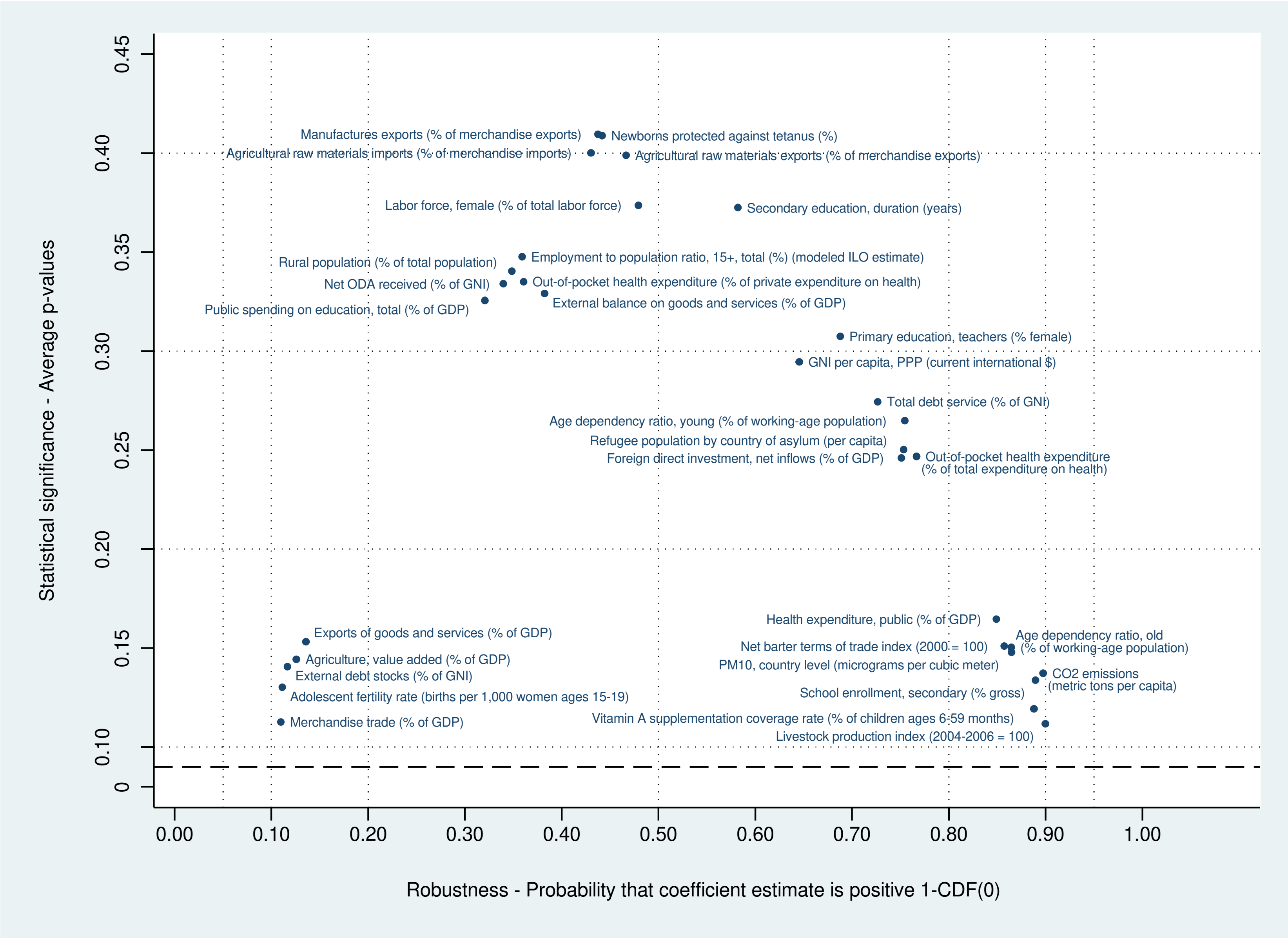
Notes: Determinants with correlation above 0.8 with all others are excluded from analysis.

Figure 3: Robustness and significance for non-robust determinants of life expectancy at birth (0.6 sample)



Notes: the figure only shows determinants where 1-CDF(0)<0.9 adn 1-CDF(0)>0.1, and average p-value>0.1; determinants towards the right/left have positive/negative impact on LEB; statistical confidence levels of 0.90, 0.80 and 0.50 are indicated by the vertical and horizontal dashed lines; determinants with correlation above 0.6 with all others are excluded from analysis.

Figure 4: Robustness and significance for non-robust determinants of life expectancy at birth (0.8 sample)



Notes: Determinants with correlation above 0.8 with all others are excluded from analysis.