

Is Foreign Direct Investment Good for Health in Low and Middle Income Countries? An Instrumental Variable Approach

Abstract –This paper investigates the relationship between overall foreign direct investment (FDI) and population health in low and middle income countries (LMICs) using annual panel data from 85 LMICs between 1974 and 2012. When controlling for time trends, country fixed effects, correlation between repeated observations, relevant covariates, and endogeneity via a novel instrumental variable approach, we find FDI to have a beneficial effect to overall health, proxied by life expectancy, in LMICs. When investigating age-specific mortality rates, we find a stronger beneficial effect on adult mortality, yet no association with either infant or child mortality, suggesting the predominance of the FDI effect on overall health to be related to adult populations within LMICs. Notably, FDI effects on health remain undetected in all models which do not control for endogeneity. Exploring the effect of sector-specific FDI on health in LMICs, we provide preliminary evidence of a weak inverse association between secondary sector FDI and overall life expectancy, in line with previous findings.

Keywords: Foreign Direct Investment; Health; Low and Middle Income Countries; Instrumental Variables

1 Introduction

There is a long-standing debate in the literature on the importance of the macroeconomy to population health. Whilst the predominant view, in the spirit of Pritchett & Summers (1996) seminal paper ‘Wealthier is Healthier’, appears to be that economic development over the long run or in a cross section of countries is good for health. Yet the same may not apply for short run macroeconomic fluctuations (Gerdtham, 2006).

One important macroeconomic determinant of health could be foreign direct investment (FDI), defined by the World Bank (2014) as cross-border investment to establish a lasting interest. FDI is widely acknowledged to promote economic growth, increases in wages and generally improved working conditions in low and middle

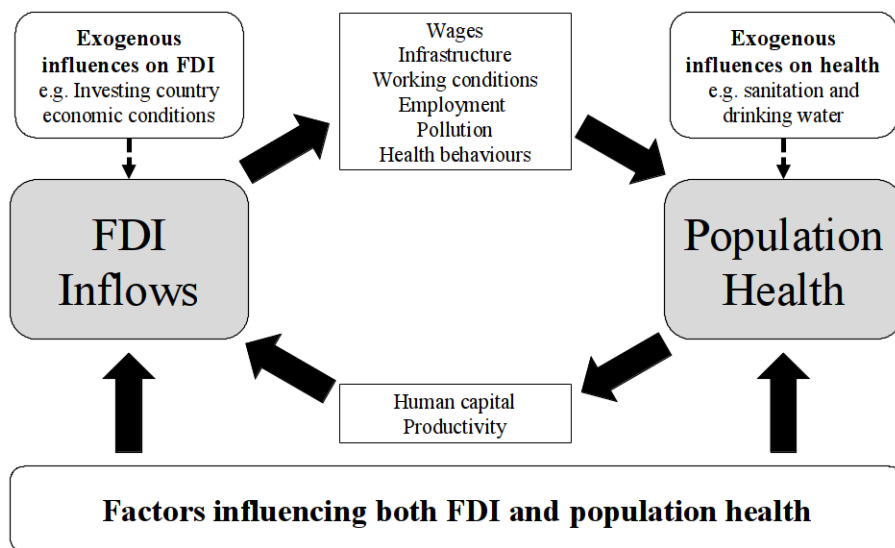
23 income countries (LMICs) (Blouin et al., 2009; Feenstra, 1997; Moran, 2004). As these factors could affect
24 access to healthcare, especially in LMICs where access to care is strongly dependent on ability to pay, it may be
25 the case that FDI is beneficially associated with population health. Yet conversely, FDI may also have adverse
26 effects on health.

27 For example, there is a considerable body of work suggesting links between FDI and consumption of tobacco or
28 unhealthy foods, rising levels of harmful pollution, and increasing over-nutrition, all of which directly harm
29 population health (Gilmore, 2005; Hawkes, 2005; Jorgenson 2009, 2009a; Labonté et al., 2011). This suggests a
30 complex and ex ante ambiguous overall relationship between FDI and health in LMICs. Just three articles to date
31 have quantitatively investigated the health impacts of FDI in LMICs. Two very similar studies by Jorgenson
32 (2009, 2009a) focus on FDI into secondary sector industries (See Appendix Table 3)[**PLEASE INSERT A**
33 **LINK TO APPENDIX.DOCX**], and levels of water pollution using panel analysis of annual data from 30
34 countries. Their results suggest that secondary sector FDI is associated with elevated pollution, which in turn
35 increases infant and child mortality. Another study investigated the effect of FDI and international trade on life
36 expectancy, using annual time-series data from Pakistan (Alam et al., 2015). Results from vector error correction
37 models indicated that in Pakistan, increases of FDI were associated with both short and long-term benefits to life
38 expectancy.

39 Whether the findings from these studies extend to LMICs in general is yet to be rigorously tested. We address
40 this by empirically investigating the overall impact of FDI on health, with health being proxied by a set of
41 general population health indicators. Additionally, as Jorgenson (2009, 2009a) raised the possibility that
42 industrial composition of FDI affects its association with health, we also begin to further unpack the role of FDI
43 by exploring the potentially specific, differential health impacts resulting from different types of FDI. To achieve
44 this, FDI to LMICs was disaggregated into investments into primary, secondary, and tertiary industries, as
45 defined by the United Nations Conference on Trade and Development (UNCTAD; see Appendix Table 3)
46 [**PLEASE INSERT A LINK TO APPENDIX.DOCX**].

47 In empirically assessing the impact of FDI on health, it is important to acknowledge the likelihood that there is a
 48 reverse impact running from health to FDI inflows in LMICs, as described in Figure 1 (Burns et al., 2016). As
 49 Alsan et al. (2006) argue, health affects the human capital of the workforce, and consequently productivity. If
 50 this is the case, then this relationship leads to LMICs with better population health subsequently receiving more
 51 FDI. The authors report some empirical support for this, in the form of regression analysis of life expectancy and
 52 FDI inflows in 85 LMICs. Since then, empirical studies of health influencing FDI have generally supplemented
 53 evidence for healthier LMICs receiving more FDI, using similar methods and panel datasets (Asiedu et al., 2015;
 54 Azemar, 2009; Ghosh, 2015).

55 If the FDI and health association is truly bi-directional, regression analyses failing to take this into account will
 56 be biased by so-called “endogeneity”, meaning that FDI will be correlated with the error term, leading to an
 57 erroneous estimated coefficient and standard error (Gujarati, 2009). To adjust for this issue and the misleading
 58 results it can lead to, an exogenous determinant of FDI inflows which is not related to population health (see
 59 Figure 1) is required. In this article, therefore, we investigate the existence of a causal relationship between FDI
 60 and population health in LMICs whilst explicitly taking endogeneity into account using a novel instrumental
 61 variable (IV) regression approach.



63 *Figure 1: Conceptual framework of the association between FDI and population health in LMICs*
64 Our findings suggest that after explicitly adjusting for endogeneity, FDI is weakly associated with a marginal
65 benefit to overall life expectancy in LMICs, yet more closely associated with adult mortality. We also find some
66 weak preliminary evidence of secondary sector FDI harmfully impacting upon health in LMICs.

67 **2 Data**

68 Table 1 lists the data sources and descriptive characteristics of all the variables used. Sections 2.1 to 2.3 briefly
69 comment on the population health, FDI and factors influencing both FDI and health cells in Figure 1. To
70 investigate whether FDI is related to overall health in LMICs, annual panel data from 85 LMICs, over the period
71 1974-2012 was used. Countries were categorized as LMICs based on the World Bank, (2015) classification of
72 income and lending groups. Information on countries included in the analysis is available in Appendix tables 1
73 and 2 **[PLEASE INSERT A LINK TO APPENDIX.DOCX]**.

74 We explored whether the industrial decomposition of FDI was related to health using panel data from a subset of
75 31 LMICs 1987-2008 (see Appendix table 3) **[PLEASE INSERT A LINK TO APPENDIX.DOCX]**. Except
76 for FDI data, both the overall and sectoral analyses utilized the same data sources.

77 **2.1 outcome variables**

78 Life expectancy at birth, as reported in the World Bank (2015) World Development Indicators (WDI) was used
79 as a primary measure of overall population health because it was the most encompassing measure which was
80 also widely available for LMICs. Measures incorporating both length and quality of life are preferable, but were
81 unavailable for a large number of countries and years. Other health outcome variables were used to investigate
82 the relationship between FDI and health in different age groups, and these included infant, under-five and adult
83 mortality rates.

84 **2.2 Predictor Variables**

85 Foreign investment was measured using data on FDI inflows to LMICs taken from the UNCTAD (2014)
86 bilateral investment database, as is common in research within this context (Ghosh et al., 2015). Although it has
87 been suggested that aggregate FDI inflows are unlikely to fully account for multinational corporation activity,
88 FDI is the only measure which is available for most LMICs over longer time periods (Lipsey, 2008).

89 Data on the sectoral breakdown of FDI inflows to LMICs was combined with data on total FDI inflow to
90 calculate the proportion of total FDI made up of primary, secondary or tertiary sector investments, (defined by
91 UNCTAD (2009), see Appendix Table 3) **[PLEASE INSERT A LINK TO APPENDIX.DOCX]**. This
92 ‘industrial concentration’ measure originated from two sources; several editions of the UNCTAD world
93 investment directory, and the China statistical yearbook, as taken from the National Bureau of Statistics of China
94 website (NBSC, 2014; UNCTAD, 2004; UNCTAD, 2003, 2008).

95 The world investment directory includes sectoral FDI data from many LMICs, but no data on FDI to China.
96 China has received large quantities of FDI since the early 1990s. Annual data on FDI inflows by industry to
97 China are publicly available, and Chinese FDI data was therefore included in the sectoral analysis. To test
98 whether including this data affected the results, models omitting China were also estimated and compared to
99 those including the full sample.

100 **2.3 Other Covariates**

101 Control variables were included if they were expected to be factors influencing both FDI and population health
102 (as in Figure 1).

103 **Gross Domestic Product per capita**

104 The association between FDI and population health is likely to be confounded by a country’s economic
105 conditions. We included gross domestic product per capita (GDPPC), a widely available and commonly used
106 proxy measure for economic conditions (Blonigen, 2005; Moore et al., 2006). LMICs with a higher GDPPC
107 were expected to both receive larger FDI inflows and have better population health. Finally, as discussed further

108 in Section 3.2, countries in better economic situations are more likely to have higher FDI outflows, suggesting
109 that the inclusion of GDPPC of the 85 LMICs included in our regression sample improves the validity of the
110 instrumental variables.

111 **Education**

112 Evidence suggests that countries with higher human capital receive more FDI, and have better population health
113 (Noorbakhsh et al., 2001; Veenstra, 2002). Education is a commonly used proxy measure for human capital, and
114 is also associated with population health (Antràs et al., 2015; Burns et al., 2016; Daude & Stein, 2007). The most
115 widely used measures are school enrolment, years of education, and secondary education graduation (Alsan et
116 al., 2006; Barro & Lee, 2013). Education is unlikely to be associated with a purely linear manner with either FDI
117 or population health. Hence a squared term was also included to capture the potential non-linear component.
118 Nationally aggregated years of education estimated by Barro et al. (2013) were used to measure levels of
119 education. This data is quinquennial, so linear interpolation was used to provide an annual value, as is common
120 in the relevant literature (Azemar et al., 2009; Nunnekamp, 2002). Enrolment in secondary education was used
121 as a sensitivity check, and was taken from the World Bank (2015).

122 **Quality of Institutions**

123 Institutional quality and governance are acknowledged to be determinants of population health worldwide, and
124 have also been linked to FDI, suggesting that they may have a confounding effect on the FDI-health association
125 (Bénassy-Quéré et al., 2007; Marmot et al., 2008). An index of civil liberty compiled by Freedom House (2015)
126 was used in all estimations, as this adequately proxies institutional and governmental quality whilst not explicitly
127 including information on population health (see e.g. Azemar et al. (2009) for a similar use of this measure). A
128 range of alternative institutional, governance and globalization measures were explored. These were all found to
129 explicitly contain information about FDI, or severely limit the size of our dataset due to missingness, and largely
130 did not affect our results. Nevertheless, in the Appendix, we also include models controlling for a measure of
131 political rights, also from Freedom House (2015), and the Heritage Foundation overall policy score (See
132 Appendix Table 4) **[PLEASE INSERT A LINK TO APPENDIX.DOCX]** (Miller, 2015).

133 **Urban population**

134 Urban population size is likely related to population health in LMICs (Yusuf et al., 2001b, 2001a). There is also
135 some evidence to suggest that the share of urban population size is a driver of FDI inflows, suggesting its
136 confounding effect in the context of FDI and health (Hsiao, 2003). Consequently, World Bank (2015) data on
137 urban population was included in all models.

138 **3 Econometric Approach**

139 **3.1 Empirical strategy**

140 The suggestions of Preston (1978) indicate that the income and health association is non-linear, time-variant and
141 heterogeneous, and we expected that this was also the case for FDI and health. Consequently, the study design
142 for all our final estimations was a longitudinal panel analysis of country-level data which included country level
143 covariates, time dummy variables, heteroscedacity robust standard errors and accounted for correlation between
144 repeated observations for each country. Infant, child, and adult mortality rates were log-transformed, as they
145 were right-skewed (Wooldridge, 2002).

146 Ordinary least squares (OLS) regression models were used as baseline estimations of the association between
147 FDI and population health. These corrected for within-cluster correlation, and included time dummy variables.
148 This is a useful benchmark, yet can be biased by time invariant differences between countries, and endogeneity.
149 As a second benchmark, we used fixed-effects (FE) regression. This strategy adjusts for unobserved time-
150 invariant heterogeneity between countries potentially correlated with both FDI and health, yet not for the
151 endogeneity which would be a consequence of the bi-directional association between FDI and health
152 (Wooldridge, 2002).

153 (Burns et al., 2016) identified evidence indicating a two-way association between FDI and health (Figure 1).

154 This two-way association highlights the possibility that traditional OLS or FE regression analysis will be
155 affected by endogeneity bias (See Wooldridge (2002) for a full discussion). Instrumental variable fixed effects

156 (IVFE) estimation was used for our main analysis, as this approach is robust to endogeneity bias. This then
 157 allowed us to reliably test whether FDI is associated with health in LMICs. (Section 3.2 below elaborates on our
 158 proposed IV strategy). These estimations were computed using the package xtivreg2 in Stata 13 (StataCorp Inc.,
 159 Schaffer (2015)) and are equivalent to estimates using two-stage least-squares estimation (Angrist & Pischke,
 160 2008; Wooldridge, 2002). In two-stage least squares estimation, the first stage is an OLS fixed-effects regression
 161 of FDI as explained by a set of 'excluded' instruments, Z , ('Exogenous influences on FDI' in Figure 1), along
 162 with a set of 'included' instruments, X , and country-level fixed effects λ_i ('Factors influencing both FDI and
 163 population health' in Figure 1) (See Equation 1). The second stage is a similar OLS fixed-effects regression of
 164 health, explained by the fitted values of FDI from the first stage, $F\hat{D}I_{it}$, X , and λ_i (Equation 2). Z are excluded
 165 from the second stage, resulting in them being referred to as excluded instruments. The results are robust to
 166 endogeneity only if the excluded instruments (Z) can adequately explain variations in FDI (in which case they
 167 are considered 'relevant'), whilst also lacking any ability to independently explain variations in health (in which
 168 case they are considered 'valid').

169 Equation 1:

$$170 \quad FDI_{it} = \gamma Z + \delta X + \lambda_i + \mathbf{t} + u_{it}$$

171 Equation 2:

$$172 \quad H_{it} = \alpha F\hat{D}I_{it} + \beta X + \lambda_i + \mathbf{t} + v_{it}$$

173 where FDI is FDI as a percentage of recipient country GDP and X is the set of control variables.

174 The ratios of secondary sector to total FDI, and tertiary to total, were used to explore industrial composition of
 175 FDI in relation to health in LMICs (Equation 3). The proportion of FDI composed of investments into primary
 176 industries was omitted. The interpretation of secondary FDI in this regression was consequently the impact on
 177 Hit of increased secondary industrial concentration of FDI with respect to primary, whilst holding tertiary and

178 total FDI inflows constant. In this case, we were unable to identify any valid and relevant instrumental strategy,
179 which is why the analysis was limited to OLS and fixed-effects models.

180 Hausman specification tests indicated random effects estimation to be inconsistent for the sectoral analysis,
181 leading to the use of FE. Results of this analysis are robust to time-invariant heterogeneity, yet vulnerable to bias
182 caused by endogeneity.

183 Equation 3:

$$184 \quad H_{it} = \psi + \theta_1 FDI_{it} + \theta_2 SEC_{it} + \theta_3 TER_{it} + \rho X + \lambda_i + w_{it}$$

185 where SEC stands for secondary FDI as a proportion of total FDI and TER for tertiary FDI as a proportion of
186 total FDI.

187 **3.2 Instrumental Strategy**

188 We used determinants of FDI outflows from origin countries, weighted by the proportion of FDI received from
189 the recipient's perspective as instrumentation (i.e. 'Exogenous influences on FDI' in Figure 1) for all IVFE
190 models in this investigation. This approach was inspired by research by Aggarwal et al. (2011) and Ahmed
191 (2013), who investigate the consequences of cross-national income remittances to LMICs. Aggarwal et al.
192 (2011) suggest that economic performance in origin countries can adequately estimate remittances (indicating
193 'relevance'), with the argument that in times of economic prosperity, people have more disposable income to
194 repatriate. At the same time, economic conditions in the origin countries are unlikely to directly affect financial
195 development in recipient countries in a meaningful way (thereby indicating 'validity'). In a similar vein, Ahmed
196 (2013) uses oil prices to instrument remittances to Muslim, non-oil producing countries, finding these origin
197 country determinants to be valid and relevant instruments.

198 Analogously to remittances, firms operating in a prosperous economic environment accumulate more profit and
199 thus tend to have more capital to invest, leading to a larger outflow of FDI from the countries they are based in.
200 Kyrkilis & Pantelidis (2003), Wang & Wong (2007), and Tolentino (2010) empirically support this, suggesting

201 that factors like gross national income, interest rates, international trade levels, and exchange rate volatility affect
202 outward flows of FDI.

203 We used levels of gross fixed capital formation, and volatility of exchange rates in FDI origin (mostly high-
204 income) countries as instruments for FDI flows into LMICs. Capital formation is a general measure of economic
205 performance, and for reasons discussed above, we expected the final instrument to be positively associated with
206 FDI inflows to LMICs, yet independent from LMICs population health. Our measure of exchange rate volatility
207 was a five-year moving average of the standard deviation of local currency to USD exchange rate. As discussed
208 by Wang et al. (2007), exchange rate volatility in high income countries is likely to be a determinant of FDI
209 outflows, and after controlling for GDP per capita, fluctuations in high income countries' exchange rates are
210 unlikely to directly impact on population health, despite the fact many of them import pharmaceuticals. The set
211 of origin countries included when calculating instruments was unrestricted, and as most FDI to LMICs originates
212 from high income countries (see: UNCTAD (2015a)), the capital formation and exchange rate volatility in the
213 LMICs themselves were not a major influence on the final instruments. After controlling for GDP per capita in
214 the destination country (i.e. the LMIC), the moving average of exchange rate volatility from the (mostly high
215 income) origin countries was expected to be positively associated with FDI inflows to the destination country.

216 LMICs receive FDI inflows from multiple origins. Incorporating this information increases the explanatory
217 power of the instruments, resulting in their increased relevance, whilst also maintaining a low level of
218 explanatory power for health outcomes. The weighted versions of both instruments were computed as below,
219 where i is FDI destination country, j is FDI origin country, W is proportion of FDI to i originating from j , EX is
220 exchange rate volatility, and CF is capital formation (Equation 4)

221 Equation 4:

$$222 \quad Wg(EX_{it}) = W_{ij}(EX_{jt})$$

$$223 \quad Wg(CF_{it}) = W_{ij}(CF_{jt})$$

224 We used statistical tests to examine how relevant and valid instruments were (see section 3.1). Kleibergen &
225 Paap (2006) rank Lagrange Multiplier statistics (KP), with the null hypothesis that the instruments insufficiently
226 explained variations in FDI (or lacked relevance), are reported as F-tests for the first-stage regressions (Equation
227 1). Hansen J-statistics, which have the null hypothesis that the instruments are jointly unable to explain
228 variations in health (are valid), are reported for the IV estimations (Equation 2) (Hayashi, 2000; Schaffer, 2015).
229 Nevertheless, it is possible that economic performance of FDI origin countries may impact upon destination
230 country economic performance more directly due to globalization. Health in the recipient country could
231 consequently be affected since macroeconomic performance is related to population health, resulting in the
232 instruments becoming invalid. To control for this, all models therefore included destination country GDP per
233 capita as included instruments (see section 3.1).

234 **3.3 Testing for Endogeneity**

235 Endogeneity tests are intuitive, yet only reliable when the excluded instruments used are both valid and relevant
236 (Greene, 2003). Estimates from a method which is robust to endogeneity (in this case, IVFE) are compared to
237 estimates from a method which is not (in this case, OLS). If the two sets of estimated coefficients vary
238 significantly, this indicates endogeneity (Wooldridge, 2002). The Durbin-Hausman-Wu implementation of this
239 approach is commonly used, yet is unreliable in the presence of heteroscedasticity. We therefore used a
240 bootstrapped variant suggested by Cameron & Trivedi (2009) with 5000 iterations.

241 **4 Results**

242 **4.1 OLS and FE Analysis**

243 Table 2, Models 1 and 2 report results from simple OLS and FE models of the relation between FDI and life
244 expectancy in LMICs. The OLS estimates do not imply that FDI is associated with life expectancy, and the FE
245 estimations in Model 2 also indicates no correlation. However, Models 1 and 2 may both be affected by
246 endogeneity bias, which can affect both the estimated coefficients and standard errors.

247 GDP per capita is reported to be positively related to life expectancy in Models 1 and 2. Years of schooling is
248 associated positively with life expectancy in both models, as expected, and the negative coefficient on years of
249 education squared indicates diminishing health returns to mean years of education amongst the population.
250 Improvements in the institutional variable (lower scores) are not associated with health improvements in either
251 model.

252 **Table 2** *Models of FDI and ln(Life Expectancy) in LMICs*

253 [Table 2]

254 *Standard errors robust to repeat observations within clusters and heteroscedasticity*

255 *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

256 **4.2 IV Analysis**

257 In Table 2, Model 3, we report our instrumental variable fixed effects estimates of the association between life
258 expectancy and FDI inflows in 85 LMICs 1974-2012. After controlling for the biasing effects of endogeneity,
259 we found that a 1% of GDP increase in FDI is weakly statistically associated with 0.99-year increase in life
260 expectancy. We did not observe any net-effect of FDI on infant or under-five mortality rates, however (Table 3).
261 Finally, in Model 6 we report that 1% of GDP increases in FDI are moderately associated with 0.79% reductions
262 in adult mortality.

263 When substituting years of schooling for enrolment in secondary education, the model (A4 in Appendix Table 4)
264 **[PLEASE INSERT A LINK TO APPENDIX.DOCX]** includes more LMICs (105 Versus 85), yet has fewer
265 observations overall. The estimated results remain similar, suggesting that the use of interpolated years of
266 education did not noticeably affect the results. Similarly, when using an alternative measure of institutional
267 quality from Freedom House (2015) (Model A1, see section 2), the results were not affected. When using the
268 Heritage Foundation freedom index overall policy score (Model A2), FDI was not found to be statistically

269 associated with health, yet this is likely because the institutional measure contains information on FDI and
270 international trade.

271 Statistical testing suggests that the instruments were both able to explain variations in FDI, and unable to directly
272 explain variations in health (i.e. the instruments were relevant and valid). In Model 3, the instruments were
273 jointly significant ($F=6.82$). The instruments and their lags were also individually significant. We were unable to
274 reject the J-statistic, suggesting that the instruments were jointly valid ($P=.0436$). The results were not sensitive
275 to including only weighted fixed capital as an instrument (not reported). However, when using only weighted
276 exchange rate volatility in Model A4, FDI inflow was not statistically significant, suggesting it to be a weaker
277 instrument in isolation.

278 The bootstrapped Hausman statistic of 11.96 ($P < 001$) comparing coefficients estimated by OLS and IV
279 models of FDI and life expectancy indicated that Models 1 and 2 were systematically estimating different
280 coefficients to Model 3. As our instruments were likely to be both valid and relevant in model 3, this implies that
281 Models 1 and 2 were affected by endogeneity bias, and thus that endogeneity is indeed present when
282 investigating FDI and health in LMICs.

283 Statistical tests indicate that the instrumentation used in Models 4-6 was relevant and valid. This can be seen by
284 the 1st stage F-statistics and Hanson's J-statistic results in Table 4, (Refer to Wooldridge (2002) for further
285 discussion).

286 **Table 3** *IVFE models of FDI and Age-specific mortality in LMICs*

287 [Table 3]

288 *Standard errors robust to repeat observations within clusters and heteroscedasticity*

289 *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

290 **4.3 Sectoral FDI and Health**

291 Table 4 reports OLS and FE models of total FDI, its industrial concentration, and life expectancy in 31 LMICs.

292 In Model 7 We report weak evidence that relative to primary sector FDI, and whilst holding secondary sector

293 and total FDI constant, increased investment in the tertiary sector is net beneficial to life expectancy, yet this is
294 not true of the secondary industries. In Model 8, which takes time invariant differences between LMICs into
295 account, no association between tertiary FDI and health was found. Rather, we report that increases in FDI
296 industrial concentration in secondary industries are associated with reduced life expectancy. Finally, when
297 investigating age-specific mortality (Not reported), an increased share of total FDI made up from secondary
298 sector investments was found to be moderately statistically associated with a small harmful impact on infant and
299 child mortality, concurring with the findings of Jorgenson (2009, 2009a).

300 However, when investigating aggregate FDI and health, we found strong evidence of endogeneity. This implies
301 that Models 7 and 8, which do not appropriately adjust for endogeneity in this case, are likely to be affected by
302 the same biases which were found to affect Models 1 and 2. These results should therefore be interpreted
303 cautiously. Finally, when removing data from China and repeating the sectoral analysis, the results were similar
304 (total inflow coef.<.001, P=.46; Secondary FDI coef.=-1.19, P=.002).

305 **Table 4** *Sectoral FDI inflows to LMICs and Life expectancy at birth*

306 [Table 4]

307 *Standard errors robust to repeat observations within clusters and heteroscedasticity*

308 *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

309 **5 Discussion**

310 **5.1 Principal Findings**

311 Ordinary least-squares (OLS) and fixed-effects (FE) models of the association between aggregate FDI and life
312 expectancy (Models 1 and 2 in Table 2) do not support the idea that FDI has a net-impact on health in LMICs.
313 However, we found strong evidence of endogeneity using bootstrapped Hausman tests, which indicated that
314 these methods were susceptible to producing both biased coefficients and standard errors, leading to unreliable
315 results and inference. Our instrumental variable fixed-effects (IVFE) model of life expectancy (Model 3), which

316 controls for the influence which endogeneity has on the estimated coefficients and standard errors, links a 1% of
317 GDP increase in FDI to a 0.993-year increase in life expectancy. Over the study period, the mean FDI inflow to
318 LMICs scaled by GDP has increased from 0.83% to 5.01% (UNCTAD, 2014; World Bank, 2015). This implies
319 that FDI in LMICs may be associated with an up to 4.15-year increase in life expectancy between 1974-2012.
320 This is a moderate effect over a 38 year period in which the majority of LMICs underwent many other
321 significant developmental changes, undoubtedly overshadowing this effect. Nevertheless, we conclude that
322 increased FDI to LMICs, which itself is a result of increased freedom of trade and globalization worldwide, has
323 had a net-positive impact to population health over the 38 years we considered.

324 We explored the differential impacts of FDI on age-specific mortality, after adjusting for endogeneity as in the
325 main analysis. In Model 6 we find moderate evidence that a 1% of GDP increase in FDI is associated with a
326 0.08% reduction in adult mortality, while we were not able to identify any net-effect of FDI on either child or
327 infant mortality rates. Consequently, the overall positive effect of FDI on life expectancy appears to be driven by
328 improvements in adult health, as opposed to child or infant health, in LMICs. This is plausible, given that
329 increases in wages for skilled labor and improvements in working conditions owing to FDI are arguably more
330 relevant to adults than children (Feenstra et al., 1997; Moran, 1998, 2004). Further, Jorgenson (2009, 2009a)
331 shows that FDI related pollution is associated with elevated child and infant mortality, yet not adult mortality.
332 One interpretation is then that the harmful effects of FDI in LMICs may be stronger in child and infant
333 populations, offsetting the otherwise beneficial effects. Going forward, researchers should be mindful of this
334 potential differential impact, and at least test the sensitivity of their findings to use of infant, child, and adult
335 health outcomes where possible.

336 We found the ratio of tertiary FDI to total FDI to be beneficially associated with life expectancy in OLS models,
337 yet not associated in fixed-effects models, *ceteris paribus*. On the other hand, we found the ratio of secondary
338 FDI to total FDI to be not associated in OLS models, yet harmfully associated when using a fixed-effects
339 approach. We were unable to appropriately control for endogeneity, however, and these findings are therefore
340 likely to be confounded by similar levels of endogeneity bias to Models 1 and 2. This bias could be affecting

341 both the model coefficients and standard errors, and hence those results should consequently be treated as
342 exploratory and interpreted with care. Nevertheless, whilst FDI can and does on aggregate improve conditions in
343 LMICs, the extent to which this is happening is related to the kinds of industries which are entering markets.
344 This indicates that both the amount of FDI *and* the type of FDI could be important influences on its overall
345 health impacts. Yet, the extent to which this can be reliably explored in LMICs is currently limited by the
346 availability and quality of industrially disaggregated FDI data.

347 **5.2 Recommendations for Future Research**

348 More research investigating the association between FDI in specific industries and overall health is needed. The
349 work hitherto undertaken focused on tobacco, calorie consumption, and pollution (Gilmore et al., 2005; Hawkes,
350 2005; Jorgenson 2009, 2009a). These works identify the channels connecting FDI and the determinants of health
351 outcomes in LMICs. However, the impact of FDI on population health in different industries remains unclear.
352 Work attempting to identify the industries which might be associated with the most health benefit would be
353 valuable in shaping future trade agreements and FDI promotions internationally. Further, we suggest that future
354 data collection and research at the intersection of international macroeconomics and population health in LMICs
355 should focus on important sub-populations, such as those based on demographics and socioeconomics (for
356 instance, adult and infant mortality in urban and rural settings). This will allow researchers to more precisely
357 explore how macroeconomics and globalization are affecting health in LMICs.

358 From a methodological perspective, we recommend that when investigating bilateral international
359 macroeconomic variables like trade and FDI, there is a need to take endogeneity into account, to avoid biased
360 results and unreliable inference. The IV approach used here may be one promising avenue, in which case
361 indicators of the economic environment in countries which trade heavily with the country of interest could be
362 suitable candidates for instrumental variables. At the same time, other quasi-experimental approaches may also
363 be worth exploring in this context (Craig et al., 2012)

364 **5.3 Strengths and Limitations**

365 The reported estimations draw from many LMICs, and are therefore reasonably generalizable to all LMICs.

366 Most notably perhaps, we employ a novel instrumental variable strategy, for the first time in the cross-country
367 health impacts of FDI literature. The instruments used appear to be both valid and relevant in this case. Weighted
368 origin country gross capital formation is a strong predictor of FDI, and is exogenous if IVFE models also include
369 GDP per capita to account for economic integration of the origin and destination countries. For future cross-
370 country studies of macroeconomic factors and health investigating bilateral FDI statistics, IV strategies taking
371 the country of origin into account are worthy of consideration.

372 Data on FDI to LMICs which is disaggregated by sector or industry is very limited, and Theodore H Moran
373 (2011) has argued that the primary, secondary, and tertiary categories used by UNCTAD (2015b) may not be
374 optimal for identifying developmental and health impacts of FDI. Use of sectoral rather than industrial level FDI
375 inflows limits the possibility of parsing out the specific industries, or combination of industries which as a group
376 translate to country-level outcomes of interest, including population health. Work to improve the availability and
377 quality of cross-national FDI data by sector or industry in LMICs would facilitate research investigating deeper
378 into the association between FDI and population health and the determinants and consequences of FDI in
379 specific industries.

380 Some previous empirical study has indicated that the association between FDI and population health is likely to
381 be long term as well as short term (Alam et al., 2015). Although Feenstra et al. (1997) suggest short term
382 increases in pay for skilled workers result from FDI to LMICs, the health implications of this, and more
383 incremental changes identified by Moran (2004), and Theodore H Moran (2005) suggest a gradual cumulative
384 effect. Our study design did use lagged variables and took correlation over time within individual countries into
385 account, yet our findings was still unlikely to capture the potential longer-term health impacts of FDI to LMICs.

386 Yang & Martinez (2006) suggest that currency depreciation affects a migrant's level of remittance to their home
387 country, which may have its own separate effect on population health. This weakens the case for the validity of

388 exchange rate volatility as an instrument for FDI. However, both instruments used were individually significant
389 in the first stage estimation, and exclusion restrictions testing indicated their joint exogeneity. For this
390 investigation, therefore, both instruments were considered appropriate.

391 Levels of labour market informality may confound the association between FDI and health, particularly if firms
392 engaging in FDI to LMICs take advantage of it. Unfortunately, to our knowledge, no widely available data on
393 this exists for LMICs, and we must therefore leave this aspect of the association to future research.

394 Some research has identified flaws in disaggregating FDI by primary, secondary and tertiary sectors, suggesting
395 that using sectoral classifications based on the nature of the work involved (from the perspective of workers)
396 may better isolate developmental, and potentially health, effects associated with FDI (Theodore H Moran, 2011).
397 Future attempts to measure FDI to LMICs, and investigations into health effects should seek to investigate more
398 closely, and with hopefully more comprehensive data, the ways in which different types of FDI matter for health.
399 There is some evidence to suggest that population health may drive income in LMICs, as it does FDI
400 (Borensztein et al., 1998; Hansen & Rand, 2006; Li & Liu, 2005). If this is the case, inclusion of GDP per capita
401 in Models 1-8 may have led to a small amount of endogeneity bias, through the relationship between income and
402 population health. However, controlling for income was crucial to the validity of the instruments. Finally, trade
403 agreements and bilateral investment treaties may have confounded the analysis. These agreements may instigate
404 the changes that lead to improvements in population health, and not FDI (Busse et al., 2010). However, the fixed
405 effects estimator, inclusion of time-dummies and calculation of cluster-robust standard errors were likely to
406 largely adjust for this.

407 **6 Conclusions**

408 We conclude that when adjusting for endogeneity, aggregate FDI to LMICs is beneficially related to life
409 expectancy and adult mortality, yet is not associated with infant or child mortality rates. We find some evidence
410 to suggest that secondary sector FDI is harmful to overall health in LMICs when taking time-invariant country-

411 level heterogeneity into account, but this conclusion remains tentative due to data constraints prohibiting a more
412 robust approach. Taken literally, at least based on mortality data that we used, FDI into LMICs appears to
413 chiefly affect the adult population, which may warrant some adult-oriented focus of further research on the
414 association between FDI and health in LMICs.

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