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IS FOREIGN DIRECT INVESTMENT GOOD FOR HEALTH IN LOW AND MIDDLE INCOME COUNTRIES? AN INSTRUMENTAL VARIABLE APPROACH

Authors

Darren K Burns[1]

Professor Andrew P Jones[2]

Yevgeniy Goryakin[3]

Professor Marc Suhrcke[1,4]

1. Health Economics Group, Norwich Medical School, University of East Anglia, Norwich, NR47TJ, UK
2. Norwich Medical School, University of East Anglia, Norwich, NR47TJ, UK
3. Organisation for Economic Co-operation and Development, Paris, France
4. Centre for Health Economics, University of York, Heslington, York, YO105DD, UK

Corresponding Author

Darren K Burns

Corresponding Author Email Address:

DBurns@bresmed.com

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

There is a scarcity of quantitative research into the effect of FDI on population health in low and middle income countries (LMICs). This paper investigates the relationship 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 on overall health, proxied by life expectancy. When investigating age-specific mortality rates, we find a stronger beneficial effect of FDI on adult mortality, yet no association with either infant or child mortality. 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 (i.e. manufacturing) sector FDI and overall life expectancy. Our results thus suggest that FDI has provided an overall benefit to population health in LMICs, particularly in adults, yet investments into the secondary sector could be harmful to health.

Keywords: Low and Middle Income Countries; Foreign Direct Investment; Instrumental Variables; Population Health; Development; Panel data regression

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

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

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

[PLEASE INSERT A LINK TO APPENDIX.DOCX].

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

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

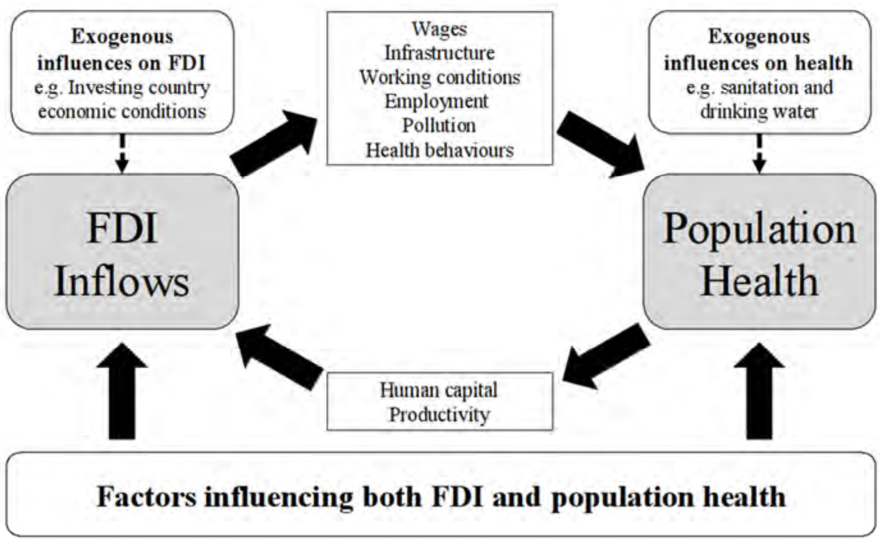

Figure 1: Conceptual framework of the association between FDI and population health in LMICs

Our findings suggest that after explicitly adjusting for endogeneity, FDI is weakly associated with a marginal benefit to overall life expectancy in LMICs, yet more closely associated with adult mortality. We also find some weak preliminary evidence of secondary sector FDI harmfully impacting upon health in LMICs.

2 Data

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

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

2.1 outcome variables

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

2.2 Predictor Variables

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

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

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

2.3 Other Covariates

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

Gross Domestic Product per capita

The association between FDI and population health is likely to be confounded by a country's economic conditions. We included gross domestic product per capita (GDPPC), a widely available and commonly used proxy measure for economic conditions (Blonigen, 2005; Moore et al., 2006). LMICs with a higher GDPPC were expected to both receive larger FDI inflows and have better population health. Finally, as discussed further in Section 3.2, countries in better economic situations are more likely to have higher FDI outflows, suggesting that the inclusion of GDPPC of the 85 LMICs included in our regression sample improves the validity of the instrumental variables.

Education

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

Quality of Institutions

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

Urban population

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

3 Econometric Approach

3.1 Empirical strategy

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

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

(Burns et al., 2016) identified evidence indicating a two-way association between FDI and health (Figure 1). This two-way association highlights the possibility that traditional OLS or FE regression analysis will be affected by endogeneity bias (See Wooldridge (2002) for a full discussion). Instrumental variable fixed effects (IVFE) estimation was used for our main analysis, as this approach is robust to endogeneity bias. This then allowed us to reliably test whether FDI is associated with health in LMICs. (Section 3.2 below elaborates on our proposed IV strategy). These estimations were computed using the package xtivreg2 in Stata 13 (StataCorp Inc., Schaffer (2015)) and are equivalent to estimates using two-stage least-squares estimation (Angrist & Pischke, 2008; Wooldridge, 2002). In two-stage least squares estimation, the first stage is an OLS fixed-effects regression of FDI as explained by a set of 'excluded' instruments, Z, ('Exogenous influences on FDI' in Figure 1), along with a set of 'included' instruments, X, and country-level fixed effects λ_i ('Factors influencing both FDI and population health' in Figure 1) (See Equation 1). The second stage is a similar OLS fixed-effects regression of 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 from the second stage, resulting in them being referred to as excluded instruments. The results are robust to endogeneity only if the excluded instruments (Z) can adequately explain variations in FDI (in which case they are considered 'relevant'), whilst also lacking any ability to independently explain variations in health (in which case they are considered ‘valid’).

Equation 1:

$$FDI_{it} = \boldsymbol{\gamma Z} + \boldsymbol{\delta X} + \lambda_i + \boldsymbol{t} + u_{it}$$

Equation 2:

$$H_{it} = \alpha \widehat{FDI}_{it} + \boldsymbol{\beta X} + \lambda_i + \boldsymbol{t} + v_{it}$$

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

The ratios of secondary sector to total FDI, and tertiary to total, were used to explore industrial composition of FDI in relation to health in LMICs (Equation 3). The proportion of FDI composed of investments into primary industries was omitted. The interpretation of secondary FDI in this regression was consequently the impact on Hit of increased secondary industrial concentration of FDI with respect to primary, whilst holding tertiary and total FDI inflows constant. In this case, we were unable to identify any valid and relevant instrumental strategy, which is why the analysis was limited to OLS and fixed-effects models.

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

Equation 3:

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

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

3.2 Instrumental Strategy

We used determinants of FDI outflows from origin countries, weighted by the proportion of FDI received from the recipient's perspective as instrumentation (i.e. 'Exogenous influences on FDI' in Figure 1) for all IVFE models in this investigation. This approach was inspired by research by Aggarwal et al. (2011) and Ahmed (2013), who investigate the consequences of cross-national income remittances to LMICs. Aggarwal et al.

(2011) suggest that economic performance in origin countries can adequately estimate remittances (indicating 'relevance'), with the argument that in times of economic prosperity, people have more disposable income to repatriate. At the same time, economic conditions in the origin countries are unlikely to directly affect financial development in recipient countries in a meaningful way (thereby indicating 'validity'). In a similar vein, Ahmed (2013) uses oil prices to instrument remittances to Muslim, non-oil producing countries, finding these origin country determinants to be valid and relevant instruments.

Analogously to remittances, firms operating in a prosperous economic environment accumulate more profit and thus tend to have more capital to invest, leading to a larger outflow of FDI from the countries they are based in. Kyrkilis & Pantelidis (2003), Wang & Wong (2007), and Tolentino (2010) empirically support this, suggesting that factors like gross national income, interest rates, international trade levels, and exchange rate volatility affect outward flows of FDI.

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

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

Equation 4:

$$Wg(EX_{it}) = W_{ij}\left(EX_{jt}\right)$$

$$Wg(CF_{it}) = W_{ij}\left(CF_{jt}\right)$$

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

3.3 Testing for Endogeneity

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

4 Results

4.1 OLS and FE Analysis

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

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

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

[Table 2]

Standard errors robust to repeat observations within clusters and heteroscedasticity

$*** \;\; p < 0.01$, $** \;\; p < 0.05$, $* \;\; p < 0.1$

4.2 IV Analysis

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

Finally, in Model 6 we report that 1% of GDP increases in FDI are moderately associated with 0.79% reductions in adult mortality.

When substituting years of schooling for enrolment in secondary education, the model (A4in Appendix Table 4) **[PLEASE INSERT A LINK TO APPENDIX.DOCX]** includes more LMICs (105 Versus 85), yet has fewer observations overall. The estimated results remain similar, suggesting that the use of interpolated years of education did not noticeably affect the results. Similarly, when using an alternative measure of institutional quality from Freedom House (2015) (Model A1, see section 2), the results were not affected. When using the Heritage Foundation freedom index overall policy score (Model A2), FDI was not found to be statistically associated with health, yet this is likely because the institutional measure contains information on FDI and international trade.

Statistical testing suggests that the instruments were both able to explain variations in FDI, and unable to directly explain variations in health (i.e. the instruments were relevant and valid). In Model 3, the instruments were jointly significant (F=6.82). The instruments and their lags were also individually significant. We were unable to reject the J-statistic, suggesting that the instruments were jointly valid (P=.0.436). The results were not sensitive to including only weighted fixed capital as an instrument (not reported). However, when using only weighted exchange rate volatility in Model A4, FDI inflow was not statistically significant, suggesting it to be a weaker instrument in isolation.

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

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

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

[Table 3]

Standard errors robust to repeat observations within clusters and heteroscedasticity

$*** \; p < 0.01, ** \; p < 0.05, * \; p < 0.1$

4.3 Sectoral FDI and Health

Table 4 reports OLS and FE models of total FDI, its industrial concentration, and life expectancy in 31 LMICs. In Model 7 We report weak evidence that relative to primary sector FDI, and whilst holding secondary sector and total FDI constant, increased investment in the tertiary sector is net beneficial to life expectancy, yet this is not true of the secondary industries. In Model 8, which takes time invariant differences between LMICs into account, no association between tertiary FDI and health was found. Rather, we report that increases in FDI industrial concentration in secondary industries are associated with reduced life expectancy. Finally, when investigating age-specific mortality (Not reported), an increased share of total FDI made up from secondary sector investments was found to be moderately statistically associated with a small harmful impact on infant and child mortality, concurring with the findings of Jorgenson (2009, 2009a).

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

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

[Table 4]

Standard errors robust to repeat observations within clusters and heteroscedasticity

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

5 Discussion

5.1 Principal Findings

Ordinary least-squares (OLS) and fixed-effects (FE) models of the association between aggregate FDI and life expectancy (Models 1 and 2 in Table 2) do not support the idea that FDI has a net-impact on health in LMICs. However, we found strong evidence of endogeneity using bootstrapped Hausman tests, which indicated that these methods were susceptible to producing both biased coefficients and standard errors, leading to unreliable results and inference. Our instrumental variable fixed-effects (IVFE) model of life expectancy (Model 3), which controls for the influence which endogeneity has on the estimated coefficients and standard errors, links a 1% of GDP increase in FDI to a 0.993-year increase in life expectancy. Over the study period, the mean FDI inflow to LMICs scaled by GDP has increased from 0.83% to 5.01% (UNCTAD, 2014; World Bank, 2015). This implies that FDI in LMICs may be associated with an up to 4.15-year increase in life expectancy between 1974-2012. This is a moderate effect over a 38 year period in which the majority of LMICs underwent many other significant developmental changes, undoubtedly overshadowing this effect. Nevertheless, we conclude that increased FDI to LMICs, which itself is a result of increased freedom of trade and globalization worldwide, has had a net-positive impact to population health over the 38 years we considered.

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

We found the ratio of tertiary FDI to total FDI to be beneficially associated with life expectancy in OLS models, yet not associated in fixed-effects models, ceteris paribus. On the other hand, we found the ratio of secondary FDI to total FDI to be not associated in OLS models, yet harmfully associated when using a fixed-effects approach. We were unable to appropriately control for endogeneity, however, and these findings are therefore likely to be confounded by similar levels of endogeneity bias to Models 1 and 2. This bias could be affecting both the model coefficients and standard errors, and hence those results should consequently be treated as exploratory and interpreted with care. Nevertheless, whilst FDI can and does on aggregate improve conditions in LMICs, the extent to which this is happening is related to the kinds of industries which are entering markets. This indicates that both the amount of FDI *and* the type of FDI could be important influences on its overall health impacts. Yet, the extent to which this can be reliably explored in LMICs is currently limited by the availability and quality of industrially disaggregated FDI data.

5.2 Recommendations for Future Research

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

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

5.3 Strengths and Limitations

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

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

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

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

Yang & Martinez (2006) suggest that currency depreciation affects a migrant's level of remittance to their home country, which may have its own separate effect on population health. This weakens the case for the validity of exchange rate volatility as an instrument for FDI. However, both instruments used were individually significant in the first stage estimation, and exclusion restrictions testing indicated their joint exogeneity. For this investigation, therefore, both instruments were considered appropriate.

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

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

6 Conclusions

We conclude that when adjusting for endogeneity, aggregate FDI to LMICs is beneficially related to life expectancy and adult mortality, yet is not associated with infant or child mortality rates. We find some evidence to suggest that secondary sector FDI is harmful to overall health in LMICs when taking time-invariant country-level heterogeneity into account, but this conclusion remains tentative due to data constraints prohibiting a more robust approach. Taken literally, at least based on mortality data that we used, FDI into LMICs appears to chiefly affect the adult population, which may warrant some adult-oriented focus of further research on the association between FDI and health in LMICs.

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Table 1: Descriptive Statistics and Descriptions of Variables, 85 LMICs (1974-2012)

Variables	Variables definition	N	Mean	S.D.	Min	Max
Outcome variables						
Life Expectancy	Life expectancy at birth in years, from World bank (2015b)	2642	61.81	9.14	26.76	79.70
Infant Mortality	Infant mortality, per 10,000 live births, from World bank (2015b)	2642	57.76	33.86	6.90	165.90
under 5 Mortality	Under 5 mortality, per 10,000 under-5's, from World bank (2015b)	2642	86.14	61.50	8.10	336.50
Adult Mortality	Adult mortality at birth, per 10,000 Adults, from World bank (2015b)	2642	258.94	114.39	66.12	723.98
Covariate variables						
FDI inflows	Foreign Direct Investment inflows as a percentage of GDP, from UNCTAD (2014)	2642	2.58	4.60	-13.96	85.96
Secondary/Total	Proportion of total FDI made up of investments into secondary industries, from UNCTAD (2003, 2004, 2008)	262	0.38	0.27	-0.1	1
Tertiary/Total	Proportion of total FDI made up of investments into tertiary industries, from UNCTAD (2003, 2004, 2008)	262	0.44	0.24	0	1
Years of Schooling	National average of years spent in education, as estimated by Barro & Lee (2013)	2642	5.52	2.56	0.51	12.90
Years of Schooling, Squared	National average of years spent in education, as estimated by Barro & Lee (2013), squared	2642	37.01	30.99	0.26	166.54
Civil Liberties Index	Index of national levels of civil liberty, estimated by Freedom House (2015)	2642	4.13	1.41	1	7
GDPPC	Gross Domestic Product per capita of the FDI recipient LMIC, in year 2010 United States Dollars, from World bank (2015b)	2642	180.26	19.66	<0.01	13803.71
Urban Population	Urban population as a percentage of total population, from World bank (2015b)	2642	41.39	18.47	3.37	86.37
Instrumental Variables						
Weighted sd(exchange rate)	5-year moving average of origin country standard deviation of local to US dollar exchange rate, weighted, from International Monetary Fund (2015); UNCTAD (2015)	2642	3853831	81000000	0.00	2020000000
Weighted Capital Formation	Origin country gross capital formation as a percentage of origin country GDP, weighted. From UNCTAD (2015);	2642	22.83	5.57	6.51	48.17

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

Model number	(1)		(2)		(3)	
Estimation method	OLS		FE		IVFE	
Model variables	Coef.	pval	Coef.	pval	Coef.	pval
FDI inflow (% GDP)	-0.096	(0.178)	0.033	(0.249)	0.993*	(0.055)
Years of schooling	3.897***	(<.001)	2.139**	(0.046)	2.706**	(0.022)
Years of schooling, squared	-0.175***	(0.003)	-0.165***	(0.002)	-0.193***	(0.003)
Civil Liberties Index, lagged	-0.192	(0.625)	0.090	(0.660)	0.221	(0.332)
ln(GDPPC in 2010 USD), lagged	0.486**	(0.018)	0.292**	(0.012)	0.197	(0.007)
Urban population (% population)	0.120***	(0.002)	0.018	(0.856)	0.026	(0.775)
Constant	41.579***	(<.001)	48.752***	(<.001)	-	-
Observations	2642		2642		2,642	
Number of countrycoded	-		84		85	
F-test	43.90		21.80		17.68	
F-test: 1st stage	-		-		6.82	
J-statistic	-		-		0.606	
(J-stat) Prob > P	-		-		0.436	

Standard errors robust to repeat observations within clusters and heteroskedasticity
**** p<0.01, ** p<0.05, * p<0.1*

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

Model number	(4)		(5)		(6)	
Estimation method	Infant mortality, logged		under-5 mortality, logged		Adult mortality, logged	
Model variables	Coef.	pval	Coef.	pval	Coef.	pval
FDI inflow (% GDP)	-0.02	(0.512)	-0.03	(0.366)	-0.079**	(0.029)
Years of schooling	-0.116**	(0.042)	-0.155**	(0.025)	-0.10	(0.155)
Years of schooling, squared	0.00	(0.604)	0.00	(0.247)	0.01	(0.174)
Civil Liberties Index, lagged	-0.01	(0.304)	-0.02	(0.234)	-0.028*	(0.080)
ln(GDPPC in 2010 USD), lagged	-0.023***	(0.001)	-0.024***	(0.002)	0.00	(0.757)
Urban population (% population)	0.00	(0.653)	0.00	(0.701)	0.00	(0.634)
Observations	2,642		2,642		2,642	
Number of countries	85		85		85	
F-test	21.38		20.21		7.574	
F-test: 1st stage	6.01		6.01		6.01	
J-statistic	0.17		0.24		0.09	
(J-stat) Prob > P	0.68		0.62		0.77	

Standard errors robust to repeat observations within clusters and heteroskedasticity
**** p<0.01, ** p<0.05, * p<0.1*

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

Model Number	(7)		(8)	
Estimation Method	OLS		FE	
Model variables	Coef.	pval	Coef.	pval
FDI inflow (% GDP)	0.022	(0.873)	0.010	(0.598)
Ratio of Secondary FDI to total FDI	4.544	(0.105)	-0.757*	(0.099)
Ratio of Tertiary FDI to total FDI	4.896*	(0.092)	-0.318	(0.470)
Years of schooling	4.525*	(0.061)	2.291**	(0.026)
Years of schooling, squared	-0.285	(0.168)	-0.135**	(0.049)
Civil Liberties Index, lagged	0.277	(0.716)	-0.243*	(0.075)
ln(GDPPC in 2010 USD), lagged	1.775	(0.152)	-0.577***	(0.000)
Urban population, % total	0.098	(0.147)	0.156***	(0.002)
Constant	30.697***	(0.009)	55.165***	(0.000)
Observations	262		262	
R-squared	0.602		0.86	
Number of countrycoded			32	

Standard errors robust to repeat observations within clusters and heteroskedasticity

**** p<0.01, ** p<0.05, * p<0.1*

High DPI version:

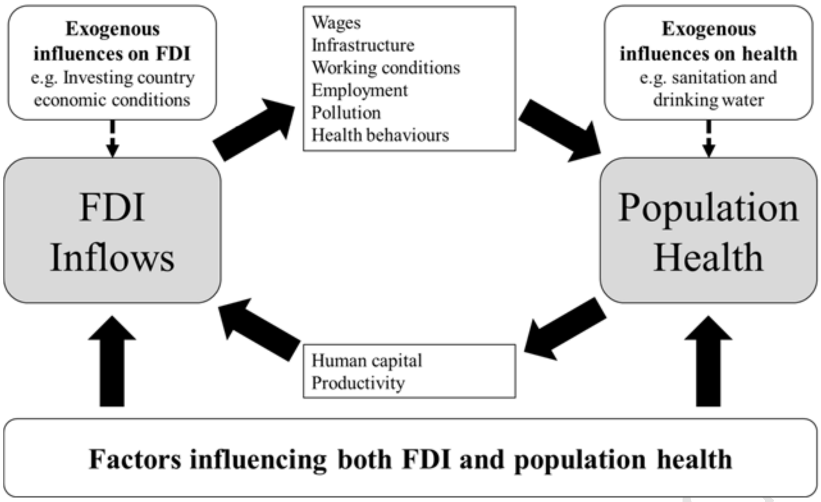
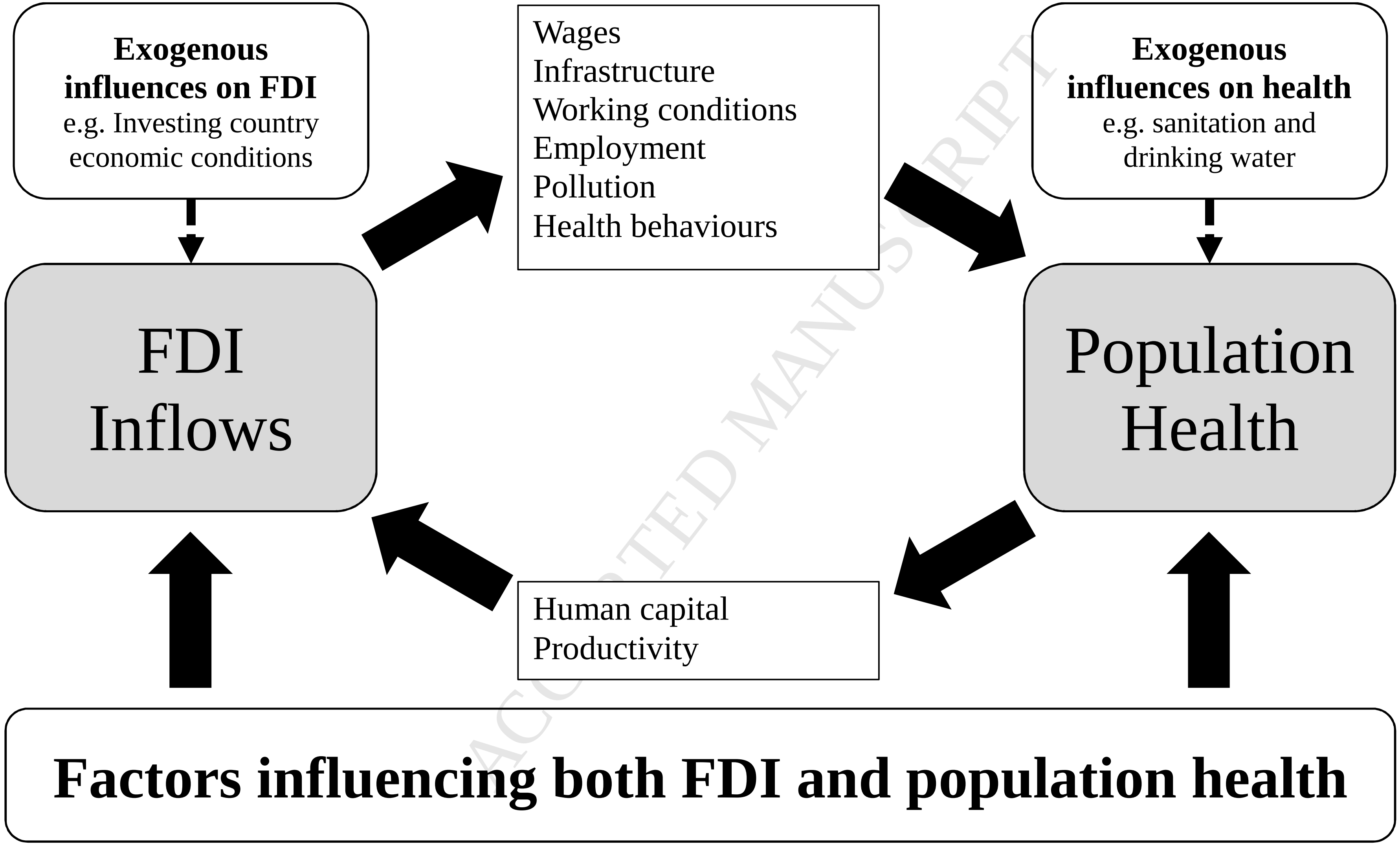
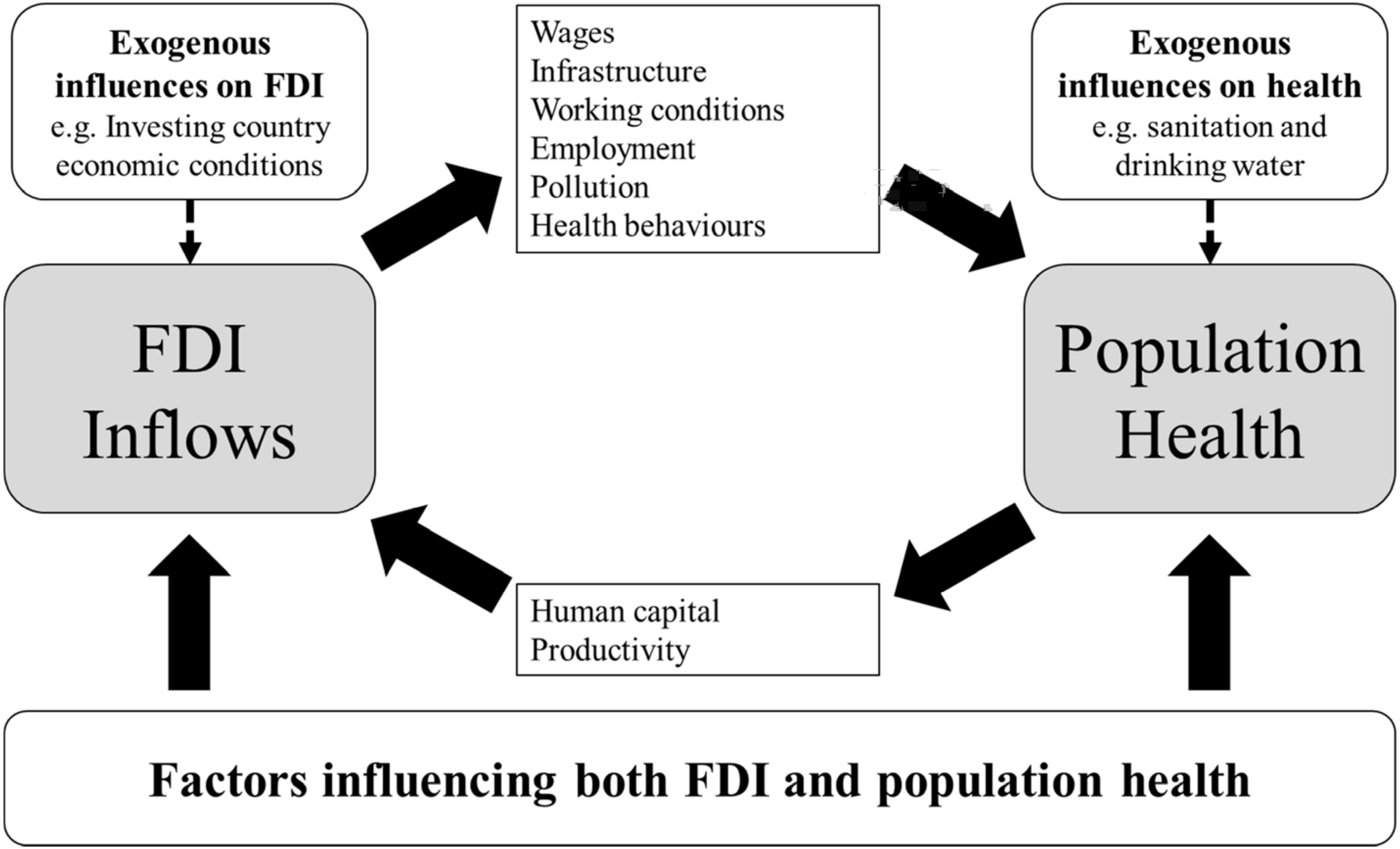


Figure 1: Conceptual Framework of the association between FDI and population health in LMICs

Vectorized version:



Large Raster version:



Instrumental variable approach utilising determinants of FDI from origin countries

First evidence that FDI generally benefits health in low and middle income countries

The effects of FDI on life expectancy are driven by its effect on adult mortality

Preliminary evidence that secondary sector FDI is harmful to overall health