The Effect of Trade on Child Mortality in the LDCs: The Role of Institutions and the Environment

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Abstract

Child mortality is a persistent problem for the world's least developed countries (LDCs). In this paper, we investigate if trade has a causal effect on child mortality for the LDCs, and if so, what sign this effect might be and whether institutions matter in how trade and child mortality are related. To do so, we construct a new instrument for trade using information from the Baltic Dry Index (BDI), which reflects the cost of transporting primary goods, which are the main exports of the LDCs. We find that trade may increase child mortality in LDCs with autocratic governments, but similar evidence is not observed for democratic LDCs. We explore whether environmental quality, in particular, pollution, is a possible channel through which trade and child mortality are linked. We find that an increase in trade may lead to higher levels of pollution, which in turn may cause the child mortality rates in autocratic LDCs to rise.

Keywords: International trade · Environment · Institutions · Child Mortality · Health
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1 Introduction

In 1990, more than 12 million children died before their fifth birthday. Faced with this loss of young lives, the United Nations, in 2000, introduced the Millennium Development Goal 4 with the hope that by 2015, the global under-5 mortality rate would be reduced to one-third the level in 1990. However, in the world's least development countries (LDCs), the problem of child mortality still persists. As recent as 2012, the LDCs have an average under-5 mortality rate of 8.1%, or roughly sixteen times the mortality rate in OECD countries.[1] Moreover, the decline in the rate of child mortality has been much slower in the LDCs than in the rest of the world. In 1990, 1 in 4 children (under 5) who died were from the LDCs.[2] Today, this ratio has risen to more than a third.

From a macroeconomic perspective, increasing trade seems to be one possible answer to the child mortality conundrum in the LDCs. This stems from the evidence that trade is beneficial for economic development (see, *inter alia*, Frankel and Romer, 1999; Feyrer, 2009a, 2009b), and given that the LDCs are somewhat economically insular, they could improve their living standards by becoming more open to trade.[3] However, the benefits of trade may not always trickle down to ordinary citizens, especially in terms of better health. For instance, it is known that developing countries may become pollution havens when they become more open (Frankel and Rose, 2005). In this case, trade expansions may lead to poorer environmental quality, which may be harmful to children in the LDCs.

Our objective in this paper is to investigate if trade has a causal effect on child mortality in the LDCs, and if so, what sign this effect might be. Although the question is straightforward, identifying the effect of trade (even if qualitatively) is challenging as the issues of reverse causality and omitted variable bias are likely to be present. As explained by Levine and Rothman (2006), healthy children tend to become productive higher income adults who may later on choose more trade to meet their demand for a wider variety of goods.[4] In this case, the higher incidence of child mortality may lead to lower levels of trade, causing the trade and child mortality relationship to be downward biased. Moreover, trade and health could be driven simultaneously by omitted

[1] See World Development Indicators of the World Bank: `http://databank.worldbank.org`.

[2] This is with respect to the current LDCs (48 of them), which are fewer than the set of LDCs in 1990.

[3] The LDCs account for only 1% of global trade whilst having 12% of the world's population.

[4] Moreover, decisions on whether to trade, and how much to trade, are clearly not randomly assigned. Therefore, the regression analysis may be confounded by the feedback going from health, then income, then to trade.

cross-country heterogeneity such as disease environments (e.g. McArthur and Sachs, 2001), tastes and cultural characteristics (e.g. Feyrer, 2009a, 2009b).

To address these issues, we pursue an instrumental variable strategy and exploit the panel structure in our dataset, which contains information on 48 LDCs from 1995 to 2012. Our utilization of panel data allows us to purge both time invariant cross-country heterogeneity and systemic macroeconomic shocks that may confound the relationship between trade and health. To overcome the problem of reverse causality, we employ an instrumental variable for LDCs' trade proposed in Lin and Sim (2013). Their idea uses the fact that primary goods are among the most important exports of the LDCs, and these goods are transported mainly by a class of vessels known as dry bulk carriers. Consequently, the cost of bulk carrier charter, as summarized by the Baltic Dry Index (BDI), could potentially influence the volume of LDCs' trade. Based on this insight, Lin and Sim (2013) construct a new instrument for LDCs' trade as the interaction between the log of the BDI and the country's primary products share of its total trade. The primary products share captures the relative intensity of bulk shipping utilization across the LDCs. By interacting it with the BDI, a larger primary product share would then amplify the impact of the BDI and generate country-specific effects of the BDI on trade across time.

In pursuing this topic, it is important to bear in mind that child mortality is typically a problem of households in the lowest income quantiles,[5] who because of their weak economic status, are vulnerable to the types of political environment they live in (Sen, 1999). Therefore, institutions could affect the way trade and child mortality are linked. For example, when it comes to alleviating child mortality, an autocracy is perhaps not the best regime, as people cannot freely punish their governments through the electoral process if poor living conditions persist (Acemoglu et al., 2004; Padró-i-Miquel, 2007; Besley and Kudamatsu, 2008).[6] Furthermore, autocracies tend to have more power over the allocation of resources (Ross, 2006). Hence, with greater autonomy, an autocrat could pursue trade-promoting policies even if they are deleterious to the poor.

[5]For example, within a developing country, Wagstaff (2000) shows that incidence of child mortality can be unevenly distributed across households, where usually, infant and under-5 mortality are significantly higher among the poor (see, also, Victora et al., 2003). In Bangladesh, Halder and Kabir (2008) show that child mortality tends to be concentrated in households from lower socio-economic groups.

[6]For instance, even if there are elections, Acemoglu et al. (2004) show that in certain autocratic developing countries, individuals may still vote for a corrupt incumbent if they receive private benefits from doing so (i.e. are in the circle favored by the incumbent), or for fear of punishment if he is re-elected (see, also, Padró-i-Miquel, 2007). Therefore, low income households who tend to be the ones outside the "favored" group might persistently face poor living conditions as long as the kleptocrats are still in power (Besley and Kudamatsu, 2008).

Focusing on autocratic and democratic LDCs separately, we find that trade may cause child mortality to increase, but only in autocratic LDCs. This suggests that institutions matter in how trade and child mortality are related.[7] In addition, the adverse effect of trade on health appears to be robust when we consider other health measures such as infant mortality rate and life expectancy, and is not sensitive to including different control variables such as foreign direct investment, foreign aid, population density and urbanization rate, all of which could affect health directly.

To understand why trade may increase child mortality in autocratic LDCs, we investigate if environmental quality – in particular, higher pollution levels – could be a reason for this negative relationship. As early as Congleton (1992), autocracies have been observed to have preferences for lower environmental standards. This is because stringent environmental protection can lead to higher cost of production, which then reduces the amount of output available for the autocrat to expropriate. Our paper fits into this scenario as we find that in autocratic LDCs, trade may reduce environmental quality by increasing pollution, such as by raising the emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrous oxide (N_2O).[8] Importantly, by using the variation in pollution generated by the BDI, we have evidence that pollution may increase infant and child mortality and reduce life expectancy.[9] Because trade may increase pollution, which affects health, this suggests that the worsening of environmental quality due to trade is a possible reason for why more trade can lead to higher child mortality rates.

1.1 Relation to the Literature

Our paper is closest to the seminal work of Levine and Rothman (2006), who examine the effect of trade openness on children's health for both developed and developing countries. Methodology-

[7]Generally, we find that a 1% increase in trade is associated with a 0.14% increase in the child mortality rate on average.

[8]We do not have evidence that trade could cause water pollution. However, existing literature suggests water pollution is a negative determinant of children's health. For example, Anand (2013) finds that infant and under-5 mortality are positively associated with the proportion of population assessing unsafe water in the Asia-Pacific regions. Zhang (2012), focusing on rural China, finds that the improvement in children's health (measured by gains in weight-for-height and height) is associated with better access to clean water.

[9]This implies that pollution is an adverse causal factor of health in the LDCs, which adds to the existing literature that looks at the relationship between pollution and health from the correlation point of view. For example, in her review article, Currie (2013) argues that the causality of pollution on health outcome is difficult to establish especially from micro-level data. For instance, she notices that maternal mobility, which is related to social-economic status, can influence children' health outcomes, since mobile mothers are likely to be more informed about the harmful sources of pollution and be able to leave polluted areas actively. However, maternal mobility is hard to control for due to the lack of data, and this makes estimating the causality between pollution and child mortality an extremely difficult thing to do at the micro-level.

wise, our paper contains one significant departure: while we utilize panel data, Levine and Rothman (2006) examine the relationship between trade and health at the cross-sectional level. This is borne out of necessity rather than design, given that Levine and Rothman (2006) follow the Frankel and Romer (1999) approach to construct an instrument for trade using geographical distance, presumably distance is a plausibly exogenous indicator of trade cost. However, because distance is time invariant, the distance-based instrument for trade in Levine and Rothman (2006) cannot be used in conjunction with country fixed effects. Consequently, if geographical distance is correlated with geography-based factors such as cultural characteristics, colonial institutions and disease environments,[10] which could in turn influence health outcomes, the exclusion restriction in Levine and Rothman (2006) may not be satisfied in the presence of these geography related confounders. In our paper, we may avoid this critique as our BDI-based instrument contains not only cross-country variation, but also time variation. This allows us to pursue an instrumental variable strategy that enables the use of country fixed effects, and the combination of instrumental variable estimation with fixed effects is, to our best knowledge, the first on the topic of trade and child mortality.

Our paper is related to two themes within the literature on trade, globalization and the environment. Firstly, it is related to the literature that focuses on the question of whether trade and globalization could affect health outcomes. Although trade liberalization is often thought to be favorable for economic development, empirical evidence on the effect of trade on health has been mixed.[11] In fact, recent evidence has called into question on whether the deepening of trade and globalization has led to actual improvements in health (Case and Deaton, 2006; Ruhm, 2007; Oster, 2012).[12] Our paper is in line with this literature by showing that trade expansions may not lead to improved health outcomes, especially in developing countries with autocratic regimes.

Secondly, our work is related to the literature that examines the contentious issue of whether trade expansions could lead to overall environmental degradation. This is reminiscent of the pollution haven hypothesis, which warns that with the rise of trade and globalization, polluting industries will tend relocate to places where environmental regulations are less stringent. In the "first gen-

[10] This critique is due to Feyrer (2009a, 2009b).

[11] For instance, there are evidence suggesting that an increase in globalization and trade in the developing world will make people better off not only through increases in income but also through improvements in health (Dollar, 2001; Levine and Rothman, 2006; Owen and Wu, 2007).

[12] For instance, Oster (2012) finds that an increase in trade, as measured by an increase in exports, is associated with doubling the incidence of HIV in Sub-Saharan Africa.

eration" literature, Antweiler et al. (2001) and Frankel and Rose (2005) provide some assurance that trade would not harm the environment. However, this observation may not be robust to the subset of less developed countries. For instance, Managi et al. (2009) find that trade openness could in fact lead to higher SO_2 and CO_2 emissions in non-OECD countries, although the opposite is true in OECD countries. Examining U.S. multinational firms in foreign countries, Kellenberg (2009) finds that when production activities are located in developing and transition economies, a much greater proportion of the U.S. multinational production growth is driven by falling relative levels of environmental stringency and enforcement. These results, together with ours, point to the potential role of poor countries as pollution havens, so that stages of development could matter in how trade may eventually affect the environment.

Our paper is also related to the literature that seeks to empirically investigate the "impact of international trade on standards of living" (Frankel and Romer 1999, p. 379). In this research, the most common measure of living standards is income, and numerous papers, including the landmark contribution of Frankel and Romer (1999), have shown that income can improve when trade increases.[13] Our paper looks at another dimension of well-being – the child mortality rate – as an indicator of national development and welfare. Unlike Frankel and Romer (1999), who show that trade-promoting policies have positive effects on development in the aggregate, our paper suggests that people belonging to different income segments may benefit differently from trade. In particular, given that child mortality is usually more prevalent among households in the lowest income distribution, our finding that trade can increase child mortality suggests that the negative by-products of trade, such as the rise in pollution and environmental degradation, could have a greater impact on the poor than on the more well-to-do even within the LDCs.

Finally, to the best of our knowledge, our paper is the first to offer a unified discussion on the link between trade, pollution, and child mortality, while the existing literature tends to focus more on the pairwise relationship between trade and pollution (Antweiler et al., 2001; Cole, 2004; Frankel and Rose, 2005; Kellenberg, 2009; Managi et al., 2009), pollution and child mortality (Franklin et al., 2007; Zhang, 2012; Anand, 2013; Currie, 2013), and trade and child mortality (Levine and

[13] More recently, Feyrer (2009a) uses a natural experiment approach by exploiting the closing and re-opening of the Suez canal during 1967–1975 to generate shocks to shipping distance and hence to the variation in trade. Focusing on the LDCs, Lin and Sim (2013) exploit the BDI to construct a time-varying measure of the cost of primary goods trade. These papers, like Frankel and Romer (1999), find that trade has a sizable causal effect on income, where the trade elasticity of income ranges from 0.2 (Feyrer, 2009a) to 0.5 (Lin and Sim, 2013).

Rothman, 2006). Our paper is also among the first to consider how political economy, in particular institutions, may shape the way trade, pollution, and child mortality interact. This complements the literature that looks mainly at the direct effect that institutions may have on child mortality (Ross, 2006), trade (Brückner and Ciccone, 2010; Arezki and Brückner, 2012a, 2012b; Brückner et al., 2012) and pollution (Congleton, 1992; Cao and Prakash, 2012).

1.2 The Organization of the Paper

The remainder of the paper is structured as follows. In Section 2, we discuss our data sources and the construction of our BDI-based instrument for trade. We present our key estimating equations in Section 3 and discuss our estimation results in Section 4. In Section 5, we examine the empirical evidence of the environment as one possible channel through which trade affects child mortality. Section 6 concludes.

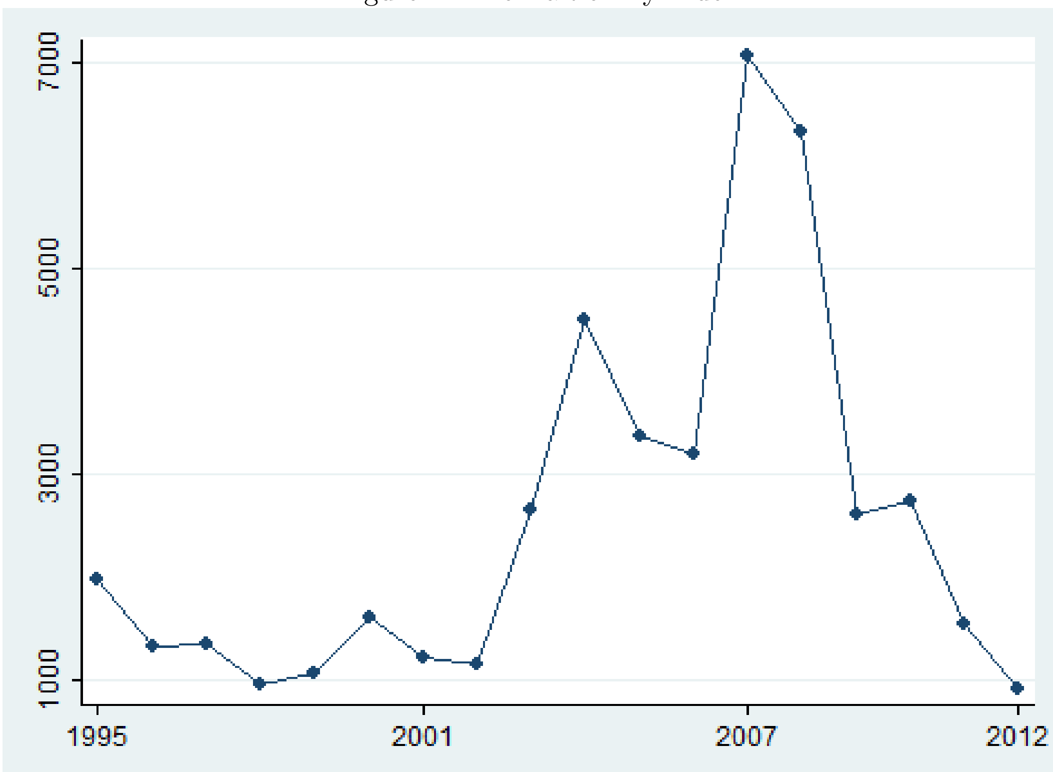
2 Data

Our dataset consists of a panel of 48 LDCs during the period of 1995 to 2012. The dataset is constructed from four main sources: the UNCTAD database, the World Development Indicators, the Environmental Performance Index, and the Polity IV database of Marshall and Jaggers (2009). The key variables in our study are described below. The summary statistics are presented in Table A1 and the variable definitions and sources are documented in Table A2, both of which are in the appendix.

2.1 Baltic Dry Index Based Instrument

In this paper, we follow Lin and Sim (2013) to construct an instrument for trade that exploits information from the Baltic Dry Index (BDI), a cost of shipping index from the Baltic Exchange, which is plotted in Figure 1. In 1985, the Baltic Exchange launched the BDI as a general indicator of shipment rates for dry bulk cargoes, consisting mainly of raw commodities such as grain, coal, iron ore, copper and other primary materials. The BDI, reflecting the cost of bulk shipping, is relevant for the trade of the LDCs, which consist of 48 countries across Africa, Asia, Latin America and the Caribbean. Being among the least technologically developed, the LDCs produce and export mainly primary goods, many of which require bulk carriers for international transportation. Therefore, the cost of global bulk shipping, which is summarized by the BDI, is a relevant indicator of the cost of trade that would affect the LDCs.

Figure 1: The Baltic Dry Index



To exploit country- and time-specific implications of the BDI, we construct a BDI-based instrument based on Lin and Sim (2013) as

$$Cost_{i,t} = \theta_{i,t-1} \log(BDI_t), \tag{1}$$

where $\theta_{i,t-1}$ is the country i's predetermined proportion of total trade that consists of primary commodities trade, which also includes iron and steel but excluding oil fuels.[14] The primary products share captures the relative intensity of utilizing bulk shipping, and the interaction specification in Eq. (1) allows the impact of BDI to be amplified for countries where primary goods trade is more

[14]Concerning Eq. (1), in place of $\theta_{i,t-1}$, we have tried interacting the log of BDI with contemporaneous primary trade share, i.e. $\theta_{i,t}$, or with fixed primary trade share, i.e. $T^{-1}\sum_{t=1}^{T}\theta_{i,t}$. The results of our regressions based on these different specifications are very similar. In this paper, we use lagged primary products share in order to follow Lin and Sim (2013) more closely.

important. To obtain data on primary goods trade, we collect information for the 1995-2012 period from UNCTAD Commodity Statistics (UNCTAD, 2014) based on the SITC 0 + 1 + 2 + 4 + 32 + 67 + 68 classification of primary commodities. This classification covers a wide-range of primary commodities including iron and steel, but excluding crude oil as it is transported not by dry ships but by "wet" carriers such as tankers. Because $Cost_{i,t}$ is a measure of trade cost faced by country i that is driven primarily by the BDI, we call this "BDI cost" hereinafter.

The LDCs are small participants in global trade, accounting for less than 1 percent of world trade in goods and less than 2 percent of global trade in primary goods. In addition, their economies are very small on the global scale, accounting for less than 2 percent of worldwide GDP. Consequently, the LDCs are unlikely to be "influencers" of the BDI dynamics. By contrast, the cost of bulk shipping, broadly reflected by the BDI, can affect the trade of LDCs given that the movement of primary goods is involved. For example, Figure 2 compares the annual growth rate of the BDI with the growth in trade volume per capita for some LDCs, and shows that growth in the BDI is at times accompanied by a slowdown or even contraction in trade. For example, when the BDI increased by 131% from 2002 to 2003, the trade per capita of Central African Republic and Afghanistan, which are both landlocked countries, fell roughly by 7 and 14 % respectively. For some coastal countries, the contraction in trade is even more severe. For instance, trade per capita fell by 14% for Myanmar, 21% for Liberia and 27% for Eritrea in the same period.

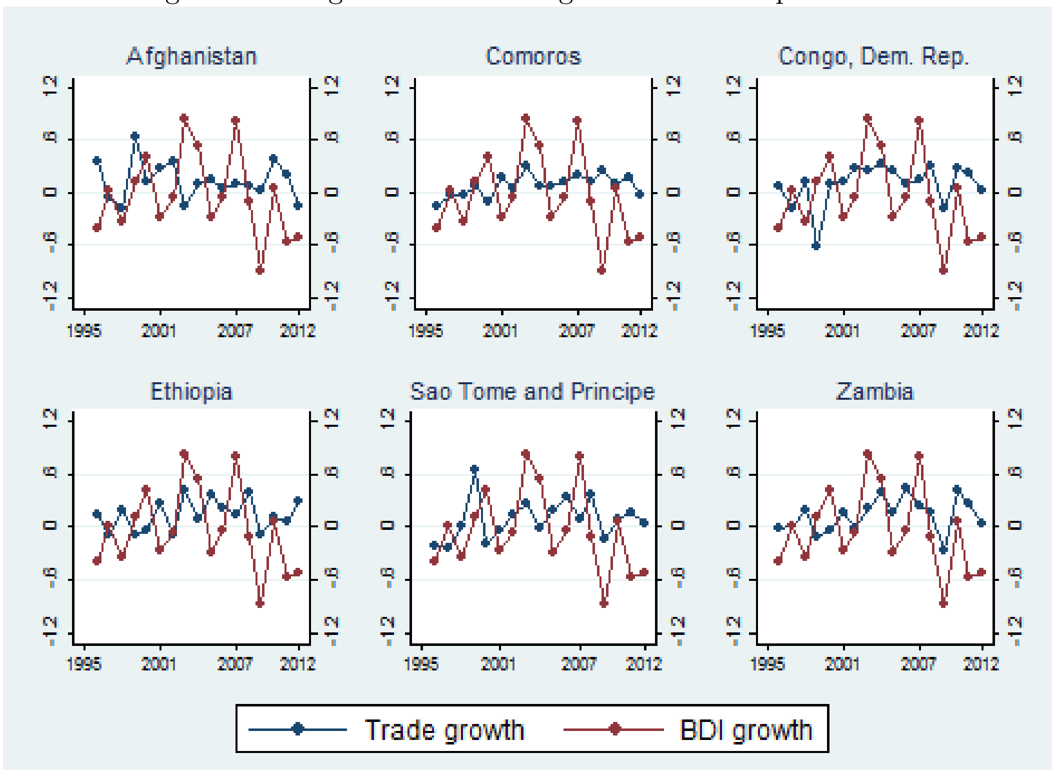
As discussed in Lin and Sim (2013), the salient features of the BDI are driven mainly by the growing demand of commodities by large emerging economies. A leading example is China, which many believed is the key driving force behind recent movements in the BDI.[15] For instance, in 2002, China replaced Japan as the top iron ore importer in the world. By 2003, China had more than doubled its iron ore imports compared to the levels in 2000.[16] This surge in iron ore demand is important because iron ore is by proportion the most important commodity transported by bulk carriers.[17] Besides iron ore, China had transformed itself from being coal exporter to an importer,

[15]Jim Buckley, the CEO of the Baltic Exchange, remarked that "To put it in extremely simplistic terms, China is importing huge amounts of raw materials and exporting manufactured goods, and that's drawing ships into the Pacific." See `http://www.stockengineering.com/pictures/090104%20-%20BDI.pdf`.

[16]According to the Chinese Ministry of Commerce, China imported 70 million tons of iron in 2000, rising to 148.13 million tons in 2003. This demand for iron ore is driven in turn by the demand for steel, which is used for the construction sector as well as the production of automobiles. China is both the world's largest steel consumer and producer, producing nearly 50 percent of the global steel output according to the World Steel Association.

[17]According to Bornozis (2006), the main commodities that utilize bulk carriers for transportation are iron ore, coal and grain. Iron ore and coal are the two most important bulk commodities, comprising 27% and 26% of total

Figure 2: BDI growth and trade growth for a sample of LDCs



Note: This figure plots the growth in the BDI and the growth in trade for a sample of LDCs. The left vertical axis measures the growth in the BDI and the right vertical axis measures the growth in trade per capita. The growth variables are constructed as the first difference of their respective values in logs.

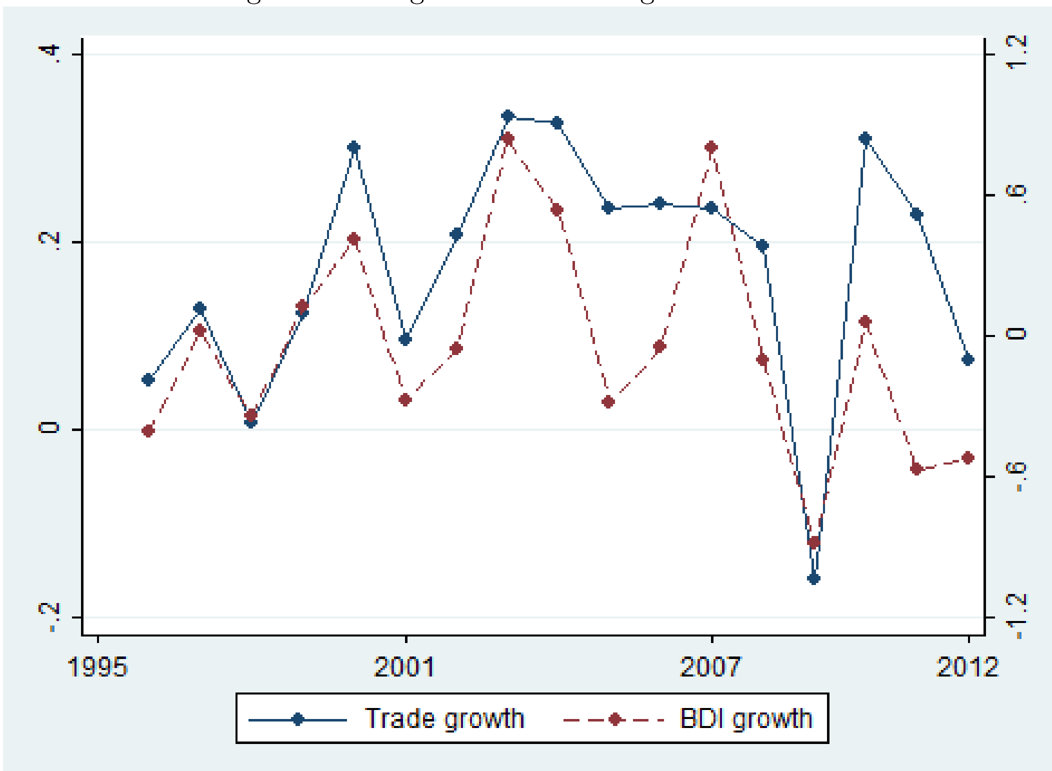
thus further driving up the demand for bulk carriers and in turn influencing the BDI.

To see the importance of China as a driving force, Figure 3 compares the growth rate of the BDI with China's growth in trade volume and shows that the two series track each other closely.[18] This tight positive co-movement is unlike what we have seen for the sample of LDCs documented in Figure 2 where the two series move in the opposite direction at various times. Because the BDI is a measure of trade cost, this positive co-movement could be symptomatic of the endogenous response of the BDI to the levels of trade of major countries such as China. By contrast, the negative co-movement observed with respect to the sample of LDCs in Figure 2 suggests that the reverse causal effect going from LDCs trade to the BDI, if it exists, is unlikely to be strong.

dry bulk trade respectively, followed by grain at 14%. However, iron ore and coal are not the main exports of the LDCs (see Table A in the appendix).

[18]It is interesting to note that China's share of world primary trade in 2010 is 17.69%, or around 10 times the share of world primary trade of all LDCs combined.

Figure 3: BDI growth and trade growth of China



Note: This figure plots the growth in the BDI and the growth in trade of China. The left vertical axis measures the growth in the BDI and the right vertical axis measures the growth in trade per capita. The growth variables are constructed as the first difference of their respective values in logs.

2.2 Health

Our primary measure of health is the mortality rate of children (in 1,000 births) under 5. The child mortality rate is informative about national development and welfare for the following reasons. First, child mortality is typically concentrated in the lowest income quintile (Wagstaff, 2000; Halder and Kabir, 2008), hence, the prevalence of child mortality rate is reflective of the socio-economic environment faced by low-income groups (Gwatkin, 2004).[19] Second, child mortality rate is a sensitive indicator of many conditions that are difficult to measure, such as the availability of clean water and sanitation, indoor air quality, prenatal and neonatal health services, caloric intake, exposure to diseases vectors, etc. (UNICEF, 1989; Ravallion, 1997; Victora et al., 2003). Third, the definition of under-5 mortality rate is universal, whereas other indicators of wellbeing such as

[19]This observation may be true even for countries that experience high economic growth or high levels of GDP per capita, since income may not trickle down from the wealthy, which perhaps explains why a large number of proposed programs for improving child mortality are specifically targeted for the poor (Victora et al., 2003).

poverty line and literacy rate could be defined differently for different countries and across different years.

Besides child mortality, we also consider infant mortality rate (in 1,000 births) and life expectancy at birth as measures of health in our robustness checks.[20] We expect the infant mortality rate to respond to trade in a similar way as the under-5 mortality rate. In fact, given that infants most physically vulnerable,[21] the infant mortality rate would be more sensitive to trade than is true of the under-5 mortality rate – if trade is in fact harmful to health. Our final measure of health is life expectancy. While we do not expect life expectancy to respond to trade as much as the infant and child mortality rates might, it is nonetheless useful to see trade affects life expectancy (if it does) in a consistent way as it might affect infant and child mortality.

Our data on the under-5 mortality rate, infant mortality rate and life expectancy are taken from the World Development Indicators,[22] which could contain imputed data for missing observations.[23] For example, the infant and under-5 mortality rates in the World Development Indicators are provided by the U.N. Inter-agency Group for Child Mortality Estimation (IGME),[24] whose objective is to estimate trends in child mortality from which infant and neonatal mortality rates are derived.[25] Consequently, the within-country variation of child mortality may contain interpolated information that has little to do with trade. In this case, the estimated relationship of trade with child mortality, as well as with other health measures, could be weaker than what it actually is.

2.3 Political System

Our main measure of political system is the revised combined Polity score (Polity2) of the Polity IV data base (Marshall and Jaggers, 2009). The Polity2 score ranges from -10 to +10. Positive (negative) values of Polity2 are indicative of democracies (autocracies). A score of 10 reflects the most democratic institution, a score of -10 reflects the most autocratic one, and a score of zero

[20] Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.

[21] According to WHO, the first-month newborn deaths account for 44% of children deaths under the age of 5. In other words, a newborn faces a higher risk of death than a child who survives after their first year of age. See http://www.who.int/mediacentre/factsheets/fs178/en/

[22] See http://data.worldbank.org/news/release-of-world-development-indicators-2014. Note that information on life expectancy at birth data is not available for Tuvalu.

[23] See http://data.worldbank.org/about/data-overview/methodologies for more details.

[24] See www.childmortality.org.

[25] An entire issue in PLOS Medicine in 2012 is dedicated on the estimation methods of child mortality by the IGME. See www.plosmedicine.org/attachments/Child_Mortality_Estimation_Methods.pdf.

indicates a political institution that is neither democratic or autocratic.[26] In the literature, the Polity2 score has been used to distinguish democracies from autocracies. One example is Arezki and Brückner (2012b), who examine whether the effect of international price booms of exported commodities on the reduction of external debt is contingent on whether countries are democratic or autocratic. They identify democratic (autocratic) institutions within countries based on strictly positive (negative) values of the Polity2 score and run separate regressions of external debt on international commodity price booms for democracies and autocracies (see, also, Brückner et al., 2012).[27] In this paper, we identify democracies and autocracies in the same way as Arezki and Brückner (2012b) and examine the relationship of trade on health separately for democracies and autocracies, just as how they did when investigating the link between commodity price windfalls and external debt.

2.4 Trade and the Environment

We obtain data on nominal trade, measured by million U.S. dollars, from the UNCTAD website.[28] After computing trade per capita, we then deflate with the U.S. CPI for all urban consumers using 2005 as the base year.[29]

Environment quality is measured by both air and water indicators. Our air quality indicators consist of the emissions of carbon dioxide (CO_2), nitrous oxide (N_2O) and sulfur dioxide (SO_2). The information on CO_2 (emissions per capita, in kilograms) and N_2O (emission per capita, in kilograms of CO_2 equivalent) are taken from World Development Indicators.[30] Information on SO_2 (emissions per capita, in metric tons) is obtained from the Environmental Performance Index, which is produced by the Yale Center for Environmental Law and Policy.[31] Water quality is measured

[26] For instance, Polity2 assigns a score of zero (which Polity IV refers to as neutral) to periods where polities cannot exercise effective authority over at least half of their established territory. The Polity IV project refers to such periods as interregnum periods. See `http://www.systemicpeace.org/inscr/p4manualv2013.pdf`.

[27] Arezki and Brückner (2012b) find that increases in the international prices of exported commodity goods lead to a significant reduction in the level of external debt in democracies (Polity2 score greater than zero) but to no significant reduction in the level of external debt in autocracies (Polity2 score less than zero) and they show that in autocracies commodity windfalls lead to a statistically significant and quantitatively large increase in government consumption expenditures while in democracies government consumption expenditures did not increase significantly.

[28] See `http://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx`.

[29] The data comes from `ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt`.

[30] See `http://data.worldbank.org/news/release-of-world-development-indicators-2014`. Data on CO_2 is only available over the period 1995-2010. Data for Tuvalu is completely missing, thus information for 47 LDCs is available. The N_2O data is highly incomplete as it is available for four years 2000, 2005, 2008 and 2010 and for 17 countries.

[31] See `http://epi.yale.edu`, the SO_2 data is available over the period 1995-2005 for only 17 LDCs.

by renewable internal freshwater resources (per capita, in cubic meters), which is taken from the World Development Indicators.[32]

3 Methodology

Our main estimating equation relates the log of a measure of health to the log of trade per capita for country i at year t as

$$\log(health_{i,t}) = \beta \log(trade_{i,t}) + \phi' x_{i,t} + \delta_r\, t + \mu_i + \mu_t + v_{i,t}, \tag{2}$$

where $x_{i,t}$ is the set of control variables that we consider in our robustness checks. In this paper, we focus on the under-5 mortality rate as our main measure of health. Our objective is to investigate if there exists a causal effect of trade on health, which is summarized by β. Unlike the Frankel and Romer (1999) approach, where the exogenous variation in trade is generated by trade distance which is time invariant (see, also, Levine and Rothman, 2006; Frankel and Rose, 2005), our instrumental variable strategy allows us to fully exploit the panel structure in our dataset. In particular, it allows us to include country fixed effects, represented generically by μ_i, that capture all time invariant country-specific characteristics and cross-country heterogeneity such as geography, culture, and disease environments. It also allows us to take into account of all macroeconomic variations through year fixed effects, represented generically by μ_t. In addition to country and year fixed effects, we include region-specific trends for LDCs in Africa, Asia and the others parts of the world to, hopefully, partial out the trends that could be present in the model.[33]

Fixed effects estimation is a powerful way of soaking up certain determinants that cannot be observed or controlled for.[34] However, it is not a panacea for solving the problem of reverse

[32]See `http://data.worldbank.org/news/release-of-world-development-indicators-2014`. Data is available in 1997, 2002, 2007 and 2010 for 44 LDCs. This information is completely missing for Kiribati, Samoa, Tuvalu, and Vanuatu.

[33]We include two regional time trends, one for African LDCs and the other for Asian LDCs. Because of year fixed effects, we can only include two regional time trends as the third time trend (for non-African and non-Asian LDCs) will be absorbed by the year fixed effects. Our regressions are also not affected by the trend specification. For instance, we obtain very similar results if the squared of the time trends are included into the regressions.

[34]For example, high prevalence of tropical disease could reduce trade and and harm health (McArthur and Sachs, 2001). Indirectly, this suggests that geography matters for trade and income. For example, Hall and Jones (1999) argue that income is positively related with the absolute value of latitude. Gallup et al. (1999) show that in the tropics, income is generally lower and human health is adversely affected by tropical climate, and at the other extreme, Masters and McMillan (2001) show that winter frost can restrict economic activity and reduce output.

causality, which may exist. For example, because traders might avoid malarial regions, decisions on whether to trade, how much to trade, and with whom, could depend on health outcomes themselves. Moreover, healthy children tend to become more productive adults, who might desire more trade to enjoy a wider variety of goods.[35]

To deal with this issue, we employ BDI cost as an instrumental variable for LDCs trade. Our baseline instrumental variable equation postulates a linear relationship between the log of trade and BDI cost ($Cost_{i,t}$) as

$$\log(trade_{i,t}) = \gamma Cost_{i,t} + \psi' x_{i,t} + \delta_r t + \mu_i + \mu_t + w_{i,t}. \tag{3}$$

As a "robustness check", we also consider including the squared of $Cost_{i,t}$ in Eq. (3) to capture any nonlinear relationship that might be present between BDI cost and the log of trade. Moreover, the additional information provided by the squared of BDI cost enables us to construct the overidentifying restrictions test. Rejecting the test implies that one or more instruments are invalid, or the model is misspecified, or both. Although the overidentifying restriction test does not distinguish which condition or if both conditions are violated, "passing" this test should at least be a minimal requirement given that its power is often low (Small, 2007).[36]

4 Empirical Results

4.1 OLS Estimates

Table 1 reports several OLS estimates of the effect of trade on child mortality. Column I reports the simple linear regression relationship between trade per capita and child mortality. Without purging out the fixed effects and regional time trends, the OLS regression shows trade and under-5 child mortality are negatively associated. This encouraging result, however, eventually evaporates when country and year fixed effects and regional time trends are included successively into the regression (Column IV). If the inclusion of country and year fixed effects and regional time trends has brought us closer to the true model, the OLS results suggest at first pass that trade is unlikely

[35] We have borrowed this insight from Levine and Rothman (2006).

[36] In other words, because the power of overidentifying restriction test is low, this makes it harder for the test to be rejected. Therefore, rejecting the test would indicate that there are serious concerns model misspecification or invalidity of the instruments.

Table 1: OLS Regression of Trade on Child mortality

	I	II	III	IV
Dependent Variable:	Log(Child mortality rate)			
Log(Trade per capita)	-0.235***	-0.169***	-0.030*	-0.001
	(0.021)	(0.021)	(0.016)	(0.016)
Regional trend	no	yes	yes	yes
Country fixed effects	no	no	yes	yes
Year fixed effects	no	no	no	yes
Observations	856	856	856	856
Countries	48	48	48	48
Adj.R-squared	0.255	0.420	0.952	0.953

Note: Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

to be beneficial in reducing child mortality.

4.2 IV Estimates - Basic Regressions

Table 2 reports the first and second stage regression results, where Column I uses BDI cost as the only instrument for trade and Column II uses both BDI cost and its quadratic term. We first consider if BDI cost and its squared are sufficiently strong instruments, since weak instruments may cause, among other problems, the standard errors to be understated. To do so, we report the Kleibergen and Paap (KP) (2006) F-statistic and evaluate it against a critical value, adopted from Stock and Yogo (2005), that corresponds to the notion that 15% is the maximal rejection rate the researcher is willing to tolerate if the true rejection rate is 5%.[37] If the KP statistic exceeds this critical value, this implies that the maximal rejection rate is smaller than 15%, hence the actual size of the test is between the 5% and 15% levels.

In both Columns I-II, Table 2 shows that KP F-statistics are much greater than the Stock and Yogo critical value, which suggests that BDI cost and its squared are both powerful instruments for trade. The first stage regression shows that BDI cost affects trade negatively, where a one standard deviation increase in BDI cost is associated with a 13.6% decrease in trade. When the squared

[37] This follows from the suggestion of Stock et al. (2002).

of BDI cost is used as an additional instrument, Column II shows that the negative effect of BDI cost on trade is present as well. These observations are consistent with the idea that BDI cost is a measure of the cost of primary goods trade, hence, it should be negatively associated with the levels of LDCs trade.

Despite the strength of BDI cost, the second stage estimates are not conclusive about the relationship between trade and child mortality. In Column I, the estimated effect of trade is very weak and statistically insignificant. However, in Column II, trade appears to have a positive and statistically significant effect on child mortality. If BDI cost is a valid instrument, these opposing results suggest that the model might be misspecified. In fact, this appears to be plausible as the Hansen J test in Column II shows that the overidentifying restriction test is rejected. Because its null hypothesis postulates that the instruments are valid and the model is correctly specified, rejecting the test if the instruments are valid would imply that the model is incorrect.

4.3 IV Estimates –Autocracies and Democracies

Child mortality is typically a problem faced by poor households (Wagstaff, 2000; Victora et al., 2003; Halder and Kabir, 2008). These households, as Sen (1999) argues, are especially vulnerable to the types of political environment they live in.[38] For instance, without a robust electoral process, an autocrat can avoid punishment if poor living conditions persist (Acemoglu et al., 2004; Padró-i-Miquel, 2007; Besley and Kudamatsu, 2008), and thus has greater control over the use of national resources in ways that may not help to improve the well-being of people.

To see if the trade-child mortality relationship is different across political systems, Table 3 re-estimates the model for democracies (Columns I-II) and for autocracies (Columns III-IV) separately. For democracies, the first stage regression of BDI cost on trade is statistically insignificant. Hence, we cannot make any assertion about the causal effect of trade on child mortality that the second stage regression aims to provide. However, for autocracies, not only is the effect of BDI cost on trade statistically significant, the first stage F-statistic is also more than twice of what is found in the "pooled" regression of Table 2 (i.e. pooling democracies and autocracies together). In other words, BDI cost becomes a stronger instrument when we limit our attention to autocratic LDCs

[38] For example, Sen (1999 p.13) argues that 'the protective role of democracy may be particularly important for the poor", and that "the evidence is entirely against that claim [that] the poor do not care about civil and political rights".

Table 2: IV Regression of Trade on Child Mortality

	I	II
Second-stage Dependent Variable:	Log(Child mortality rate)	
Log(Trade per capita)	-0.056	0.096**
	(0.062)	(0.044)
First-stage Dependent Variable:	Log(Trade per capita)	
BDI cost ($\text{BDI}^C_{i,t}$)	-0.125***	-0.601***
	(0.026)	(0.095)
BDI cost square		0.090***
		(0.016)
First-stage Kleibergen-Paap F-Stat	22.88	21.20
Stock and Yogo critical value (15%)	8.96	11.59
Hansen J statistic (p-value)	.	0.000269
Regional trend	yes	yes
Country FE	yes	yes
Year FE	yes	yes
Observations	808	808
Countries	48	48

Note: BDI Cost is defined in Eq. (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

even though there are fewer observations in doing so.

Focusing on autocratic LDCs, Column IV shows that the overidentifying restriction test is now “passed”, whereas the test was rejected when the full sample was used (see Column II of Table 2). Given that the same instruments are used in both Tables 2 and 3, rejecting the overidentifying restriction test in Table 2 but not in Table 3 suggests that the “pooled” regression model is wrong. One possible reason for this misspecification, we surmise, is that institutions do matter in how BDI cost, trade and child mortality are related.

For autocratic LDCs, the estimated trade elasticity of child mortality is between 0.130 to 0.145 (Columns III-IV). This implies that a 1% increase in trade may increase the child mortality rate by about 0.14% on average.[39] To interpret this result in terms of the actual number of children

[39] This is based on the average of 0.130 in Column III and 0.145 in Column IV.

at risk, we carry out some back-of-the-envelope calculations. For a small autocratic LDC such as Equatorial Guinea, a 1% increase in trade could approximately lead to 18 additional deaths of under-5s. For larger autocracies such as Tanzania and Uganda, the approximate number of under-5s resulting from a 1% increase in trade could be as high as 695 and 722 respectively.[40] If we take a conservative perspective by using the two standard deviation lower bound of the point estimate of 0.14%, the estimated number of deaths in Tanzania and Uganda from a 1% increase in trade is around 417 and 433 respectively. Considering how volatile the BDI is, and recall that a one standard deviation increase in BDI could increase trade by as much as 13.6%, the number of children at risk could be a lot larger.

The effect of BDI on trade is heterogeneous across LDCs, as this effect depends on how important primary goods trade is for each LDC in question (see Eq. (1)). Hence, using the country-specific effect of the BDI on trade, we may estimate the effect of the BDI on child mortality for each country. To do so, we first estimate the reduced form relationship between child mortality and BDI cost given by[41]

$$\log(health_{i,t}) = \alpha Cost_{i,t} + \delta_r t + \mu_i + \mu_t + u_{i,t}. \tag{4}$$

Then based on the estimate of Eq. (4), we construct the absolute time-averaged elasticity of child mortality with respect to the BDI as the absolute value of

$$\frac{1}{T-1}\sum_{t=2}^{T} \hat{\alpha}\theta_{i,t-1}, \tag{5}$$

where $\hat{\alpha}$ (equals to -0.046) is the reduced form estimate of BDI cost on child mortality, and $\theta_{i,t-1}$ is period $t-1$ primary trade share of country i.

Figure 4 plots the absolute average elasticity of child mortality with respect to the BDI for a sample of autocratic LDCs,[42] and show that the effect of the BDI on child mortality is heterogeneous across countries. For the LDCs featured in Figure 4, the BDI elasticity of child mortality (in absolute

[40] This is computed using 2010 figures for the under-5 population and child mortality rate. For instance, Tanzania's under-5 population and child mortality rate are 8,052,680 and 6.16%. Hence, using the elasticity of 0.14%, we compute the approximate number of additional deaths as $0.0014 * 0.0616 * 8052680 \approx 695$. The under-5 population data is taken from the United Nations at `http://esa.un.org/wpp/Excel-Data/population.htm`.

[41] Results are available upon request.

[42] The autocratic country is chosen based on the principle that they are mainly autocratic (with Polity2<0 for more than 8 years) during the sample period between 1995-2012.

Table 3: IV Regression of Trade on Child Mortality

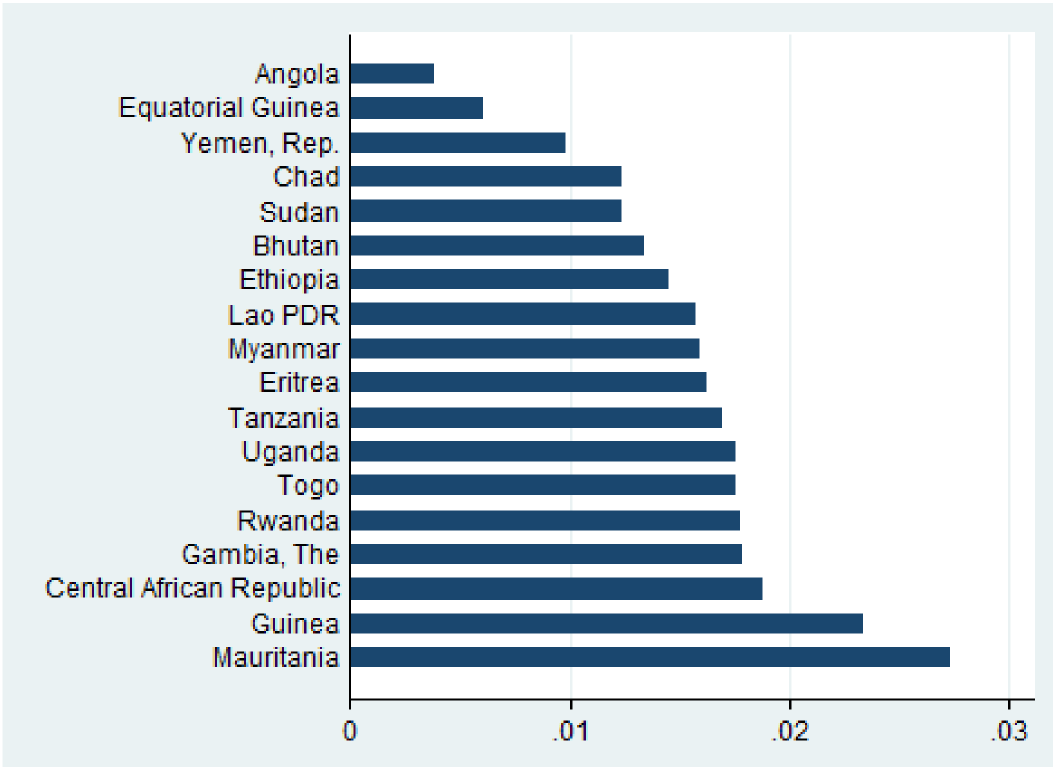
	I	II	III	IV
	Democracy Polity2>0		Autocracy Polity2<0	
Second-stage Dependent Variable:	Log(Child mortality rate)			
Log(Trade per capita)	-2.832	0.523	0.130***	0.145***
	(10.452)	(0.754)	(0.028)	(0.028)
First-stage Dependent Variable:	Log(Trade per capita)			
BDI cost ($BDI^C_{i,t}$)	-0.006	-0.102	-0.357***	-0.971***
	(0.024)	(0.088)	(0.045)	(0.140)
BDI cost square		0.017		0.127***
		(0.014)		(0.026)
First-stage Kleibergen-Paap F-Stat	0.0630	0.773	61.82	41.58
Stock and Yogo critical value (15%)	8.96	11.59	8.96	11.59
Hansen J statistic (p-value)	.	0.275	.	0.240
Regional trend	yes	yes	yes	yes
Country FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Observations	402	402	280	280
Countries	29	29	18	18

Note: BDI Cost is defined in Eq. (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

value) is between 0.0039 and 0.0274, suggesting that the rate of child mortality declines by around 0.04% to 0.27% when the BDI increases by 10%. Mauritania's child mortality rate is by far the most sensitive to variations in the BDI. On the other hand, Angola is least affected by the BDI, which makes sense as oil but not primary products is its most important export.[43] In short, Figure 4 suggests that sharp swings in the BDI are not innocuous, since trade booms following large declines in the BDI could have adverse consequence on child mortality in autocratic LDCs.

[43] Oil is transported by wet tankers, not by dry ships. Given that Angola is an important oil exporter, this would weaken the effect of BDI on Angola's trade. Note that Angola, along with Nigeria, are now the top oil exporters in Sub-Saharan Africa. See "Angola rivals Nigeria for top spot in African oil exports", *Reuters*, September 17 2013.

Figure 4: The (Absolute) Average BDI Elasticity of Child Mortality for a Sample of Autocratic LDCs.



Note: This figure plots the absolute value of the (time) average BDI elasticity of child mortality for each LDC that is mainly autocratic, defined as a country with Polity2<0 for more than 8 years through the sample period 1995-2012. This elasticity is computed based on Eq. (5). It shows the average percentage decline in child mortality rate in each country following a 1% increase in the BDI.

4.4 Robustness checks

This section examines the robustness of our baseline instrumental variable estimates. The first robustness check re-examines if the effect of trade on child mortality is contingent on institutional types. In our baseline regression, we find that trade expansions could worsen the incidence of child mortality in autocratic LDCs. For democratic LDCs, we cannot observe the relationship between trade and child mortality as BDI cost is not statistically significant for trade in the first stage regression.

To conduct our first robustness check, we exploit a country-specific commodity price index as an alternative instrument for trade. This estimation strategy is based on the idea that international commodity prices capture information about the global demand for commodities.[44] Given that the LDCs are predominantly primary goods producers, the global demand for commodities could influence the demand for LDCs exports. In particular, if the exports of certain commodities are important to an LDC, an increase in global demand for these commodities (reflected by their international prices) would affect the demand for that LDC's exports with greater force. Therefore, international commodity price movements can have country-specific effects on trade, where the specificity of this effect depends on how important exporting these commodities are across different LDCs.

Based on this idea, also explored by Brückner and Ciccone (2010) and Arezki and Brückner (2012a, 2012b),[45] we construct a country-specific commodity price index to capture the country-specific effect that international commodity prices have on trade:

$$\overline{ComPI}_{i,t}^{C} = \sum_{c} \theta_{i,c} \log(ComPrice_{c,t}), \tag{6}$$

where $\log(ComPrice_{c,t})$ is the international price of commodity c in year t, and $\theta_{i,c}$ is the average (time invariant) value of exports of commodity c in the GDP of country i. We obtain data on annual international commodity prices for the 1995–2010 period as well as data on the value of commodity exports from UNCTAD Commodity Statistics (UNCTAD, 2011).[46] The commodities included in our index are aluminum, bananas, beef, cocoa, coffee, copper, cotton, gold, iron, maize, lead, oil, pepper, rice, rubber, sugar, tea, tobacco, wheat, wood, and zinc. When there were multiple prices listed for the same commodity, we use the simple average of all the relevant prices.

Table 4 constructs the instrumental variable estimates for the pooled sample (Column I), for the sample of democracies only (Column II), and for autocracies only (Column III) using $\overline{ComPI}^{C}$ as an instrument of trade. Column I Table 4 shows that $\overline{ComPI}^{C}$ is a strong instrument as its F-statistic is well above the Stock and Yogo critical value for instrument strength when democratic and autocratic countries are combined. However, $\overline{ComPI}^{C}$ turns out to be a weak instrument when the sample is split, i.e. the first-stage F-statistic is below 10 in Columns II and III. Nevertheless,

[44] As an analogy, Kilian and Park (2009) argue that in the context of oil, prices are driven mainly by demand driven shocks than production shocks.

[45] Arezki and Brückner (2012a, 2012b) examine the macroeconomic effects of international commodity price shocks on economic growth using a similar price index.

[46] See `http://www.unctad.org/Templates/Page.asp?intItemID=1584&lang=1`.

Table 4: Robustness Check 1: Using Commodity Price Index as Instrument for Trade

	I	II	III
	Pool sample	Democracy Polity2>0	Autocracy Polity2<0
Second-stage Dependent Variable:		Log(Child mortality rate)	
Log(Trade per capita)	0.103	-0.213	0.907**
	(0.120)	(0.180)	(0.413)
First-stage Dependent Variable:		Log(Trade per capita)	
Commodity Price Index ($\overline{ComPI}_{i,t}^{C}$)	0.890***	1.005**	0.942**
	(0.216)	(0.430)	(0.374)
First-stage Kleibergen-Paap F-Stat	16.96	5.457	6.344
Stock and Yogo critical value (15%)	8.96	8.96	8.96
Regional trend	yes	yes	yes
Country FE	yes	yes	yes
Year FE	yes	yes	yes
Observations	632	338	201
Countries	40	25	14

Note: Commodity Price Index ($\overline{ComPI}_{i,t}^{C}$) is defined in Eq. (6). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

the second-stage regressions in Column I-III are consistent with our baseline results that trade is positively associated with child mortality for autocratic LDCs. For democratic LDCs, trade is statistically insignificant, just as before.

Focusing on autocratic LDCs for the rest of the paper, our second robustness check considers two alternative measures of health: the infant mortality rate and life expectancy at birth. If trade is harmful to health, it should worsen the incidence of infant mortality and shorten life expectancy, which appears to be true as Table 5 shows. For example, Columns I-II suggest that a 1% increase in trade has a statistically significant effect of raising the infant mortality rate by about 0.1% on average, which is similar to the ballpark estimate of 0.14% when child mortality is used as a measure of health (see Table 3). Furthermore, the observation that trade affects health adversely in autocratic LDCs is supported by Columns III-IV, where a 1% increase in trade is associated

Table 5: Robustness Check 2: Trade, Infant Mortality and Life Expectancy

	I	II	III	IV
Second-stage Dependent Variable:	Log(Infant mortality rate)		Log(Life expectancy)	
Log(Trade per capita)	0.090***	0.106***	-0.024**	-0.031***
	(0.026)	(0.026)	(0.010)	(0.009)
First-stage Dependent Variable:	Log(Trade per capita)			
BDI cost ($BDI^{C}_{i,t}$)	-0.357***	-0.971***	-0.357***	-0.971***
	(0.045)	(0.140)	(0.045)	(0.140)
BDI cost square		0.127***		0.127***
		(0.026)		(0.026)
First-stage Kleibergen-Paap F-Stat	61.82	41.58	61.82	41.58
Stock and Yogo critical value (15%)	8.96	11.59	8.96	11.59
Hansen J statistic (p-value)	.	0.220	.	0.197
Regional trend	yes	yes	yes	yes
Country FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Observations	280	280	280	280
Countries	18	18	18	18

Note: BDI Cost is defined in Eq. (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

with a decline in life expectancy by around 0.03% on average.

In the third robustness check, we check for the sensitivity of the baseline estimates by controlling for additional variables that might be relevant to child mortality.[47] In this exercise, we consider five possible variables – foreign aid, FDI, population density, urbanization rate, and the rate of HIV. For a start, living standards could be improved by inward FDI (Nair-Reichert and Weinhold, 2001) and foreign aid (Werker et al., 2009). If these improvements trickle down to the poor, child mortality could be reduced directly by FDI and foreign aid. In addition to these foreign inflows, health may also be affected by population density (Root, 1997) and urbanization (Cutler et al., 2006).[48] For example, better access to medical facilities in urbanized areas could help to reduce

[47]Because these variables are not in the baseline regression, they may be contained in the error term of the child mortality equation. Consequently, if BDI cost is a valid instrument, our baseline results would be consistent and should be robust to the inclusion of these additional variables.

[48]Focusing on Zimbabwe, Root (1997) argues that the transmission of diseases and infections is quicker in high

child mortality (Leon, 2008; Van de Poel et al., 2007), although overcrowding in urban areas may facilitate the transmission of diseases and infections (Cutler et al., 2006; Fay et al., 2005). Finally, the prevalence of HIV can affect child mortality, which may arise when the child dies from the disease or indirectly if the child's mother dies (see, for example, Zaba et al. 2005).

The data sources and the variable definitions for inward FDI flows, foreign aid, population density, urbanization rate, and HIV prevalence rate are provided in Table A2 of the appendix. For inward FDI and foreign aid, we apply the appropriate deflator to obtain real values denoted in million U.S. dollars, then apply log transformation. In this exercise, we use the first lag of the additional variables as controls.[49] To conserve space, Table 6 reports the regressions that use BDI cost (not its squared) as the only instrument for trade.[50]

Columns I-IV show that the estimated effect of trade on child mortality is generally robust to the inclusion of these control variables. For example, when the log of foreign aid, log of FDI, or HIV prevalence rate is added, the elasticity of child mortality rate with respect to trade remains close the baseline elasticity estimate of 0.13 (see Column III of Table 3). The estimated trade elasticity becomes weaker when population density or urbanization rate is controlled for, although this effect remains statistically significant at the 1% level. Among the control variables, the effect of HIV prevalence rate on child mortality is the strongest, both in the sense of statistical significance and influence, where a one percentage point increase in the HIV prevalence rate is associated with a 12 percent increase in under-5 mortality on average.

density areas, and finds that the child mortality rate is much lower in lower density regions in Zimbabwe.

[49] The results are similar when contemporaneous values of these variables are used instead.

[50] The results are very similar if we use both BDI cost and its squared of BDI as instruments.

Table 6: Robustness Check 3: Additional Control Variables

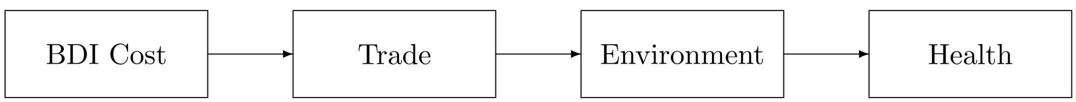
	I	II	III	IV	V
	Foreign aid	FDI	Population density	Urbanization rate	HIV
Second-stage Dependent Variable:	Log(Child mortality rate)				
Log(Trade per capita)	0.138***	0.131***	0.075***	0.095***	0.133***
	(0.031)	(0.033)	(0.023)	(0.029)	(0.039)
Additional Control	-0.022	-0.013*	-0.004***	-0.010	0.122***
	(0.016)	(0.007)	(0.001)	(0.006)	(0.027)
First-stage Dependent Variable:	Log(Trade per capita)				
BDI cost	-0.362***	-0.360***	-0.347***	-0.363***	-0.367***
	(0.048)	(0.050)	(0.045)	(0.051)	(0.051)
Additional Control	-0.038	0.030	-0.002	0.005	0.247***
	(0.049)	(0.027)	(0.001)	(0.018)	(0.082)
First-stage Kleibergen-Paap F-Stat	56.75	52.04	58.70	51.10	51.35
Stock and Yogo critical value (15%)	8.96	8.96	8.96	8.96	8.96
Regional trend	yes	yes	yes	yes	yes
Country FE	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes
Observations	280	256	280	280	253
Countries	18	18	18	18	16

Note: BDI Cost is defined in (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

5 The Environmental Channel

In this section, we investigate if the environment is one possible channel through which trade can affect child mortality and health in general. Schematically, the causal structure we have in mind is summarized by Figure 5, which describes the causal chain that first begins with BDI cost. Because BDI cost is a reflection of trade cost, it would have an immediate effect on trade. Hence, if it does affect the environment at all, this effect must be indirect in the sense that the environment is caused by trade, which in turn is driven directly by BDI cost. Furthermore, in the short run, it is plausible that the environment can affect health directly but not the other way around.[51] Therefore, the chain of events would run from BDI cost to trade, then to the environment, and ultimately to health outcomes.

Figure 5: The Proposed Causal Chain of Trade, Environment and Health



One explanation for this causal structure is the pollution haven hypothesis (see, for example, Frankel and Rose, 2005), which posits that large industrialized nations seeking to set up factories abroad are likely to look for countries that are less environmentally stringent. Given that environmental regulations are usually less demanding in developing countries, the LDCs will tend to attract the inflow of polluting activities and become pollution havens for industrialized countries.[52] In autocracies, the "pollution haven effect" may be more pronounced as the system of check-and-balance is weak. In fact, there is evidence to suggest that environmental regulations are usually less stringent in countries with low political constraints, as these autocratic-like countries may adopt lower regulatory standards and/or weaker enforcements of regulations so that output can be produced more cheaply (Cao and Prakash, 2012).

[51] In the long run, poor health can lead to changes in policies for improving the environment.

[52] For example, higher pollution regulations in advanced countries render production of pollution intensive goods more costly in domestic markets. Therefore, "dirty" productions are likely to migrate from developed to developing countries (Cole, 2004) where pollution regulations are usually less stringent (Dinda, 2004). To attract more trade flows, industrializing countries may create a downward environment standard by lowering the price of pollution intensive goods (Porter, 1999). Consequently, pollution intensive productions concentrate on less developed countries (i.e. LDCs) so that their environment bears a higher risk of pollution.

5.1 The Effect of Trade on the Environment

We first examine if trade has an effect on the environment. To capture environmental quality, we consider four indicators of pollution – the levels of sulfur dioxide (SO_2), carbon dioxide (CO_2), nitrous oxide (N_2O), and access to clean, renewable freshwater (see Table A2 for definitions).[53] Table 7 reports the relationship between trade and the pollution indicators. Other than the statistically insignificant relationship between trade and clean water (Column IV), Table 7 shows that trade has negative effect on environmental quality in autocratic LDCs, where Columns II-IV show that a 1% increase in trade is associated with an increase in SO_2, CO_2 and N_2O emissions by over 0.81%, 0.80% and 0.66% on average.

Table 7: Trade and Pollution

	I	II	III	IV
Second-stage Dependent Variable:	Log(SO_2)	Log(CO_2)	Log(N2O)	Log(Water)
Log(Trade per capita)	0.811***	0.799***	0.660*	0.022
	(0.111)	(0.129)	(0.373)	(0.026)
First-stage Dependent Variable:				
BDI cost	-0.348***	-0.395***	-0.465***	-0.397***
	(0.048)	(0.045)	(0.130)	(0.078)
First-stage Kleibergen-Paap F-Stat	53.65	77.17	12.75	26.11
Stock and Yogo critical value (15%)	8.96	8.96	8.96	8.96
Regional trend	yes	yes	yes	yes
Country FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Observations	70	249	65	31
Countries	7	18	18	8

Note: BDI Cost is defined in Eq. (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

The negative effect of trade on health could have been stronger if not for a possible mitigating factor. In the literature, it is known that trade generally has a positive effect on income levels

[53]These variables have been used as indicators of environmental quality in the literature. For example, Frankel and Rose (2005) consider SO_2, CO_2 , N_2O emissions and clean water access as indicators of environmental quality, while Managi et al. (2009) look at the level of SO_2 and CO_2 emissions.

Table 8: Trade and Public Health Expenditure (PHE)

	I	II
Second-stage Dependent Variable:	Log(PHE)	Log(PHE per capita)
Log(Trade per capita)	0.285*	0.299*
	(0.147)	(0.152)
First-stage Dependent Variable:	Log(Trade per capita)	
BDI cost ($BDI^C_{i,t}$)	-0.357***	-0.357***
	(0.045)	(0.045)
First-stage Kleibergen-Paap F-Stat	61.82	61.82
Stock and Yogo critical value (15%)	8.96	8.96
Regional trend	yes	yes
Country FE	yes	yes
Year FE	yes	yes
Observations	280	280
Countries	18	18

Note: BDI Cost is defined in Eq. (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

(Frankel and Romer, 1999). If the increase in income resulting from trade generates more tax revenues, this could help to fund more public health services and mitigate the impact of trade on child mortality. In Table 8, we document the response of public health expenditure to trade for autocratic LDCs.[54] Columns I-II show that trade expansions are associated with an increase in the log of public health expenditure (Column I) and the log of public health expenditure per capita (Column II) with an elasticity of around 0.3 in both cases.

Therefore, the negative consequence of trade on child mortality, despite the fact that trade may generate more public health expenditure, suggests that the positive effect of public health expenditure has been "outdone" by negative effect of pollution from trade. One relevant question might then be, has the increase in public health expenditure been commensurate with the increase in pollution?[55] To see this, we examine the effect of trade on the ratio of public health expenditure

[54]Information on public health expenditure is taken from the World Development Indicators.

[55]This does not imply that by increasing public health expenditure proportionately more than the rise in pollution, the effect of trade on child mortality will be reversed, since spending could be wasteful and healthcare technologies

(PHE) over the levels of SO_2 or CO_2 emissions ($emissions$), i.e.

$$ratio_{i,t} = \frac{PHE_{i,t}}{emissions_{i,t}}$$

which approximates the level of public health expenditure per unit of pollution.[56] The regressions, which are reported in Table 9, show trade has a negative effect on *ratio* (whether or not *emissions* is defined in terms of SO_2 or CO_2 emissions). In other words, while trade tends to increase pollution and public health expenditure simultaneously, the rise in pollution has been faster than that of public health expenditure, which may explain why the overall effect of trade on children's health has been detrimental.

Table 9: Trade and the Ratio of Public Health Expenditure (PHE) over SO_2 or CO_2 Emissions

	I	II
Second-stage Dependent Variable:	PHE/SO_2	PHE/CO_2
Log(Trade per capita)	1.723	-0.094***
	(1.977)	(0.026)
First-stage Dependent Variable:	Log(Trade per capita)	
BDI cost ($BDI^C_{i,t}$)	-0.348***	-0.395***
	(0.048)	(0.045)
First-stage Kleibergen-Paap F-Stat	53.65	77.17
Stock and Yogo critical value (15%)	8.96	8.96
Regional trend	yes	yes
Country FE	yes	yes
Year FE	yes	yes
Observations	70	249
Countries	7	18

Note: BDI Cost is defined in Eq. (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

and manpower could be limited.

[56] Both ratios are in million U.S. dollars per thousand metric ton.

5.2 The Effect of the Environment on Health

Next, we exploit the BDI cost driven variation in environmental quality to study if pollution has a causal effect on health. From Figure 5, this involves constructing a reduced form relationship between the environment and BDI cost. Then, using the BDI driven variation in pollution, we estimate if the environment does affect health at all. We focus on the levels of SO_2 and CO_2 emissions as our measure of pollution and consider all three health indicators – under-5 mortality, infant mortality, and life expectancy – in this exercise.

Table 10 reports the estimated effect of pollution on health in autocratic LDCs. The first stage regression shows that BDI cost has a negative effect on both SO_2 and CO_2 emissions, where a one standard deviation increase in BDI cost is associated with a reduction in SO_2 and CO_2 emissions of about 30% and 34% on average. The second stage regression, our main focus, confirms that pollution could have negative causal effects on health. For example, Table 10 shows a 1% increase in SO_2 (CO_2) is associated with a 0.10% (0.14%) increase in under-5 mortality rate and 0.08% (0.10%) increase in infant mortality rate (Columns I-II and IV-V). Furthermore, Columns III and VI show that a 1% increase in SO_2 or CO_2 is associated with a 0.03% decline in life expectancy. To be clear, these results are not sufficient for us to conclude that SO_2 and CO_2 emissions *per se* have causal effects on health. However, given that SO_2 and CO_2 emissions are correlated with the overall levels of pollution, what we may infer instead is that pollution (generated by trade) can cause the incidence of child mortality to rise and public health to deteriorate.[57]

In summary, for autocratic LDCs, we have shown that trade can generate more pollution (Section 5.1) and more pollution can increase child mortality (Section 5.2). Therefore, the deterioration of environmental quality, following an increase in trade, is one possible reason for the adverse impact that trade has on child mortality.

[57] This result is consistent with the German-based panel study by Coneus and Spiess (2012) who find that certain air pollutants can cause infants to have lower birth weights and toddlers to develop respiratory problems.

Table 10: Pollution, Child Mortality, Infant Mortality and Life Expectancy

	I	II	III	IV	V	VI
Second-stage Dependent Variable:	Log(CMR)	Log(IMR)	Log(LE)	Log(CMR)	Log(IMR)	Log(LE)
Log(SO_2) in I-III, or	0.100***	0.084***	-0.028***	0.137***	0.098***	-0.028**
Log(CO_2) in IV-VI	(0.032)	(0.027)	(0.006)	(0.038)	(0.032)	(0.011)
First-stage Dependent Variable:		Log(SO_2)			Log(CO_2)	
BDI cost (BDI_{it}^{C})	-0.282***	-0.282***	-0.282***	-0.316***	-0.316***	-0.316***
	(0.035)	(0.035)	(0.035)	(0.066)	(0.066)	(0.066)
First-stage Kleibergen-Paap F-Stat	64.14	64.14	64.14	22.60	22.60	22.60
Stock and Yogo critical value (15%)	8.96	8.96	8.96	8.96	8.96	8.96
Regional trend	yes	yes	yes	yes	yes	yes
Country FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Observations	70	70	70	249	249	249
Countries	7	7	7	18	18	18

Note: BDI Cost is defined in Eq. (1). The Stock-Yogo critical value corresponds to the case where 15% is the maximal rejection rate one is willing to tolerate if the true rejection rate is 5%. Robust standard errors are reported in the parenthesis. Statistical significance at the 10%, 5% and 1% levels are indicated by *, ** and *** respectively.

6 Conclusion

One of the most important empirical findings in international trade is the positive effect that trade expansions have in raising income levels, hence, in alleviating poverty and improving living standards (Frankel and Romer, 1999). However, what is sometimes overlooked is the fact that in developing economies, trade may harm the environment and cause health to be compromised. In this paper, we document a causal link between trade and child mortality for a set of LDCs whose governments are autocratic. We find that in these countries, trade expansions may lead to poorer environmental quality, which in turn could exacerbate the problem of infant and child mortality and shorten life expectancy. Because child mortality is usually a problem of households in the lowest income distribution, our results suggest that trade could harm the poor even though it has been emphasized in the literature that trade can foster economic development in an overall sense (e.g. Frankel and Romer, 1999; Feyrer, 2009a, 2009b; Lin and Sim, 2013).

Our paper focuses on environmental quality as one possible mechanism through which an increase in trade may lead to poorer health outcomes. However, it is by no means the only channel through which trade can affect health. For example, trade may increase the amount of contact among people, causing communicable diseases to be transmitted more easily. It may also generate opportunities for individuals in trade-related work to engage in risky activities, the leading example of which is documented in Oster (2012), where the increase in exports is found to increase trucking, a profession that has high prevalence of HIV infections. Therefore, although pollution is one possible channel linking trade with health, there could be other channels in place which themselves are interesting to explore further for future research.

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Appendix

Table A1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Child mortality rate under-5 (per 1,000 live births)	864	114.6	51.59	17.80	278.9
Infant mortality rate (per 1,000 live births)	864	74.08	27.67	15.30	153.1
Life expectancy (at birth)	846	56.08	7.471	31.24	72.98
Log(Child mortality rate) (Log(CMR))	864	4.616	0.547	2.879	5.631
Log(Infant mortality rate) (Log(IMR))	864	4.219	0.450	2.728	5.031
Log(Life expectancy) (Log(LE))	846	4.018	0.137	3.442	4.290
Polity2	753	0.641	4.981	-10	9
Log(CO_2)	729	-1.751	1.067	-6.358	2.359
Log(N_2O)	68	5.937	0.794	4.527	7.676
Log(SO_2)	187	-6.642	1.221	-8.147	-2.879
Log(Water)	176	8.245	1.719	4.501	11.95
Log(Trade)	856	6.994	1.718	1.158	11.65
Log(Trade per capita)	856	-1.477	1.184	-4.010	3.599
Primary products share of total trade ($\theta_{i,t}$)	856	0.351	0.142	0.0217	0.841
Log(BDI)	864	7.632	0.618	6.824	8.865
BDI cost ($BDI^C_{i,t}$)	808	2.680	1.091	0.156	5.862

Table A2: List of Variables, Definitions and Sources

Variables	Definition	Source
Child mortality rate	The probability per 1,000 that a newborn baby will die before reaching age five	WDI
Infant mortality rate	The number of infants dying before reaching one year of age, per 1,000 live births	WDI
Life expectancy (at birth)	The number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life	WDI
Polity2	Ranging from -10 to +10, higher value, more democratic	Polity IV data
CO_2	Carbon dioxide emissions per capita, in kilograms	WDI
SO_2	Sulfur dioxide emissions per capita, in metric tons	EPI
N_2O	Nitrous oxide emissions, thousand metric tons of CO_2 equivalent	WDI
Water	Renewable internal freshwater resources per capita (cubic meters)	WDI
Trade	Million U.S. dollars trade levels (Nominal)	UNCTAD
CPI	U.S. CPI for all urban consumers, 2005 as the base year	U.S. Bureau of Labor Statistics
BDI	General indicator of shipment rates for dry bulk cargoes	The Baltic Exchange
Foreign aid	Net official development aid (million U.S. dollars)	WDI
FDI	Inward foreign direct investment (million U.S. dollars)	UNCTAD
Population density	Midyear population divided by land area in square kilometers	WDI
Urbanization rate	Urban population (% of total)	WDI
HIV prevalence rate	% of 15-49 year olds infected by HIV	WDI
Public Health Expenditure	Government (central and local) budgets, external borrowings and grants and social health insurance funds (million U.S. dollars)	WDI
Under-5 population	Population under the age of 5	UN