THE UNIVERSITY of ADELAIDE

School of Economics

Working Papers

ISSN 2203-6024

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Working Paper No. 2015-15
June 2015

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Abstract

Child mortality is a persistent problem for the world's least developed countries (LDCs). Given that trade fosters economic development, one plausible solution is to raise the low levels of trade in the LDCs, but how effective this approach might be could depend on the quality of institutions. In this paper, we use a novel instrumental variable approach to estimate the effect that trade might have on child mortality in the LDCs. We find that trade does not lead to lower levels of child mortality. In fact, in autocratic LDCs, trade could even cause child mortality to increase as we find that pollution, which adversely affects health, may rise with trade.

Keywords: Child Mortality · Trade · Institutions · Environment · Least Developed Countries
JEL Classification: I3 · O1· F18 · P16

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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 announced the forth Millennium Development Goal in 2000 that targeted the reduction of the global under-5 mortality rate. However, in the world's least developed countries (LDCs), high rates of child mortality continue to persist. 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. 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.[1] Today, this ratio has risen to more than a third.[2]

Given that trade can foster economic development (see, *inter alia*, Frankel and Romer, 1999; Feyrer, 2009a, 2009b), raising the *low levels* of trade in the LDCs could be a way of reducing child mortality in these countries.[3] However, how effective this approach might be, whether the benefits of trade activities do trickle down to ordinary citizens, could be influenced by institutions. For example, in countries with autocratic regimes, an autocrat may capture the economic benefits of trade without facing serious repercussions (see, for example, Acemoglu et al., 2004; Padró-i-Miquel, 2007; Besley and Kudamatsu, 2008).[4] Moreover, autocratic countries tend to be less willing to confront pollution and therefore have weaker environmental regulations (Congleton 1992; Cao and Prakash, 2012). In this case, trade activities in these countries are likely to be more polluting and harmful to health.

In this article, we examine the effect that trade might have on child mortality in the LDCs and explore if this relationship depends on institutions. Ascertaining if trade causes child mortality is difficult in itself, as child mortality could reverse cause trade and omitted variables could be present. As Levine and Rothman (2006) argue, healthy children tend to become productive adults

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

[2] The figures are computed using the World Development Indicators of the World Bank. See `http://databank.worldbank.org`.

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

[4] Unlike a democracy, people living in an autocratic regime do not have a fair electoral process to punish the autocrat if poor living conditions persist. Even if there are elections, individuals living in autocracies may still vote for a corrupt incumbent if they receive private benefits from doing so (Acemoglu et al. 2004) or for fear of punishment if the incumbent is re-elected (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).

who may choose to have more trade,[5] which means causality may run from child mortality to trade. Moreover, trade and health could be driven simultaneously by omitted 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 "identification" issues, we employ fixed effects instrumental variable regression based on a panel data of 48 LDCs from 1995 to 2012. To address the problem of omitted variables, we use country and year fixed effects to purge both time invariant cross-country heterogeneity and macroeconomic shocks that may confound the effect of trade on child mortality (if it exists). To deal with reverse causality, we use an instrumental variable for LDCs' trade proposed by Lin and Sim (2013, 2015). The LDCs are mainly producers and exporters of primary goods. Given that primary goods are typically transported by a class of vessels known as dry bulk carriers, the cost of bulk carrier charter – reflected by the Baltic Dry Index (BDI) – could influence how much the LDCs trade. Based on this insight, we construct an instrument for LDCs' trade as the interaction between the log of the BDI and each LDC's primary goods share of its total trade. The latter reflects the intensity of bulk shipping utilization of an LDC. By interacting it with the BDI to construct our instrument, this captures the idea that the influence of bulk shipping cost is stronger for countries where primary goods trade is important. Crucially, our instrument contains both cross-sectional and time variation and therefore can be employed in panel regressions without being "cleaned out" by country and year fixed effects.

In our regressions, we find no evidence that trade can lead to lower levels of child mortality in the LDCs. In fact, within autocratic LDCs, trade may even be harmful, as we find that a 1% increase in trade per capita is associated with a 0.13% increase in the child mortality rate on average. To explore the underlying mechanism, we consider the role that environmental quality might have in explaining this positive relationship between trade and child mortality. As discussed, environmental regulations tend to be less stringent in autocracies (Congleton, 1992), which suggests that trade activities in these countries are likely to be more polluting. Our regression results are consistent with this idea as we

[5] 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.

find that within autocratic LDCs, an increase in trade may increase pollution such as the emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrous oxide (N_2O). Furthermore, using plausibly exogenous variations in pollution generated by the BDI, we also find that pollution can cause child mortality in autocratic LDCs to rise. These results suggest that environmental quality is a plausible channel for the adverse effect of trade on child mortality that is found in this paper.

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. Besides focusing on the LDCs, our work contains one significant departure in that we utilize panel data whereas Levine and Rothman (2006) exploit only cross-sectional information. The latter is borne out of necessity as Levine and Rothman (2006) construct their instrument for trade based on geographical distance, which is incompatible with fixed effects regression as distance is time invariant.[6] Moreover, given that distance could be correlated with geography-based time invariant factors of development such as cultural characteristics, colonial institutions and disease environments, the instrument used by Levine and Rothman (2006) may not satisfy the required exclusion restriction.[7] In this paper, our instrument for trade contains both cross-sectional and time variation. The time-varying nature of our instrument allows us to implement panel IV regressions with country fixed effects, which to our best knowledge is the first within the topic of trade and child mortality.

Our paper is related to two areas within the literature on trade, globalization and the environment. Firstly, it is related to the literature that focuses on the relationship between trade and health. Although trade liberalization may foster economic development, the evidence on whether trade can improve health has been mixed.[8] In fact, recent evidence suggests that trade may not always lead to better health outcomes (Case and Deaton, 2006; Ruhm, 2007; Oster, 2012),[9] which is consistent

[6]Levine and Rothman (2006) construct their instrument based on the same approach as Frankel and Romer (1999).

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

[8]For instance, there is 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).

[9]For instance, Oster (2012) finds that an increase in exports is associated with doubling the incidence of HIV in

with what we have found in this paper.

Secondly, our work is related to the debate on whether trade can lead to environmental degradation. This is related to 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 generation" literature, Antweiler et al. (2001) and Frankel and Rose (2005) find little evidence to support this hypothesis. However, for less developed countries (in particular, non-OECD countries), Managi et al. (2009) find that trade openness can lead to higher SO_2 and CO_2 emissions. Moreover, examining U.S. multinational firms in foreign countries, Kellenberg (2009) shows that when production activities are located in developing and transition economies, a significant proportion of the U.S. multinational production growth is generated by falling relative levels of environmental stringency and enforcement. These results, together with ours, suggest that the less developed countries could be pollution havens. As such, it is not always clear that trade can lead to improvements in health and reductions in child mortality.

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 rise with trade.[10] Our paper looks at another dimension of well-being – the child mortality rate – as an indicator of development and welfare. Child mortality is typically a problem of households in the lowest income quantiles.[11] Therefore, the adverse effect of trade on child mortality that we have found for autocratic LDCs suggests that trade might cause the poorer households in these countries to be worse off even if does improve income levels on average.

Sub-Saharan Africa.

[10] 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).

[11] 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.

Finally, to the best of our knowledge, our paper is among the first to offer a unified discussion on the link between trade, pollution, and child mortality, while the existing literature has focused more specifically 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 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 (Arezki and Brückner, 2012) and pollution (Congleton, 1992; Cao and Prakash, 2012).

1.2 The Organization of the Paper

The remainder of the paper is as follows. In Section 2, we discuss our data sources and the construction of our instrument for trade. In Section 3, we present our estimating equation and discuss the relevant estimation issues. We then present our regression results in Section 4 and explore environmental quality as a channel in Section 5. Section 6 concludes.

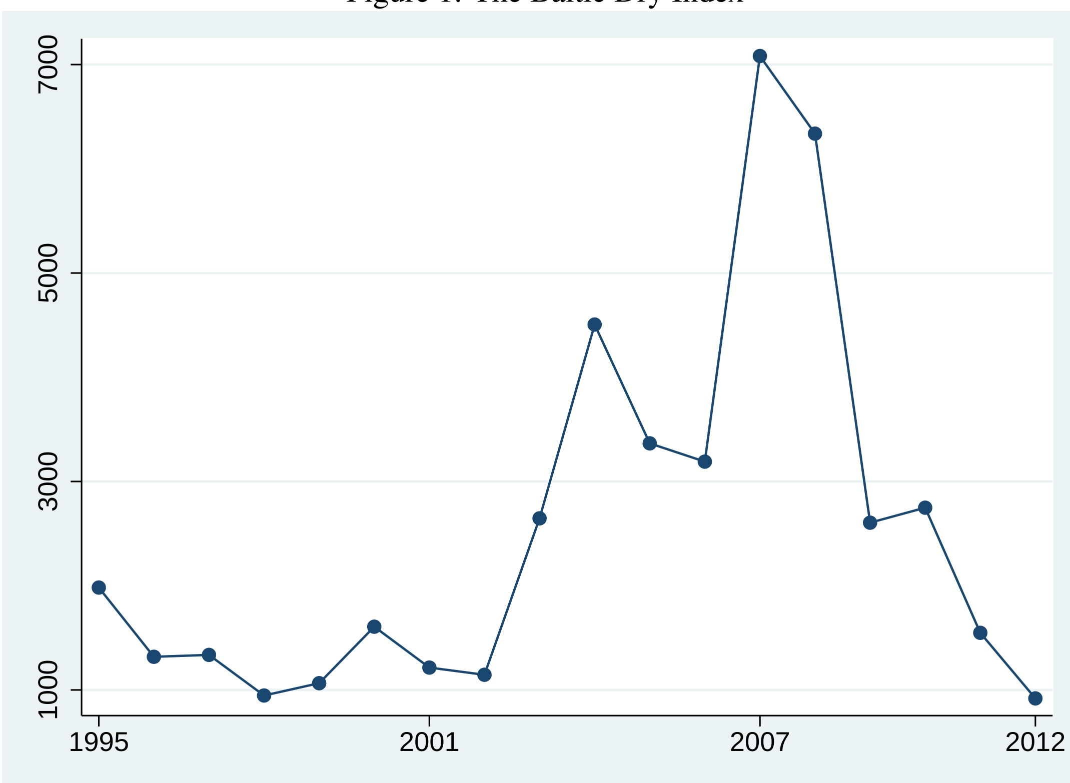
2 Data

Our dataset consists of a panel of 48 LDCs from 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 of 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 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, which consist of raw commodities such as grain, coal, iron ore, copper and other primary materials. The LDCs are mainly primary goods producers, and as such, are dependent on bulk carriers This makes the BDI, which reflects the cost of global bulk shipping, a relevant indicator of trade cost faced by the LDCs.

Figure 1: The Baltic Dry Index



To obtain an instrument for LDCs trade using the BDI, we follow Lin and Sim (2013) to construct

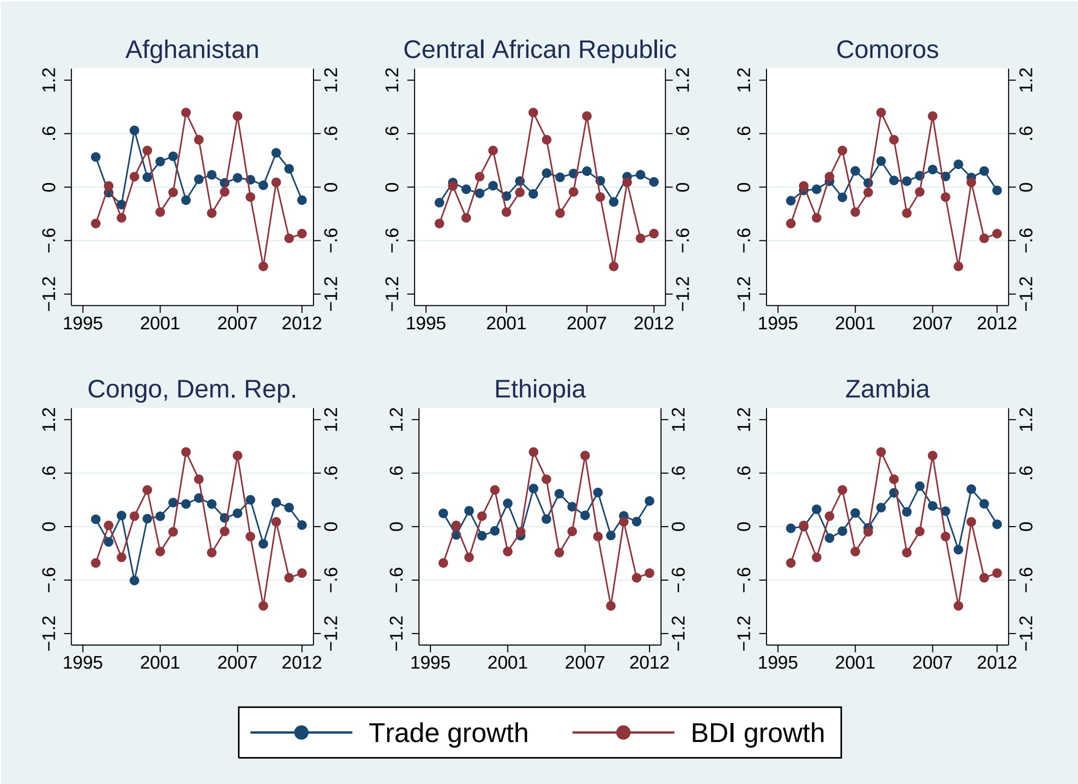
$$Cost_{i,t} = \theta_{i,t-1} \log(BDI_t), \tag{1}$$

where $\theta_{i,t-1}$ is country i's predetermined proportion of total trade that consists of primary commodities trade. Information on primary goods trade is obtained from the 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 excludes crude oil which is transported by wet (not dry) carriers such as tankers. Intuitively, the primary trade share in eq. (1) reflects the relative intensity of bulk shipping utilization. Therefore, eq. (1) captures the idea that the cost of bulk shipping would matter more for countries where primary goods trade is important.

Our instrument $Cost_{i,t}$ contains both cross-sectional and time variation. Hence, it can be employed in panel regressions without being "cleaned out" by country and year fixed effects. However, eq. (1) is not the only specification we could use. For example, we could replace the lagged primary trade share (i.e. $\theta_{i,t-1}$) in eq. (1) with a fixed primary trade share (i.e. $T^{-1}\sum_{t=1}^{T}\theta_{i,t}$), although the regression outcomes turn out to be similar. We believe the reason is that the LDCs tend to export a stable proportion of primary goods across time, which might explain why our results are not sensitive to using either the lagged or fixed primary trade share as the interaction term in eq. (1).

Lin and Sim (2013) argue that the cost of bulk shipping is an exogenous determinant of how much an LDC trade. Collectively, 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. Moreover, their economies are very small on the global scale, accounting for less than 2 percent of worldwide GDP. Consequently, each LDC is unlikely to have much influence on the cost of bulk shipping, although an increase in bulk shipping cost can negatively affect how much an LDC trade. To see this, Figure 2 shows that the growth in the BDI (i.e. the growth in bulk shipping cost) was 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, the trade per capita of Myanmar, Liberia and Eritrea fell by 14%, 21% and 27% respectively during the same period.

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.

Some commentators suggest that the recent movements in BDI are driven mainly by the growing demand of commodities by large emerging economies, such as China.[12] 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.[13] This surge in iron ore demand is a significant event because iron ore is by proportion the most important commodity transported by bulk carriers.[14]

[12]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`.

[13]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.

[14]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 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).

Besides iron ore, China had transformed itself from being coal exporter to an importer, thus further driving up the demand for bulk carriers and in turn influencing the cost of bulk shipping.

To see the importance of China as a driving force of bulk shipping cost, Figure 3 compares the growth rate of the BDI with China's trade volume and shows that the two series track each other closely.[15] Because the BDI is a measure of trade cost (thus should be negatively associated with trade), the *positive* co-movement between the two could be symptomatic of the endogenous response of the BDI to the demand for trade by China. Note that this tight positive relationship has also been reported for large primary goods producers such as Australia, Brazil, India and Russia (Lin and Sim, 2013).[16] However, for the sample of LDCs, Figure 2 shows that the BDI and trade (in growth) could co-move in the *opposite* direction. The presence of such negative co-movements, which are completely absent for China as well as for Australia, Brazil, India and Russia, suggests that an LDC is unlike large countries that could influence the cost of bulk shipping. Hence, an LDC can be treated as a price taker in the bulk shipping market and the BDI as an exogenous determinant of its trade.

2.2 Health

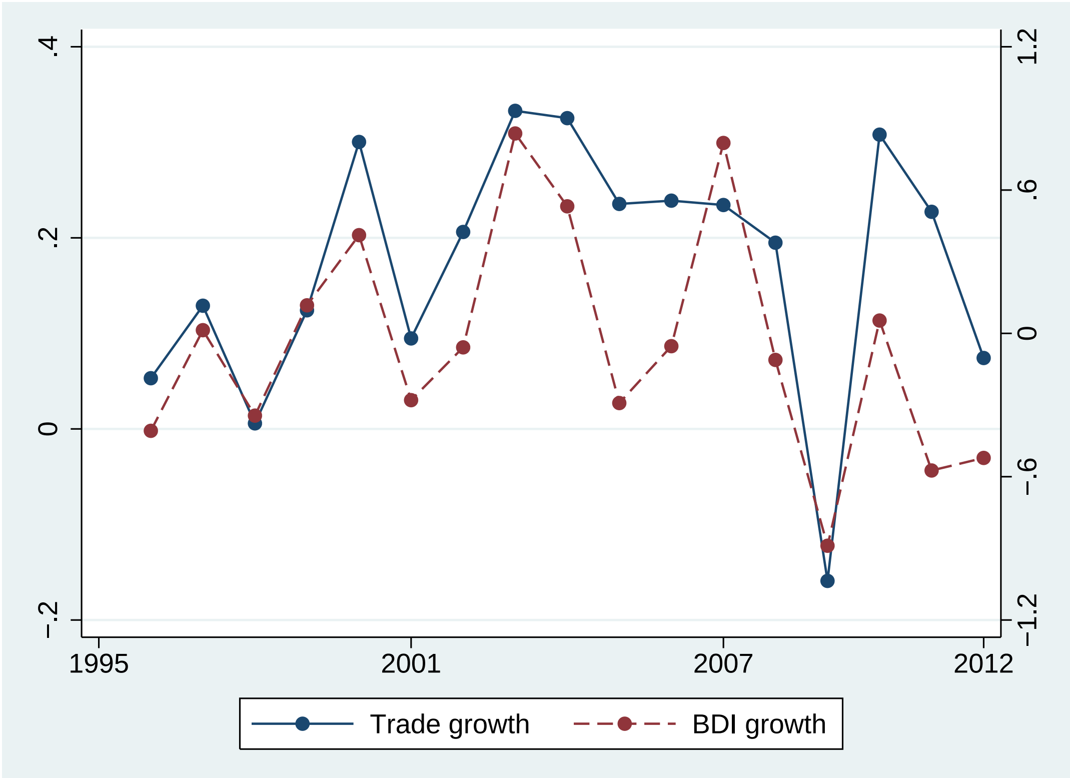
Our primary measure of health is the mortality rate of children (in 1,000 births) under 5. The child mortality rate is informative about national development and welfare for the following reasons. First, child mortality is typically concentrated in the lowest income quintile (Wagstaff, 2000; Halder and Kabir, 2008), hence, the child mortality rate is reflective of the socio-economic environment faced by low-income groups (Gwatkin, 2004).[17] Second, the child mortality rate is a reasonable indicator of living 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

[15] 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.

[16] Lin and Sim (2013) provide these figures for a shorter time period from 1995 to 2007.

[17] 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).

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.

of under-5 mortality rate is universal, whereas other indicators of wellbeing such as poverty line and literacy rate could be defined differently across countries and 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.[18] We expect the infant mortality rate to respond in a similar way to trade as the under-5 mortality rate does. Moreover, if trade affects health in general, it should also affect life expectancy, not just child mortality.

Our data on the under-5 mortality rate, infant mortality rate and life expectancy are taken from the World Development Indicators.[19] These data could contain imputed information for missing

[18]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.

[19]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.

observations.[20] 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),[21] whose objective is to estimate trends in child mortality from which infant and neonatal mortality rates are derived.[22] 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 indicates a political institution that is neither democratic or autocratic.[23] In the literature, the Polity2 score has been used to distinguish democracies from autocracies. One example is Arezki and Brückner (2012), 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. In this paper, we identify democracies and autocracies in the same way and examine the relationship of trade on health separately for democratic and autocratic LDCs.

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

[21] See `www.childmortality.org`.

[22] 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`.

[23] 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`.

2.4 Trade and the Environment

We obtain data on nominal trade, measured in million U.S. dollars, from the UNCTAD website.[24] We then deflate it with the U.S. CPI for all urban consumers using 2005 as the base year.[25]

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 the World Development Indicators.[26] 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.[27] Water quality is measured by renewable internal freshwater resources (per capita, in cubic meters), which is taken from the World Development Indicators.[28]

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 vary in our robustness checks, μ_i and μ_t are generic representations of country and year fixed effects, and $\delta_r t$ represents a set of region-specific time trends. In this paper, the under-5 mortality rate is our main measure of health but we also consider the

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

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

[26] 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.

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

[28] 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.

infant mortality rate and life expectancy as alternative measures. Our main objective is to examine if trade causes child mortality, which is summarized by the parameter β. To explore if institution matters, we estimate eq. (2) for the set of autocratic and democratic LDCs separately.

3.1 Identification Issues

There are certain challenges in identifying β. First, trade and health could be jointly influenced by unobserved omitted variables such as geography, culture and disease environments.[29] To partial out such cross-country differences, we include country fixed effects (μ_i) in eq. (2). We also include year fixed effects (μ_t) to control for macroeconomic shocks that might affect all the LDCs in the same manner. Finally, we include a separate region-specific trend for the LDCs in Africa, Asia and the others parts of the world to hopefully partial out any regional macroeconomic confouders that might be present.[30]

Second, although fixed effects are useful for soaking up information that cannot be easily observed or controlled for, it is not a panacea for the problem of reverse 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 later demand more trade.[31] To address this issue, we employ $Cost_{i,t}$ (see eq. (1)), which we call BDI cost hereinafter, as an instrument for LDCs trade:

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

In doing so, we have imposed the exclusionary restriction that BDI cost can only affect child mortal-

[29] For example, geography is likely to matter for trade and income. McArthur and Sachs (2001) show that high prevalence of tropical disease could reduce trade and and harm health; 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; Masters and McMillan (2001) show that winter frost can restrict economic activity and reduce output.

[30] 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.

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

ity (or health in general) indirectly through its effect on how much the LDCs trade. This assumption seems plausible from the perspective that BDI cost is a measure of trade cost, and trade cost should affect trade but not child mortality directly. Therefore, if trade cost does affect child mortality, we assume that it happens only through the effect of trade cost on trade.

As a caveat, our methodology has limitations in dealing with certain types of confounding factors possibly contained in $v_{i,t}$ of eq. (2). For example, when modeling the effect of trade on health, there might be macroeconomic shocks affecting the state of health in each LDC *heterogeneously*. The state of health of the LDCs could also be spatially or cross-sectionally dependent, e.g. the spread of diseases from a country to its neighbors. These unobservables, which contain both cross-sectional and time variation, cannot be purged by country and year fixed effects. Ideally, to take care of this issue, we would like to implement panel regressions with cross-sectional dependence such as the method proposed by Pesaran (2006). However, to do so, we need to have a large number of cross-sectional observations (in this case, a large number of countries), which we do not have as we are focusing only on the sample of LDCs. Therefore, our methodology would yield credible point estimates insofar the cost of bulk shipping, and hence BDI cost, is only at best weakly correlated with any unobserved health factors that have a cross-sectionally dependent structure.

4 Results

4.1 OLS and IV Estimates – Full Sample

Table 1 reports several OLS estimates of the effect of trade on child mortality. From a simple linear regression, Column I shows that a rise in trade is accompanied by a fall in the child mortality rate on average. This result, however, quickly evaporates when country and year fixed effects and regional time trends are included into the regression (Columns II-IV). If the inclusion of country and year fixed effects and regional time trends has brought us closer to point identification, the OLS results suggest at first pass that trade is unlikely to be beneficial for reducing child mortality.

Table 2 reports the IV estimates using BDI cost as an instrument for the log of trade per capita.

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

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

Our first stage regression shows that a one standard deviation increase in BDI cost is associated with a 13.6% decrease in trade per capita on average. BDI cost is a relatively strong instrument, as the Kleibergen-Paap first stage F-statistic of 22.88 exceeds the Stock-Yogo critical value of 8.96 for instrument strength.[32] However, the second stage regression result shows that trade does not have a statistically significant effect of reducing child mortality in the LDCs.

4.2 IV Estimates –Autocracies and Democracies

In this section, we examine the effect of trade on child mortality within two regimes – autocracies and democracies. In Table 3, we report the separate IV regression estimates of eq. (2) for autocratic LDCs (Column I) and democratic LDCs (Column II). In Column I, the first stage F-statistic of 61.82 shows that BDI cost is a powerful instrument for trade with respect to autocratic LDCs. By contrast, Column II shows BDI cost is not statistically significant for democratic LDCs. This disparity, we surmise, could be due to the fact that trade is considerably less important in democratic LDCs than

[32]To check if BDI cost might be weak instrument for trade, we consider 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%.[33] 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.

Table 2: IV Regression of Trade on Child Mortality

	I
Second-stage Dependent Variable:	Log(Child mortality rate)
Log(Trade per capita)	-0.056
	(0.062)
First-stage Dependent Variable:	Log(Trade per capita)
BDI cost ($Cost_{i,t}$)	-0.125***
	(0.026)
First-stage Kleibergen-Paap F-Stat	22.88
Stock and Yogo critical value (15%)	8.96
Regional trend	yes
Country FE	yes
Year FE	yes
Observations	808
Countries	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.

it is in autocratic LDCs. For example, over the sample period, the average trade per capita of democratic LDCs is only about 40% that of autocratic LDCs. Moreover, compared to autocratic LDCs, there is significantly less variation in how much democratic LDCs trade. For example, the coefficient of variation of trade per capita (i.e. the ratio of standard deviation to the mean) is only 1.13 for democratic LDCs. For autocratic LDCs, this coefficient is 3.75. In other words, democratic LDCs trade at much lower and stable levels, which may explain why the influence of BDI cost on trade is weak for these countries.

With respect to democratic LDCs, the statistical insignificance of BDI cost in the first stage regression precludes us from drawing conclusions about the relationship between trade and child mortality, an issue we will revisit in Section 4.3. For autocratic LDCs, however, we find that trade may deepen the problem of child mortality, as Table 3 suggests that a 1% increase in trade per capita is associated with a 0.13% increase in the child mortality rate on average. To interpret this result in

Table 3: IV Regression of Trade on Child Mortality (Autocracies and Democracies)

	I Autocracy Polity2<0	II Democracy Polity2>0
Second-stage Dependent Variable:	Log(Child mortality rate)	
Log(Trade per capita)	0.130***	-2.832
	(0.028)	(10.452)
First-stage Dependent Variable:	Log(Trade per capita)	
BDI cost ($Cost_{i,t}$)	-0.357***	-0.006
	(0.045)	(0.024)
First-stage Kleibergen-Paap F-Stat	61.82	0.0630
Stock and Yogo critical value (15%)	8.96	8.96
Regional trend	yes	yes
Country FE	yes	yes
Year FE	yes	yes
Observations	280	402
Countries	18	29

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.

terms of the actual number of children 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 per capita could approximately lead to 17 additional deaths of under-5s. For larger autocracies such as Tanzania and Uganda, the approximate deaths of under-5s resulting from a 1% increase in trade per capita could be as high as 645 and 670 respectively.[34] If we take a conservative perspective by using the two standard deviations lower bound of the 0.13% point estimate, the estimated number of deaths in Tanzania and Uganda would still be 367 and 381 respectively. Considering that the BDI is highly volatile, and that a one standard deviation decrease in the BDI could increase trade per capita by as

[34]This is computed using 2010 figures for the under-5 population and child mortality rate. For instance, Tanzania's under-5 population and mortality rate are 8,052,680 and 6.16%. Hence, using the elasticity of 0.13%, we compute the approximate number of additional deaths as $0.0013 * 0.0616 * 8052680 \approx 645$. The under-5 population data is taken from the United Nations at `http://esa.un.org/wpp/Excel-Data/population.htm`.

much as 13.6%, the number of children at risk could be much larger than what is computed here.

Because the importance of primary goods trade differs for each country, the effect of the BDI on trade is heterogeneous across the LDCs. Hence, using the cross-country heterogeneity in primary goods trade, we may estimate the effect that the BDI has on child mortality for each autocratic LDC. To do so, we first estimate the reduced form relationship between child mortality and BDI cost:[35]

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

Then based on the estimate of eq. (4), we construct the absolute time-averaged elasticity of the child mortality rate 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 estimate of α in eq. (4) and $\theta_{i,t-1}$ is period $t-1$ primary trade share of country i.

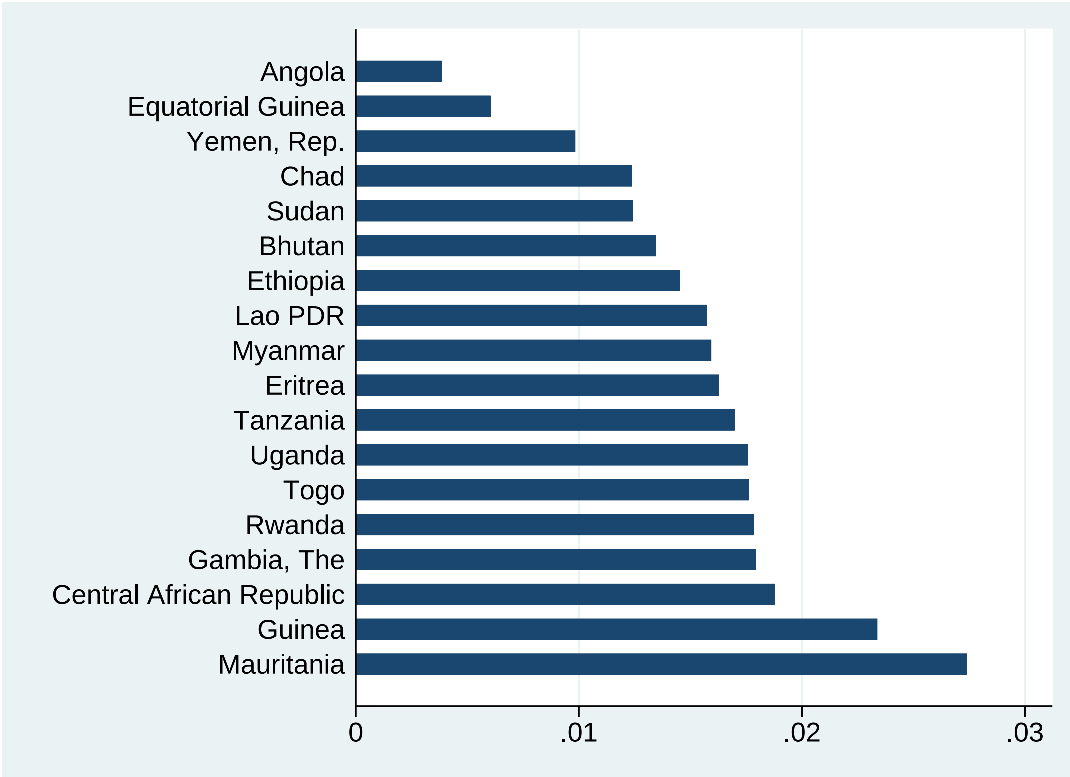
Figure 4 plots this absolute average elasticity for a sample of autocratic LDCs.[36] For the LDCs featured in Figure 4, the BDI elasticity of the child mortality rate (in absolute value) is between 0.0039 and 0.0274, suggesting that the child mortality rate would decline by around 0.04% to 0.27% when 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.[37] Overall, Figure 4 suggests that sharp swings in the BDI are not innocuous – trade booms following large declines in the BDI could significantly increase child mortality in certain autocratic LDCs.

[35]Results are available upon request.

[36]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.

[37]Oil is transported by wet tankers, not by dry ships. Given that Angola is an important oil exporter, this would weaken the effect of the 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.

4.3 Robustness checks

This section examines the robustness of our baseline instrumental variable estimates. Our first robustness check revisits the issue of whether the relationship between trade and child mortality is contingent on institutional types. While we observe that trade may increase child mortality in autocratic LDCs, we are unable to draw any conclusion for democratic LDCs as BDI cost is statistically insignificant for trade with respect to these countries.

In this exercise, we employ a country-specific commodity price index, proposed by Brückner and Ciccone (2010),[38] as an alternative instrument for trade. This estimation strategy is based on

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

the idea that international commodity prices are informative about the global demand for commodities.[39] 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 more important to an LDC, any variation in the global demand for these commodities (reflected by their international prices) would affect the demand for that country's exports more disproportionately. In this manner, international commodity price movements can exert country-specific effects on trade as this specificity depends on how important certain commodity exports are for each LDC.

Based on this idea, 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 (in logs), and $\theta_{i,c}$ is the average (time invariant) value of exports of commodity c over 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).[40] 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. Whenever multiple prices are listed for the same commodity, we use the simple average of these prices as the price of that commodity in our computation.

Table 4 reports the instrumental variable estimates for autocracies (Column I) and democracies (Column II) using $\overline{ComPI}^{C}$ as an instrument of trade. We find that $\overline{ComPI}^{C}$ is statistically significant instrument for trade in both regimes. Based on this result, we find that trade may increase child mortality for autocracies just as before, but for democracies, the link between trade and child mortality is statistically insignificant. Therefore, these results are consistent with our baseline re-

[39] 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.

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

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.

gressions that trade is not beneficial for reducing child mortality and could even exacerbate it in autocratic LDCs.

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 may also lead to higher rates of infant mortality and shorten life expectancy. Our regressions, reported in Table 5, provide some evidence that this is true. For example, Column I shows that a 1% increase in trade per capita has a statistically significant effect of raising the infant mortality rate by about 0.1% on average, which is similar to the estimate of 0.13% when the under-5 mortality rate is used as a measure of health (see Table 3). Furthermore, Column II shows that trade can shorten life expectancy, where a 1% increase in trade per capita is associated with a decline in

Table 5: Robustness Check 2: Trade, Infant Mortality and Life Expectancy (Autocracies Only)

	I	II
Second-stage Dependent Variable:	Log(Infant mortality rate)	Log(Life expectancy)
Log(Trade per capita)	0.090***	-0.024**
	(0.026)	(0.010)
First-stage Dependent Variable:	Log(Trade per capita)	
BDI cost ($Cost_{i,t}$)	-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.

life expectancy by around 0.03% on average.

Our third robustness check examines the sensitivity of the baseline estimated effect of trade (i.e. 0.13) by varying the set of control variables that might be relevant to child mortality. If BDI cost is a valid instrument, and is therefore orthogonal to these variables which are initially omitted from the baseline regression, the baseline estimate should be robust when these variables are introduced into the regression. For this sensitivity exercise, we consider five variables – foreign aid, FDI, population density, urbanization rate, and the prevalence rate of HIV. Foreign aid and FDI are found to have positive effects on development (Nair-Reichert and Weinhold, 2001; Werker et al., 2009) and therefore might affect child mortality. In addition, public health can be affected by population density (Root, 1997) and urbanization (Cutler et al., 2006).[41] For example, better access to medical

[41]Focusing on Zimbabwe, Root (1997) argues that the transmission of diseases and infections is quicker in high density areas, and finds that the child mortality rate is much lower in lower density regions in Zimbabwe.

facilities in urbanized areas may reduce 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 directly as a child may die from the disease, or indirectly if the mother dies (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 in million U.S. dollars, then apply log transformation. Here, we use the first lag of the additional variables as controls.[42]

Columns I-IV show that the estimated effect of trade on child mortality is generally robust. For example, when the log of foreign aid, log of FDI, or HIV prevalence rate is added, the elasticity of the child mortality rate with respect to trade remains close the baseline estimate of 0.13 (see Column II of Table 3). The estimated trade elasticity becomes weaker when population density or urbanization rate is controlled for, although this estimate 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 statistical significance and influence, where a one percentage point increase in the HIV prevalence rate is associated with a 12% increase in the child mortality rate on average.

5 The Environmental Channel

At this point, we have yet to explore how an increase in trade can result in higher child mortality rates as was found for autocratic LDCs. Here, we investigate if environmental quality is a possible channel for this effect. If trade causes environmental quality to deteriorate and poor environmental quality is detrimental to health, then trade can affect child mortality through the environment. Schematically, the causal structure we hope to explore is summarized by Figure 5.

Trade may affect the environment for several reasons. For instance, environmental regulations in autocratic countries tend to be less stringent (Congleton, 1992), hence, economic activities such as trade could lead to more pollution. Another possible explanation is the pollution haven hypothesis

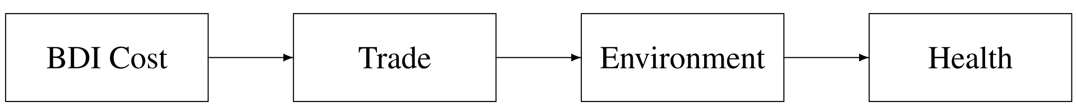
[42]The results are similar when contemporaneous values of these variables are used instead.

Table 6: Robustness Check 3: Additional Control Variables (Autocracies Only)

	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 ($Cost_{i,t}$)	-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.

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



(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.[43] In fact, the "pollution haven effect" may be more pronounced in autocratic countries

[43]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.

as regulatory standards in these countries tend to be lower and more weakly enforced (Cao and Prakash, 2012).

5.1 The Effect of Trade on the Environment

We first explore the effect that trade might have on the environment in the autocratic LDCs. To measure 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).[44] Table 7 reports the relationship between trade and these pollution indicators. Other than the statistically insignificant relationship between trade and clean water (Column IV), we find that trade has a negative effect on environmental quality, where Columns I-III show that a 1% increase in trade per capita is associated with an increase in SO_2, CO_2 and N_2O emissions by 0.81%, 0.80% and 0.66% on average.

5.2 The Effect of the Environment on Health

Next, we examine if environmental quality – in particular, pollution – causes health. To do so, we first obtain what we hope are plausibly exogenous variations in pollution by estimating a reduced form relationship between pollution and BDI cost. Then, we use this pollution variation to estimate the effect that it might have on health. We focus on the levels of SO_2 and CO_2 emissions as measures of pollution and consider all three health indicators – under-5 mortality, infant mortality, and life expectancy.

Table 8 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 suggests that pollution can affect health. For example, Table 8 shows a 1% increase in SO_2 (CO_2) is associated with a 0.10%

[44]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 7: Trade and Pollution (Autocracies Only)

	I	II	III	IV
Second-stage Dependent Variable:	Log(SO_2)	Log(CO_2)	Log(N_2O)	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 ($Cost_{i,t}$)	-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.

(0.14%) increase in the under-5 mortality rate and 0.08% (0.10%) increase in the 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* are the cause of these poorer health outcomes. Nonetheless, given that SO_2 and CO_2 emissions are correlated with the overall levels of pollution, we may reasonably infer that pollution (generated by trade) can cause child mortality to rise and public health to deteriorate.[45]

In sum, for autocratic LDCs, we have shown that trade may generate more pollution (Section 5.1) and pollution may increase child mortality and decrease life expectancy (Section 5.2). This suggests that environmental quality is a possible channel through which trade affects health.

[45] 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 8: Pollution, Child Mortality, Infant Mortality and Life Expectancy (Autocracies Only)

	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 ($Cost_{i,t}$)	-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

The positive effect that trade has on income levels, hence, on alleviating poverty and improving living standards (Frankel and Romer, 1999), is one of the most important empirical observations concerning international trade, However, in developing countries, trade could be a double-edged sword as it may also harm the environment, resulting in poorer health outcomes. In this paper, we explore if there is a causal link between trade and child mortality in the LDCs, For countries that are autocratic, we find that trade expansions may lead to poorer environmental quality and thus exacerbate the problem of child mortality. Therefore, even though the LDCs are somewhat insular and trade may foster economic development on the whole, the increase in trade may not always be beneficial especially when it comes to combating child mortality – a U.N. millennium development goal.

Our paper focuses on environmental quality as one possible channel for the effect of trade on health in general. However, other channels could exist as well. For example, trade may increase the amount of contact among people, causing 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 an increase in exports is found to increase trucking, a profession that has high prevalence of HIV infections. Therefore, although we have focused on pollution as one possible channel linking trade with health, there could be other channels which themselves are interesting to explore for future research as well.

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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 ($Cost_{i,t}$)	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