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European Economic Review, 2013; 59:1-18

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DOI: 10.1016/j.euroecorev.2012.12.004

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20 August 2013

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PII: S0014-2921(12)00159-6
DOI: http://dx.doi.org/10.1016/j.euroecorev.2012.12.004
Reference: EER2434

To appear in: *European Economic Review*

Received date: 30 January 2012
Revised date: 28 November 2012
Accepted date: 9 December 2012

Cite this article as: Faqin Lin and Nicholas C.S. Sim, Trade, income and the baltic dry index, *European Economic Review,* http://dx.doi.org/10.1016/j.euroecorev.2012.12.004

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# Trade, Income and the Baltic Dry Index*

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**Abstract**

Does trade improve the income levels of the poor and less developed nations? Focusing on the least developed countries (LDCs) designated by the United Nations, we construct a new measure of trade cost, based on the Baltic Dry Index (BDI), as an instrument for trade. The BDI reflects the cost of utilizing dry bulk carriers, which are specially designed vessels for transporting primary goods internationally, where these goods dominate the output and export sectors of the LDCs. We find that a one percent expansion in trade raises GDP per capita by approximately 0.5 percent on average. This estimate is much larger than previously found in the literature and its quantitative significance emphasizes the importance of trade towards the economic development of low income countries.

**Keywords**: Economic development · International trade · Income · Baltic Dry Index · Instrument variable
**JEL Classification**: F14 · O11 · O19

*We are grateful to the Editor, Professor Theo Eicher, and the anonymous referees for their invaluable comments that help to improve this paper.

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# 1 Introduction

As early as Sir Dennis Robertson (1940), international trade has been characterized as an "engine of growth" by which the goal of economic development and improving living standards can be achieved. From the development perspective, the positive association between trade and income levels is an encouraging fact. But belying it is an uneasy empirical regularity that the core of global trade is dominated by the exclusive trade between developed, wealthy countries (Baldwin and Martin, 1999; Krugman, 2009).[1] The weak participation levels in international trade by low income countries therefore raises an important question. If the positive association between trade and income is causal, does the benefit of trade in lifting living standards extend to them as well? In this context, the answer is not always clear cut. As early as Nurkse (1959), it has been argued that low income countries may not benefit as much from the opening of trade.[2] This is because their exports are mainly primary goods, and the world market for their output would only expand slowly given that the demand for primary goods is generally income inelastic.

In this paper, we examine the link between trade and income improvements for the 48 least developed countries (LDCs) designated by the United Nations. A main issue, often emphasized in the literature, is that trade is endogenous in the determination of income levels.[3] To address this, we construct a new measure of trade cost as an external source of variation in trade, which in turn is used to construct the within-country estimate of the causal effect that trade has on income of the LDCs. The LDCs are home to more than 880 million people, or about 12 percent of the world's population. However, they account for less than 2 percent of global output, 1 percent of global trade in goods and 2 percent of global trade in primary goods.[4] The export sectors of the LDCs are heavily dominated by the export of primary goods, many of which are transported internationally by a class of specially designed vessels known as dry bulk carriers, or bulk carriers in short. This paper exploits the cost of utilizing bulk carriers as summarized by the Baltic Dry Index (BDI) to construct a new measure of trade cost for the LDCs. Our measure of trade cost, which is used as

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[1] For instance, in 2010, the total export volume of OECD countries accounts for about 64 percent of world total exports and their total import volume accounts for about 66 percent of world total imports.

[2] As compared to higher income countries with manufacturing-based economies. See, also, Kaldor (1964).

[3] Firstly, decisions on whether to trade, and how much to trade, are not randomly assigned. Secondly, the regression analysis may be confounded by the reverse causal effect going from income to trade.

[4] These are calculated based on 2010 data from the United Nations Conference on Trade and Development (UNCTAD).

ACCEPTED MANUSCRIPT

an instrument for trade, is the interaction between the log of the BDI and the country's primary products share of its total trade. This primary products share captures the relative intensity of bulk shipping utilization across the LDCs. A larger share amplifies the response of trade to the BDI, which helps to generate country-specific effects of the BDI on trade across time.

Our empirical analysis shows that a reduction in the BDI has a positive effect on the income of the LDCs through the trade channel. Our main instrumental variable estimates reveal that a one percent expansion in trade increases GDP per capita by 0.484 to 0.534 percent on average. This elasticity of income per capita with respect to trade is especially significant in light of previous findings in the literature. For instance, Feyrer (2009a) finds the elasticity to be in the region of 0.157 to 0.253 when both developed and developing countries are taken into consideration. Since our focus is restricted to the LDCs, our results suggest that the standard of living in the LDCs may be improved from the opening of trade. Furthermore, inferring from the smaller estimates in Feyrer (2009a), our findings also suggest that a low income country could benefit much more in income improvements from the deepening of trade than its wealthier counterparts.

Even though the literature on trade and income has a rich history, it is more recently that the issue of identification is given specific attention.[5] Our paper fits into this line of research on identifying the causality of trade on income by using the variation in trade cost as an estimation strategy. The groundbreaking paper is due to Frankel and Romer (1999), who use geographic distance between countries in the gravity equation as a reflection of trade cost for identifying the exogenous variation in bilateral trade volumes. However, in his seminal work, Feyrer (2009a, 2009b) cautions that distance (or proximity) may be capturing other factors unrelated to trade cost.[6] For instance, he argues that distance may be correlated with geography-based determinants of income such as tastes, cultural characteristics, colonial institutions and disease environments, which raises

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[5]For instance, Dollar (1992) and Sachs and Warner (1995) find that trade openness and income are positively related, but they do not focus on addressing the issue that trade openness is potentially endogenous. Although Edwards (1998) uses instrumental variables based on historical information such as historical TFP growth, measures of openness, and trade to GDP ratio, he cautions that the use of instrumental variables to address the endogeneity problem has not been conclusive hitherto, and that the causal relationship of trade and income is still a somewhat open issue in the empirical literature.

[6]Other related studies, focusing on historical trade flows, include Jacks and Pendakur (2010) and Jacks, Meissner and Novy (2011). Jacks and Pendakur (2010) exploit the revolution of maritime transport to explain the historical variation in international trade from 1870 to 1913 but find no evidence that the maritime transport revolution was the primary driver of the late-nineteenth-century global trade boom. Jacks et al. (2011) look at the importance of bilateral trade costs in determining international trade flows over different periods in history.

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question about the validity of the exclusion restriction in Frankel and Romer (1999).[7] While the effects of these geography-based determinants may be purged by including country fixed effects, the cross-sectional regression design of Frankel and Romer (1999) makes it virtually infeasible to do so.[8] In this regard, although our paper is related to Frankel and Romer (1999) in its focus on trade and income, it differs by constructing an instrument that contains not only cross-country variation, but also time variation so that country fixed effects can be used to control for all unobserved permanent income differences.

In the spirit of constructing a time-varying instrument for trade to study its effect on income, our paper is related to two important papers of Feyrer (2009a,b), which introduce a key insight that distance is not a static concept. In Feyrer (2009a), a natural experiment, stemming from the Arab-Israeli conflict that saw the closing and re-opening of the Suez canal during 1967–1975, provides two major shocks to shipping distance that is crucial for identifying the exogenous variation in trade. In Feyrer (2009b), the identification strategy relies on improvements in air transportation technology that may increase the relative importance of air versus sea freight over time. Because countries utilize air and sea routes for trade in various ways, the rapid decline in the cost of air relative to sea freight would benefit countries differently,[9] generating country-specific effects of air transportation innovation that form the basis of Feyrer's (2009b) approach. While our paper shares a common goal as Feyrer (2009a,b) in trying to pin down the exogenous variation in trade, the estimation strategies of Feyrer (2009a,b) are not easily adaptable to our study focusing on the LDCs for the following reasons.

Firstly, Feyrer (2009a,b) constructs an instrument of trade using predicted values of bilateral trade from an estimated gravity equation. This procedure requires bilateral trade data, which is

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[7] Rodriguez and Rodrik (2000) argue that the instrument of Frankel and Romer (1999) may not be valid. For instance, they show that by including additional summary indicators of geography, such as distance from the equator, the percentage of a country's land area that lies in the tropics, and a set of regional dummies, the statistical and quantitative significance of trade found in Franker and Romer (1999) may be driven out completely.

[8] This critique is also relevant to Alcalá and Ciccone (2004), Irwin and Terviö (2002) and Noguer and Siscart (2005), as they examine the relationship of trade and income using the Frankel and Romer approach. Based on an extension of Frankel and Romer (1999), Alcalá and Ciccone (2004) employ all available bilateral trade data, including bilateral trade pairs with zero trade, and show that doing so would improve the explanatory power of the first stage regression and generate more robust second stage estimates of the effect of trade on income. Irwin and Terviö (2002) evaluate the findings of Frankel and Romer using data from the pre-World War I, interwar and post-war periods, and conclude that the main result of Frankel and Romer holds throughout the whole of 20th century. Noguer and Siscart (2005) use a richer data set with fewer missing observations to conduct the Frankel and Romer analysis and arrive at a similar conclusion.

[9] Feyrer (2009b, p.3) notes that the cost of moving goods by air fell by a factor of ten between 1955 and 2004.

ACCEPTED MANUSCRIPT

highly incomplete for the LDCs. For example, to use the approach of Feyrer (2009a) for our study, bilateral trade data during 1975 and earlier is required for exploiting the "Suez experiment", but such information is completely missing during this period for a significant number of LDCs.[10] The challenge of estimating the trade-income relationship for *all* 48 LDCs is not mitigated by appealing to the approach of Feyrer (2009b) as the instrument for trade is constructed in a manner that necessitates bilateral trade information, and such information for the LDCs may be substantially incomplete or even completely missing throughout the entire sample period, not just during the 1960s and 1970s.[11]

Secondly, the estimation strategies of Feyrer (2009a,b) may not be as tightly linked to the LDCs as the BDI is through its influence on primary trade. With respect to Feyrer (2009a), one feature in his natural experiment approach is that following the closing and re-opening of the Suez canal, a sharp response in the average shipping distance is only observed for a small set of countries surrounding the Indian Ocean and Arabian Sea.[12] Hence, except for the few LDCs that are located there, the average shipping distance of the remaining LDCs may only respond weakly to the Suez "shocks".[13] With respect to Feyrer (2009b), the shift toward the use of air transportation has not been that dramatic for the LDCs. For example, the volume of air freight (million ton-kilometer) of the U.S. is 50 times larger than that of all LDCs combined in 2010,[14] compared to only about 23 times larger with respect to the same LDCs in 1980.[15] This perhaps reflects the fact that air

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[10]For instance, consider the Direction of Trade (DoT) data set of the IMF used by Rose (2004), and in turn by Feyrer (2009a,b). During 1975 and earlier, bilateral trade data is completely missing for countries such as Afghanistan, Cambodia, Equatorial Guinea, Eritrea, Guinea-Bissau, Laos, Samoa, Senegal, São Tomé and Príncipe, Solomon Islands, Vanuatu, Tuvalu, Bhutan and Kiribati. Even for LDCs where bilateral trade data is available during this period, it is usually highly incomplete as information on bilateral trade with a large number of trade partners could be missing.

[11]In the 1990s, bilateral trade data is completely missing for Afghanistan, Democratic Republic of Congo, Djibouti, Eritrea, Guinea-Bissau, Liberia, Myanmar, Senegal, Somalia, Sudan, Timor-Leste and Tuvalu. In fact, bilateral trade information on Afghanistan, Eritrea, Guinea-Bissau, Senegal, Timor-Leste and Tuvalu is completely missing in the Rose (2004) sample.

[12]For example, Feyrer (2009a) shows that the top five countries in terms of trade weighted increase in sea distance (in percentages) following the closure of the Suez canal are Pakistan (31.4%), India (30.6%), Kenya (23.6%), Sri Lanka (20.4%) and Malaysia (13.7%). These countries are either located next to the Arabian Sea (i.e. India and Pakistan) or the Indian Ocean (i.e. Kenya, Malaysia and Sri Lanka).

[13]Besides Mozambique and Madagascar, for the remaining LDCs that are included in his sample, Feyrer (2009a) shows that the trade weighted increase in sea distance following the closure of the Suez canal is less than 1.4%, compared to the 31.4% and 30.6% increase for Pakistan and India.

[14]Section 1.1 of Feyrer (2009b) discusses the growing importance of air freight in the U.S.. Before the onset of the global financial crisis in 2007, the use of air freight (million ton-kilometer) by the U.S. reaches 81 times the level of utilization by all LDCs combined.

[15]These figures are computed using the World Development Indicators. The number of LDCs may change over time. For instance, Dollar (1992) focuses on a sample of 95 LDCs during 1976 to 1985.

ACCEPTED MANUSCRIPT

transportation is used mainly for moving high value to weight items such as consumer electronics, pharmaceuticals, jewelry and precious metals, but not primary products that dominate the trade of the LDCs.[16]

Improving the standard of living in low income countries is recognized as one of the most challenging problems confronting academic and policy makers alike. Our paper contributes to this discussion by affirming that international trade is an important direction based on which the economic development of low income countries can be pursued. Therefore, it is related to the literature that looks at whether there is a positive relationship between trade or trade openness on the one hand, and the economic development of less developed countries on the other (e.g. Harrison, 1996; Dollar and Kraay, 2004; Estevadeordal and Taylor, 2008),[17] although in this literature, the focus on estimation strategies to pin down the economic impact of trade or trade openness with respect to these countries is somewhat limited.[18] Since our paper exploits the variation in trade cost in the form of the BDI to identify the effect of trade on income, it is also related to the seminal paper of Donaldson (2010), who documents a strong positive link between economic development and the transition from autarky to trade among regions in colonial India, where this transition is facilitated by the construction of railroads that reduces inter-regional trade cost during that time.[19] From a broader perspective, our paper is also related to the extensive literature that studies the causal factors of economic development of low income countries, such as the effect of institutions (Acemoglu

[16]See, also, Table 1 of Feyrer (2009b) for a list of the top 20 Harmonized System (HS) trade categories imported to the US by air. Absent from this list are primary products.

[17]Using a variety of openness measures, Harrison (1996) studies the effect of openness on growth among developing countries and finds that greater openness is associated with higher economic growth. Dollar and Kraay (2004) show that economic growth can be stimulated by positive changes in trade and conclude that greater involvement in trade is associated with faster growth in developing countries. Using a difference-in-difference approach, Estevadeordal and Taylor (2008) offer some evidence that tariff reductions are correlated with growth acceleration amid growing skepticism that trade is a positive influence on economic performance (e.g. Rodriguez and Rodrik, 2000). These papers do not attempt to construct an instrument for the main causal variable, i.e. the level of trade or some measure of trade openness.

[18]With respect to developing countries, Romalis (2007) proposes a novel strategy, using the U.S. "most-favored nation" (MFN) tariffs, to identify the exogenous variation in trade openness by looking at how trade activities of these countries respond to reductions in the U.S. MFN tariffs. His approach is based on the assumption that the relaxation of trade barriers by the U.S., while encourages an expansion in trade with partner countries that are less developed, is not influenced in turn by the behavior and actions of these developing countries. However, unlike our BDI-based instrument, the instrument that Romalis (2007) proposes only varies across time but not across countries, since the MFN tariffs are applied in the same way by the U.S. to each partner recipient.

[19]As Donaldson (2010) describes, before the advent of railroads, bullocks that travel no more than 30 kilometers a day were the main source of transport of India's commodity trade. In contrast, rails during that time could travel 20 times faster and at much lower per unit distance freight rates. Therefore, the construction of railroads in colonial India has led to a dramatic reduction in trade cost, encouraging inter-regional trade that fosters regional economic development.

Accepted manuscript

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and Johnson, 2005), foreign aid (Werker, Ahmed and Cohen, 2009; Brückner, forthcoming), foreign direct investment (Borensztein, De Gregorio and Lee, 1998; Nair-Reichert and Weinhold, 2001), remittance flows (Gupta, Pattillo and Wagh, 2009) and financial development (Hassan, Sanchez and Yu, 2011).

The remainder of the paper is structured as follows. Section 2 discusses the construction of a measure of trade cost, based on the BDI, as an instrument for the trade of the LDCs. The data and methodology are presented in Section 3. Section 4 presents the baseline results of our regression and Section 5 discusses some additional robustness checks. Section 6 concludes the paper.

## 2 The Baltic Dry Index and the Trade of the LDCs

The Baltic Exchange has a long history going back to 1744 when it was first established through casual conversations between merchants and ships' captains at the Virginia and Baltick Coffee House in London's Threadneedle Street. In 1985, the Baltic Exchange launched the Baltic Dry Index (BDI), plotted in Figure 1, 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. Since its establishment, the BDI has become one of the foremost indicators on the cost of shipping and an important barometer on the volume of worldwide trade and manufacturing activity.

The BDI, reflecting the cost of bulk shipping, is especially relevant for the trade of the LDCs. The LDCs consist of 48 countries located across Africa, Asia, Latin America and the Caribbean. Their exports are mainly made up of primary goods, many of which rely on bulk carriers for international transportation. Table A in the appendix presents the list of 48 LDCs along with their main exported products. For the LDCs which some are landlocked, their main exports consist of cocoa, coffee, tea, cotton, timber and primary metals. As these goods are freight primarily by bulk carriers, the BDI reflects an important component in the cost of trade so that changes in the BDI may have an opposite influence on the trade of the LDCs.[20]

[20]The cost of exports may be borne by the exporters. Although under the definition of *Freight on Board* or *Free on Board* (FOB), the exporter is responsible for delivering, loading and securing the cargo at the ship and the buyer is responsible for the cost of shipping, this definition has become somewhat blurred as shipping cost may be shared between both parties, or even by the exporter. Under the definitions of *Cost and Freight* (CF) and *Cost, Insurance and Freight* (CIF), the exporter pays all expenses incurred in transporting the cargo from its place of origin to the port of destination.

Accepted manuscript

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To exploit country- and time-specific effects of the BDI, we construct a variable of trade cost based on the BDI as

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

where $\theta_{i,t-1}$ is the country $i$'s proportion of total trade at period $t-1$ that consists of primary commodities trade including trade in iron and steel but excluding fuels. The primary products share captures the relative intensity of utilizing bulk shipping, and the interaction specification in (1) allows the impact of BDI to be amplified for countries where primary goods trade is more important. To obtain data on primary goods trade, we collect information from United Nations Conference on Trade and Development (UNCTAD) based on the SITC 0 + 1 + 2 + 3 + 4 + 68 classification of primary commodities. We combine this trade data with the data based on the SITC 67 classification that contains information about trade in iron and steel. This combination covers a wide-range of primary commodities but excludes crude oil, since crude oil requires "wet" carriers such as tankers but not bulk carriers for transportation. While its predetermined nature motivates the use of period $t-1$ primary trade share as the interaction term in (1), our estimation results are not sensitive to using contemporaneous primary trade share instead.[21] Because $BDI^C_{i,t}$ is a measure of trade cost faced by country $i$ that draws on the BDI, we refer this simply as "BDI cost" for future reference.

Besides being 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, the economies of the LDCs are also very small on the global scale, accounting for less than 2 percent of worldwide GDP. Consequently, the LDCs are insignificant when it comes to driving the BDI dynamics. By contrast, the BDI is an important factor that influences the variation in the trade of the LDCs. Figure 2 compares the annual growth rate of the BDI with the growth in trade volume for some LDCs. It shows that growth in the BDI is at times accompanied by a slowdown or even contraction in trade. For several countries, a sharp negative co-movement between the BDI and trade is also documented. Take Central African Republic and Afghanistan, two landlocked countries, as examples. When the BDI increased by 131 percent from 2002 to 2003, trade in the two countries fell by 10 and 14 percent respectively. For some coastal countries, the contraction in trade is even more severe. For instance,

[21] This is demonstrated as a robustness check in Section 5.

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trade fell by 17 percent for Myanmar, 23 percent for Liberia and 27 percent for Eritrea during the same period.

Some commentaries have pointed out that the salient features of the BDI are driven by the growing demand of commodities by large emerging economies. A leading example is China, which many believed is the main driving force behind recent movements in the BDI.[22] 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.[23] This surge in iron ore demand is important because iron ore is by proportion the most important commodity transported by bulk carriers.[24] 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 BDI trends. 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.[25] 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.

The positive co-movement is also not peculiar to China alone. For example, Figure 4 focuses on emerging countries such as Brazil, Russia, India, as well as Australia, which is a key exporter of raw materials. Just as we saw for China, a positive co-movement between the BDI and trade (in growth) is clearly manifested with respect to Brazil, Russia, India and Australia.[26] 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 these countries as they, together with China, are dominant in the trade of primary goods in the world. In contrast, the negative co-movement observed with respect to the sample of LDCs in Figure 2 indicates that the reverse causal effect on the BDI from

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[22] 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`.

[23] 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.

[24] According to Borznois (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).

[25] 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.

[26] This tight positive relationship can also be observed with respect to the world's 15 leading countries, less BRIC and Australia, in terms of the size of primary goods trade. Details are available upon request.

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the trade is weak or negligible.

## 3 Data and Methodology

Our data spans from 1995 to 2010. The BDI data is drawn from the London-based Baltic Exchange office. Income, which is measured by real GDP per capita, as well as nominal trade data are obtained from the UNCTAD website.[27] Real GDP is measured by U.S. Dollars at constant prices and exchange rates using 2005 as the base year. The trade data is deflated by the U.S. CPI for all urban consumers, also using 2005 as the base year.[28] Table 1 presents the summary statistics of the main variables of interest.

Our main estimating equation relates $\log(y_{i,t})$, the log of income per capita for country $i$ at year $t$, as

$$\log(y_{i,t}) = c_y + \beta \log(trade_{i,t}) + \delta' z_{i,t} + \mu_i + \mu_t + v_{i,t}, \tag{2}$$

where $\log(trade_{i,t})$, the log of trade, is the main causal variable of interest, $c_y$ is a constant term, and $z_{i,t}$ is a vector that represents country-specific characteristics such as a landlocked country dummy or an island country dummy and other control variables that we use in our robustness checks.[29] We let $\mu_i$ be a generic representation of country fixed effects that capture all time invariant country-specific characteristics and permanent differences, and $\mu_t$ be a generic representation for time-varying macroeconomic shocks that affect the LDCs identically. Finally, $v_{i,t}$ is the idiosyncratic error term clustered at the country level.

The extent of how trade affects income is summarized by $\beta$, which is the elasticity of income per capita with respect to trade. This cannot be consistently estimated by OLS regression as trade is likely to be endogenous in the income equation, even in spite of controlling for country-specific characteristics and for country and year fixed effects. Firstly, other determinants of income that are correlated with trade may be contained in $v_{i,t}$, a non-exhaustive list of which includes the extent to which institutions are democratized, the level of foreign aid and foreign direct investment, and the degree of financial market development that may influence credit constraints.[30] Secondly, the

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

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

[29]Rose (2004) and Helpman et al. (2008) also employ landlocked and island dummies to capture country-specific differences. But these dummies will be excluded once we control for country fixed effects.

[30]For example, Brückner and Ciccone (2011) and Brückner, Ciccone and Tesei (2012) look at the relationship

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unobserved potential income of a country may be correlated with trade, hence the OLS regression of (2) is susceptible to self-selection bias or reverse-causality problems.[31]

This paper uses the BDI to obtain the exogenous variation in the trade of the LDCs. The estimating equation that relates the log of trade to the BDI cost variable is given by

$$\log(trade_{i,t}) = c_T + \sum_{k=0}^{2} \alpha_i BDI^C_{i,t-k} + \phi' z_{i,t} + \mu_i + \mu_t + w_{i,t}, \quad (3)$$

where $c_T$ is a constant term and $w_{i,t}$ is the idiosyncratic error term clustered at the country level. The $k$th lag of BDI cost is defined as $BDI^C_{i,t-k} = \theta_{i,t-k-1} \log(BDI_{t-k})$.[32] The inclusion of lagged effects captures how quickly the effect of BDI cost on the log of trade decays.[33] Equation (2) is estimated using two-stage least squares in conjunction with (3) as the first-stage regression. We also estimate the effect of BDI cost on income by looking at the reduced form equation:

$$\log(y_{i,t}) = c_b + \sum_{k=0}^{2} \gamma_i BDI^C_{i,t-k} + \psi' z_{i,t} + \mu_i + \mu_t + r_{i,t}. \quad (4)$$

Equation (4) allows us to directly investigate the within-country effect that BDI cost has on income that is facilitated by the trade channel.

# 4 Results

## 4.1 OLS Estimates

The positive correlation between trade and income is a well documented fact, although it is by no means indicative of a causal relationship. While OLS regression is unidentified, it nonetheless

between income and democracy, and Yu (2010) examines the link between democracy and trade. Foreign aid is one concern as recipient countries often have to adhere to pre-conditions encompassing issues such as trade openness that are imposed by the donor (Edwards, 1993; Brückner, forthcoming). The relationship between FDI and trade is investigated, among others, by Markusen and Venables (1998), Markusen (2002) and Markusen, Rutherford and Tarr (2005). Manova (2008) and Lane (2001) look at the response of trade to financial markets and credit constraints.

[31] A leading example of reverse causality is illustrated by the gravity equation as it includes income as one of the key determinants of bilateral trade (Helpman, 1987; Anderson and van Wincoop, 2003).

[32] We have also considered defining lagged instruments as $BDI^C_{i,t-k} = \theta_{i,t-1} \log(BDI_{t-k})$ for the $k$th lag, with the share of primary exports fixed at $\theta_{i,t-1}$ for each lag. This definition yields very similar results as our estimates in Section 4.

[33] Although the first two lags of the BDI cost variable are included as instruments for trade, the main conclusion about the effect of trade on income is robust even when the third to seventh lags of BDI cost are used as additional instruments in (3). Details are available upon request.

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provides a useful starting point for investigating the direction of bias in the estimate of how trade affects the income of the LDCs. Table 2 presents the OLS results with robust standard errors clustered at the country level (in parentheses) based on four variations of the income equation specified in (2). The most basic specification is the simple linear regression of income per capita on trade (both in logs) without additional controls. As reported in Column I, this naïve regression produces a negative elasticity of income per capita with respect to trade of -0.094. If the premise that trade is income improving holds, this negative sign suggests at first blush that the OLS estimate is downward biased. Since our variables are in levels, one could be concerned that the estimate reflects a spurious association due to possible comovements between the time trends in trade and GDP per capita. If this is true, a large $R^2$ would be symptomatic. However, this is not observed given that the adjusted $R^2$ in Column I is nearly zero.

To reduce the degree of endogeneity within the OLS framework, we control for omitted determinants of income that are correlated with trade. This second regression specification includes geographic specific variables in the form of island and landlocked dummy variables as additional controls. As Column II reports, including these variables improves the model's fit as the adjusted $R^2$ increases to 0.281. More importantly, the elasticity of income with respect to trade is now positive at 0.112.

Column III reports a third regression specification that subsumes the geographic factors with country fixed effects that represent time invariant permanent differences across countries. In Column IV, year fixed effects, which reflect broad macroeconomic factors that affect the LDCs in an identical manner, are added to the regression on top of country fixed effects. When country fixed effects are included, Column III shows that the OLS estimate of the trade elasticity of income increases to 0.309. Strikingly, the model's fit improves significantly as the adjusted $R^2$ increases to 0.965. Column IV shows that including time fixed effects raises the elasticity further to 0.331 with a slight improvement in the adjusted $R^2$.

Therefore, as Table 2 shows, the OLS estimates are always increasing when the geographic variables, country and year fixed effects are included in successive steps. This suggests that the OLS estimates are downward biased. One possible reason for this downward bias could be the imprecision in measuring the macroeconomic aggregates for the LDCs. Measurement error in macroeconomic aggregates, especially those of less developed countries, is a well-known problem in the empirical

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literature (Deaton, 2005). If this measurement error were classical, the OLS estimates would be biased towards zero and the estimated effect of trade on income would be attenuated. These factors confound the causal relationship when estimated using OLS regression and necessitates the use of an instrument for trade in order to obtain consistent estimates of its effect on income.

### 4.2 Reduced Form Estimates

Table 3 reports the least squares (reduced form) estimates of the within-country effect that the BDI cost variable has on income. We consider four variations of this causal relationship. Together with country and year fixed effects, Column I regresses the log of income per capita on contemporaneous BDI cost ($BDI^C_{i,t}$) only. Columns II and III explore the lagged effects of BDI cost on income by regressing the log of income per capita on the first lag of BDI cost ($BDI^C_{i,t-1}$) and on its second lag ($BDI^C_{i,t-2}$) separately. By regressing on the contemporaneous and lagged BDI cost variables one at a time, these regressions can shed light on whether the overall effect of BDI cost on income is sensitive to the choice of exploiting either contemporaneous or lagged information about the BDI. Finally, allowing both contemporaneous and lagged information of BDI cost to affect income levels, Column IV regresses the log of income per capita on $BDI^C_{i,t}$, $BDI^C_{i,t-1}$ and $BDI^C_{i,t-2}$ together. This specification, which is presented as (4), looks at the implications of BDI cost (through the trade channel) on income over time and documents the relative importance of contemporaneous versus lagged information about the BDI for predicting income levels.

Columns I-III of Table 3 reveal that each $BDI^C_{i,t}$, $BDI^C_{i,t-1}$ or $BDI^C_{i,t-2}$, when regressed separately one at a time, is a statistically significant predictor of income. Specifically, Columns I-III show that a one standard deviation increase in BDI cost reduces GDP per capita from 7 percent (Column III) to 8.5 percent (Column I). When controlling for all three $BDI^C_{i,t}$, $BDI^C_{i,t-1}$ and $BDI^C_{i,t-2}$ variables in the income regression, Column IV shows that a one standard deviation increase in each of the three regressors reduces GDP per capita by 8.3 percent. Therefore, comparing the results across Columns I-IV, the total impact of BDI cost on income is similar regardless of whether contemporaneous or lagged values of BDI cost are used in isolation as Columns I-III do, or whether these are combined as regressors as Column IV does. Column IV also shows that the impact of BDI cost on income is likely to materialize with a lag, as $BDI^C_{i,t-2}$ contributes most to the total impact that includes both contemporaneous and lagged effects of BDI cost on income.



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One striking finding is that the BDI accounts for a vastly significant proportion of the variation in income. Across Columns I-IV, the adjusted $R^2$ is above 0.95. Since BDI Cost as defined in (1) is country-specific, this allows us to compute the country-specific BDI effect on income. For each country, Figure 5 plots the absolute values of the (time) average response of the log of income per capita following a one percent increase in the BDI in periods $t$, $t-1$ and $t-2$.[34] Using equations (1) and (4), this impact is given by the absolute value of

$$\frac{1}{T-3}\sum_{t=4}^{T}(\hat{\gamma}_0\theta_{i,t-1}+\hat{\gamma}_1\theta_{i,t-2}+\hat{\gamma}_2\theta_{i,t-3}), \tag{5}$$

where recall that $\theta_{i,t-1}$ is period $t-1$ primary trade share of country $i$. The values of $\hat{\gamma}_0$, $\hat{\gamma}_1$ and $\hat{\gamma}_2$ are $-0.020$, $-0.003$ and $-0.053$. These are estimates of the contemporaneous and lagged effects of BDI cost on income obtained from Column IV of Table 3.

As Figure 5 shows, the average absolute BDI elasticity of income per capita is heterogeneous across countries. For most LDCs, this elasticity ranges from 0.02 to 0.04, implying that GDP per capita declines by 0.2 to 0.4 percent following a 10 percent increase in the BDI. Mauritania, Somalia and the Solomon Islands are the only countries where the elasticity exceeds 0.04. Hence among the LDCs, the income levels of these three countries are most sensitive to movements in the BDI. The effect of the BDI on income is generally felt more strongly by African than non-African LDCs. Among the 33 African LDCs, 29 of them (or about 88 percent of African LDCs) have an elasticity that significantly exceeds 0.02. Among the 15 non-African LDCs, this is true only for 10 of them (or about 67 percent of non-African LDCs.)

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### 4.3 Two-Stage Least Squares Estimates

Table 4 presents the 2SLS estimates of the causal effect of trade on income. Just as in Table 3, Table 4 considers four specifications. Columns I-III employ either $BDI^C_{i,t}$, $BDI^C_{i,t-1}$ or $BDI^C_{i,t-2}$ separately as a single instrument for trade. Column IV combines the three variables to instrument for trade in accordance with (3). The purpose of exploring these different regression specifications is to investigate whether the 2SLS estimates are robust to exploiting either contemporaneous or lagged

[34] This impact can also be interpreted as the absolute value of the total (time) average response of the log of income per capita over three periods, $t$, $t+1$ and $t+2$, following a one percent increase in the BDI in period $t$. This is because an increase in the BDI in period $t$ would affect income in periods $t$, $t+1$ and $t+2$ based on (4).

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information about BDI cost, or both, to instrument for trade. By combining both contemporaneous and lagged information about BDI cost, Column IV also reveals the relative importance between contemporaneous and lagged information about the BDI as a source of exogenous variation in trade.

Concerning identification, the first stage results suggest that the instruments are powerful. Across the different specifications, the instruments are significant at the one percent level with F-statistics well above the rule-of-thumb threshold of 10 suggested by Staiger and Stock (1997). While we have shown in Figure 2 that trade and the BDI (in growth) are negatively associated for a sample of LDCs, the first-stage result confirms that the BDI cost variable is a strong, negative determinant of trade. The total effect of BDI cost is robust to whether a single BDI cost variable, i.e. $BDI^C_{i,t}$, $BDI^C_{i,t-1}$ or $BDI^C_{i,t-2}$, is included into the trade regression (see Columns I-III), or whether all three of these variables are combined as instruments for trade (see Column IV). For instance, focusing on Columns I-III where a single BDI cost instrument is used, a one standard deviation increase in BDI cost reduces trade from 14 percent (Column II) to 16.1 percent (Column I). When trade is instrumented by the combination of $BDI^C_{i,t}$, $BDI^C_{i,t-1}$ and $BDI^C_{i,t-2}$, Column IV shows that a one standard deviation increase in BDI cost (in periods $t$, $t-1$ and $t-2$) leads to 16.6 percent decline in trade, which is close to the estimates in Columns I-III.

Our findings demonstrate the importance of trade for the economic development of low income countries. Table 4 shows that the 2SLS estimates of the elasticity of income with respect to trade range from 0.484 (Column III) to 0.534 (Column I). In other words, a one percent expansion in trade raises GDP per capita of the LDCs by approximately 0.5 percent on average. The 2SLS estimates are also very tight across the different specifications. For instance, the estimated causal effect differs only by 0.004 between Columns I and II, demonstrating the robustness of the 2SLS estimates to the choice of using either contemporaneous or lagged information about the BDI as an estimation strategy. The 2SLS estimates also affirm that the OLS estimates are downward biased. For instance, the OLS elasticity estimates of around 0.3 only capture 60 percent of the income response to trade based on the ballpark 2SLS elasticity estimate of 0.5. This emphasizes the importance of taking the endogeneity of trade into careful consideration as OLS regression may severely under-report the economic benefits that the LDCs may gain from the opening of trade.

Given that the BDI cost variable is country-specific, the BDI effect on trade will be heteroge-

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neous across countries.[35] For each country, Figure 6 plots the absolute values of the (time) average response of the log of trade following a one percent increase in the BDI in periods $t$, $t-1$ and $t-2$. This country-specific BDI elasticity of trade is constructed using equations (1) and (3) as the absolute value of

$$\frac{1}{T-3}\sum_{t=4}^{T}(\hat{\alpha}_0\theta_{i,t-1}+\hat{\alpha}_1\theta_{i,t-2}+\hat{\alpha}_2\theta_{i,t-3}), \tag{6}$$

where the values of $\hat{\alpha}_0$, $\hat{\alpha}_1$ and $\hat{\alpha}_2$ are -0.030, -0.012 and -0.111 respectively, which are the estimates of the impact of BDI cost on trade obtained from Column IV of Table 4. Figure 6 shows that the effect of the BDI on trade is more pronounced for African LDCs. Among the 33 African LDCs, 24 of them exhibits an absolute BDI elasticity of trade that is significantly greater than 0.05. For non-African LDCs, this is true only for 6 of the 15 countries. Therefore, not surprisingly, the impact of trade on income driven by the BDI will also be more important for African LDCs, which Figure 5 has already shown.[36]

Our paper is similar to Feyrer (2009a) in that it draws on the variation in shipping cost to construct a time-varying instrument for trade, where interestingly in both papers, the OLS estimate of the trade elasticity of income is around 0.3. However, we depart from Feyrer (2009a) in our estimation strategy and most importantly in our focus on the LDCs. While we find that the 2SLS estimates of the trade elasticity of income are larger than the OLS estimates, the opposite is observed in Feyrer (2009a). Because our paper focuses on the LDCs while Feyrer (2009a) looks at both developed and developing countries, two observations can be made. Firstly, since the OLS estimate is larger than the 2SLS estimate in Feyrer (2009a), this implies that positive selection effects are present when both developed and developing countries are taken into account. Our finding that the OLS estimate is downward biased suggests that other confounding effects could be at work with respect to the LDCs.

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Secondly, our 2SLS estimates, being about twice the size of Feyrer's (2009a) estimates, highlight once again that low income countries could benefit much from the opening of trade. If trade is indeed beneficial, this begs the question of why the size of trade of the LDCs is so small relative to the size (in particular the population) of these countries. One reason could be that the burden

[35]This in turn implies that the BDI driven effect of trade on income will be heterogeneous as well.

[36]The country-specific impact of trade on income driven by a one percent increase in the BDI is identical to the reduced form impact on income following a one percent increase in the BDI. This is already plotted in Figure 5.

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of trade cost is so high for low income countries that it inhibits the process of trade deepening. For instance, there is a growing literature that looks at whether trade cost affects developed and developing countries asymmetrically. If trade frictions between wealthy and low income countries are asymmetric in the sense that the burden of trade cost is higher for low income countries, then such asymmetric trade frictions could result in large and persistent differences in living standards between these nations (Waugh, 2010).

To follow up on this theme, we focus on a group of wealthy small-open economies and examine whether their trade activity might be affected by BDI cost in similar ways as the LDCs. Table B in the appendix lists a sample of wealthy economies with very small trade volumes that are included in this analysis. These countries belong to the group of "high income" countries, classified by the World Bank as countries whose gross national income per capita exceeds 12,276 U.S. Dollars in 2010. Like the LDCs, these high income countries account for a very small proportion of global trade (0.03 percent), although the primary goods share of their trade may be nontrivial.[37] Because their total trade volume is so small on the global scale, it is also unlikely to generate an endogenous response in the BDI. Table 5 shows that the effect of BDI cost on trade for these countries is usually statistically insignificant across the different regression specifications. If the effect is statistically significant, it is estimated with the wrong (positive) sign. In other words, the negative effect of BDI cost on trade is absent with respect to these wealthy small-open economies. Given that such negative effects are observed for the LDCs, this offers some evidence affirming the asymmetric burden of trade cost between wealthy and low income countries and highlights the possible role of trade cost in preventing the process of trade deepening among the LDCs.

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So far, our analysis has taken both landlocked and non-landlocked LDCs into account. However, as trade might be affected by a country's landlocked status, there is no reason to take for granted that our earlier estimates would be similar for both landlocked and non-landlocked LDCs. In fact, they should be more pronounced for non-landlocked LDCs given the direct access to sea transportation these countries have. Table 6 reports the regressions based on the sample of non-landlocked LDCs only. Compared to the previous estimates, the negative effect of BDI cost on trade is even stronger here, suggesting that the trade of non-landlocked LDCs is more sharply influenced

[37]The nontrivial primary goods share of total trade of these wealthy small-open economies implies that an important part of their trade relies on bulk carriers for international transport. The average primary goods share of total trade among these countries is 0.19. The maximum share is 0.66.

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by the BDI. For instance, Table 6 shows that a one standard deviation increase in BDI cost has a total effect of reducing trade from 16.8 percent (Column II) to 18.9 percent (Column IV), and these estimates are larger than the baseline estimates ranging from 14 to 16.6 percent. The second stage regression also shows that the effect of trade on income is stronger for non-landlocked LDCs. As compared to the ballpark baseline estimate of 0.5, the estimated trade elasticity of income in Table 6 ranges from 0.654 (Column III) to 0.718 (Column II), which suggests that the economic benefits from the opening of trade are even more pronounced for non-landlocked LDCs.

## 5 Robustness Checks

This section considers several robustness checks against our baseline 2SLS results. The first robustness check is related to the use of lagged primary products share of total trade, i.e. $\theta_{i,t-1}$, in the construction of the baseline BDI cost given by $BDI_{i,t}^{C}$ in (1). Instead of using the lagged share, we consider using the contemporaneous primary trade share to construct the BDI cost variable as

$$\overline{BDI}_{i,t}^{C} = \theta_{i,t} \log(BDI_t). \tag{7}$$

Table 7 presents new estimates using (7) and its lags as instruments for trade. Compared to the baseline results in Table 4 where the estimated trade elasticity of income per capita ranges from 0.484 to 0.534, Table 7 shows that the estimated elasticity using these new instruments ranges from 0.495 to 0.538. The first stage results are also very similar across Tables 4 and 7. Whereas Table 4 shows that a one standard deviation increase in the baseline BDI cost measure reduces trade from 14 to 16.6 percent, Table 7 shows that a one standard deviation increase in the new BDI cost measure reduces trade from 13.6 percent (Column III) to 18.4 percent (Column I). Such similarities suggest that our analysis is robust to using either the contemporaneous or lagged primary trade share in the construction of country-specific BDI cost variable as an instrument for trade.

The second robustness check continues by exploring the implication of using the interaction of the log of BDI with various lags ($k$) of the primary trade share ($\theta_{i,t-k}$) to construct alternative instruments for trade:

$$\widetilde{BDI}_{i,t}^{C,k} = \theta_{i,t-k} \log(BDI_t). \tag{8}$$

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The use of more distant lags in the above construction is related to the concern that country-specific productivity shocks could be persistent, possibly lasting for a few years. Because productivity shocks are unobserved determinants of income and because they could be persistent, the error term in the income equation might be correlated with the first lag of trade share that is used to construct the country-specific BDI cost in (1).[38] That being said, if our "baseline instrument" (i.e. $BDI_{i,t}^{C}$) were questionable, our baseline result would be fragile to using different lags of the primary trade share when constructing the instrument for trade, but this is not the case. For instance, when trade is instrumented with $\widetilde{BDI}_{i,t}^{C,k}$, for $k = 2$ (Column I) to $k = 5$ (Column IV), Table 8 shows that the trade elasticity of income per capita ranges from 0.465 (Column III) to 0.583 (Column IV). The average elasticity estimate across all columns is 0.51, which is in line with the ballpark 2SLS estimate of 0.5.

The third robustness check involves omitting the financial crisis years from 2008 to 2010. The BDI was extremely volatile during these years, where it peaked in the second quarter of 2008 only to crash by about 95 percent from its peak by the third quarter of 2009 (refer to Figure 1). Since the BDI was especially volatile during this period, it is useful to see to what extent the baseline results in Table 4 are driven by this volatility. Table 9 presents the results excluding the years from 2008 to 2010. Interestingly, the negative effect of the BDI on trade in the first stage is even larger than the baseline estimates, where in the former case, a one standard deviation increase in BDI cost reduces trade from 16.6 percent (Column II) to 23.4 percent (Column IV). Despite this heightened impact of BDI cost on trade in the first stage regression, it has little bearing on our elasticity estimates in the second stage regression. The second stage estimates, which range from 0.490 to 0.541, are very similar to the baseline estimates that range from 0.484 to 0.534 (see Table 4), emphasizing the fact that the baseline estimates of trade elasticity are not driven by the increased volatility in the BDI between 2008 to 2010.

The forth robustness check looks at the sensitivity of the baseline estimates to the inclusion of additional explanatory variables that might be relevant for income. Income levels, thus living standards, may be affected by institutional quality such as the extent of democratization of the country's political system (Acemoglu et al., 2008, 2009), as well as by inward FDI (Nair-Reichert and Weinhold, 2001) and foreign aid (Werker et al., 2009). To control for institutional quality of

[38]We thank the anonymous referee for sharing this important insight.



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a country, we employ a proxy based on the revised Polity score (Polity2) obtained from the Polity IV database of Marshall and Jaggers (2009). The revised Polity score is a combination of subscores that measure the constraints on the chief executive, the competitiveness of political participation, and the openness and competitiveness of executive recruitment. This score ranges from -10 to 10, where a score of 10 indicates an institution that is most democratic possible. To control for inward FDI flows and foreign aid to LDCs, we obtain these data from the UNTACD website and the World Bank's World Development Indicators respectively and apply the appropriate deflator to obtain real values denoted in million U.S. dollars. The control variables of FDI and foreign aid are expressed in logs.

Table 10 reports these robustness checks using both contemporaneous and lagged information of BDI cost as instruments for trade. Therefore, these regressions are extensions of the baseline regression reported in Column IV of Table 4. The main observation is that the baseline result is robust. Across Columns I-III, a one standard deviation increase in BDI cost (in periods $t$, $t-1$ and $t-2$) has a total effect of reducing trade from 15.4 percent (Column II) to 20 percent (Column III). This range of estimates contains the baseline result of 16.6 percent reported in Column IV of Table 4. Importantly, the baseline estimate of the effect of trade on income is also robust to the inclusion of the additional controls. For instance, the estimated elasticity in Table 10 ranges from 0.465 (Column III) to 0.509 (Column II). These effects are much larger than the OLS estimates but similar to the baseline estimate of 0.489.

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## 6 Conclusion

The economic development of low income countries is an important priority facing both policy makers and academic researchers. For these countries, one important question is whether the opening of trade would help to improve their income levels and living standards. Even though reservations have been expressed as early as Nurkse (1959),[39] our main conclusion in this paper is an emphatic yes.

In this paper, we construct a new measure of shipping cost based on the Baltic Dry Index as an instrument for trade, which is then used to construct the within-country estimate of the effect

[39] See, also, Kaldor (1964) and Cohen (1965).

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that trade has on income of the LDCs. We find that the BDI generates a statistically significant and quantitatively large response in the trade of the LDCs. Our 2SLS estimates suggest that a one percent expansion in trade increases the GDP per capita of the LDCs by around 0.5 percent. This estimated trade elasticity of income per capita is much larger than the OLS estimates, implying that ignoring the endogeneity in trade would cause the estimates to be severely attenuated. Our 2SLS estimates are also twice as large as previous estimates in the literature that take into account of both developed and developing countries (Feyrer, 2009a). From the development perspective, our paper therefore affirms that trade is pivotal for improving the income and living standards especially of the less developed nations.

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Table 1: Summary statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| log(GDP per capita) | 760 | 6.155 | 0.806 | 4.234 | 9.720 |
| log(Trade) | 760 | 6.993 | 1.603 | 1.358 | 11.345 |
| Primary products share of total trade ($\theta_{i,t}$) | 760 | 0.355 | 0.142 | 0.022 | 0.846 |
| log(BDI) | 768 | 7.695 | 0.614 | 6.853 | 8.865 |
| BDI Cost ($BDI^{C}_{i,t}$) | 712 | 2.728 | 1.094 | 0.155 | 5.895 |

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Table 2: OLS Regression of income on trade

| | I | II | III | IV |
|---|---|---|---|---|
| *Dependent Variable*: log(GDP per Capita) | | | | |
| log(Trade) | -0.094 | 0.112 | 0.309*** | 0.331*** |
| | (0.075) | (0.073) | (0.059) | (0.116) |
| Landlocked & island dummies | no | yes | yes | yes |
| Country fixed effects | no | no | yes | yes |
| Year fixed effects | no | no | no | yes |
| Countries | 48 | 48 | 48 | 48 |
| Observations | 760 | 760 | 760 | 760 |
| Adj. $R^2$ | 0.034 | 0.281 | 0.965 | 0.966 |

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

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Table 3: Reduced form regression of income on BDI cost

| | I | II | III | IV |
|---|---|---|---|---|
| *Dependent Variable*: log(GDP per Capita) | | | | |
| BDI Cost ($BDI^C_{i,t}$) | -0.078** | | | -0.020 |
| | (0.041) | | | (0.019) |
| BDI Cost, First Lag ($BDI^C_{i,t-1}$) | | -0.068** | | -0.003 |
| | | (0.035) | | (0.013) |
| BDI Cost, Second Lag ($BDI^C_{i,t-2}$) | | | -0.064** | -0.053** |
| | | | (0.033) | (0.026) |
| Adj. $R^2$ | 0.962 | 0.969 | 0.973 | 0.973 |
| Country fixed effects | yes | yes | yes | yes |
| Year fixed effects | yes | yes | yes | yes |
| Countries | 48 | 48 | 48 | 48 |
| Observations | 712 | 664 | 616 | 616 |

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

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Table 4: 2SLS regression of income on trade

| | I | II | III | IV |
|---|---|---|---|---|
| *Dependent Variable* (2nd Stage): log(GDP per Capita) | | | | |
| log(Trade) | 0.534*** | 0.530*** | 0.484*** | 0.489*** |
| | (0.186) | (0.172) | (0.150) | (0.158) |
| *Dependent Variable* (1st Stage): log(Trade) | | | | |
| BDI Cost ($BDI^C_{i,t}$) | -0.147** | | | -0.030 |
| | (0.061) | | | (0.036) |
| BDI Cost, First Lag ($BDI^C_{i,t-1}$) | | -0.128** | | -0.012 |
| | | (0.054) | | (0.025) |
| BDI Cost, Second Lag ($BDI^C_{i,t-2}$) | | | -0.132*** | -0.111*** |
| | | | (0.050) | (0.039) |
| First-stage adj. $R^2$ | 0.971 | 0.974 | 0.977 | 0.977 |
| First-stage F-Stat | 59 | 71 | 61 | 153 |
| Second-stage adj. $R^2$ | 0.969 | 0.974 | 0.978 | 0.978 |
| Country fixed effects | yes | yes | yes | yes |
| Year fixed effects | yes | yes | yes | yes |
| Countries | 48 | 48 | 48 | 48 |
| Observations | 712 | 664 | 616 | 616 |

*Note*: To instrument for trade, Column I uses the contemporaneous BDI cost ($BDI^C_{i,t}$) defined in (1), Column II uses its first lag ($BDI^C_{i,t-1}$), Column III uses its second lag ($BDI^C_{i,t-2}$), and Column IV uses all three variables. Cluster robust standard errors are reported in the parenthesis. Statistical significance at the 10, 5 and 1 percent levels are indicated by *, ** and *** respectively.

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Table 5: 2SLS regression of income on trade for high income developing and small-open economies

| | I | II | III | IV |
|---|---|---|---|---|
| *Dependent Variable* (2nd Stage): log(GDP per Capita) | | | | |
| log(Trade) | 0.097 | -0.070 | -0.075 | -0.112 |
| | (2.200) | (0.368) | (0.205) | (0.136) |
| *Dependent Variable* (1st Stage): log(Trade) | | | | |
| BDI Cost ($BDI^C_{i,t}$) | -0.0069 | | | -0.114 |
| | (0.084) | | | (0.075) |
| BDI Cost, First Lag ($BDI^C_{i,t-1}$) | | 0.057 | | 0.065* |
| | | (0.073) | | (0.038) |
| BDI Cost, Second Lag ($BDI^C_{i,t-2}$) | | | 0.163*** | 0.156*** |
| | | | (0.056) | (0.043) |
| First-stage adj. $R^2$ | 0.944 | 0.955 | 0.958 | 0.969 |
| First-stage F-Stat | 35 | 35 | 15 | 30 |
| Second-stage adj. $R^2$ | 0.984 | 0.982 | 0.981 | 0.980 |
| Country fixed effects | yes | yes | yes | yes |
| Year fixed effects | yes | yes | yes | yes |
| Countries | 13 | 13 | 13 | 13 |
| Observations | 149 | 139 | 130 | 130 |

*Note*: To instrument for trade, Column I uses the contemporaneous BDI cost ($BDI^C_{i,t}$) defined in (1), Column II uses its first lag ($BDI^C_{i,t-1}$), Column III uses its second lag ($BDI^C_{i,t-2}$), and Column IV uses all three variables. Cluster robust standard errors are reported in the parenthesis. Statistical significance at the 10, 5 and 1 percent levels are indicated by *, ** and *** respectively.

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Table 6: 2SLS regression of income on trade excluding landlocked LDCs

| | I | II | III | IV |
|---|---|---|---|---|
| *Dependent Variable* (2nd Stage): log(GDP per Capita) | | | | |
| log(Trade) | 0.680*** | 0.718*** | 0.654*** | 0.664*** |
| | (0.200) | (0.197) | (0.167) | (0.175) |
| *Dependent Variable* (1st Stage): log(Trade) | | | | |
| BDI Cost ($BDI^C_{i,t}$) | -0.172** | | | -0.012 |
| | (0.089) | | | (0.042) |
| BDI Cost, First Lag ($BDI^C_{i,t-1}$) | | -0.154** | | -0.020 |
| | | (0.079) | | (0.034) |
| BDI Cost, Second Lag ($BDI^C_{i,t-2}$) | | | -0.158** | -0.141** |
| | | | (0.076) | (0.061) |
| First-stage adj. $R^2$ | 0.975 | 0.978 | 0.981 | 0.981 |
| First-stage F-Stat | 30 | 36 | 39 | 182 |
| Second-stage adj. $R^2$ | 0.964 | 0.968 | 0.976 | 0.976 |
| Country fixed effects | yes | yes | yes | yes |
| Year fixed effects | yes | yes | yes | yes |
| Countries | 32 | 32 | 32 | 32 |
| Observations | 472 | 440 | 408 | 408 |

*Note*: The regressions exclude the sample of landlocked LDCs. To instrument for trade, Column I uses the contemporaneous BDI cost ($BDI^C_{i,t}$) defined in (1), Column II uses its first lag ($BDI^C_{i,t-1}$), Column III uses its second lag ($BDI^C_{i,t-2}$), and Column IV uses all three variables. Cluster robust standard errors are reported in the parenthesis. Statistical significance at the 10, 5 and 1 percent levels are indicated by *, ** and *** respectively.

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Table 7: 2SLS regression using an alternative BDI cost variable (1st robustness check)

| | I | II | III | IV |
|---|---|---|---|---|
| *Dependent Variable* (2nd Stage): log(GDP per Capita) | | | | |
| log(Trade) | 0.495*** | 0.538*** | 0.537*** | 0.530*** |
| | (0.170) | (0.190) | (0.177) | (0.193) |
| *Dependent Variable* (1st Stage): log(Trade) | | | | |
| BDI Cost ($\overline{BDI}_{i,t}^{C}$) | -0.168** | | | -0.044 |
| | (0.068) | | | (0.044) |
| BDI Cost, First Lag ($\overline{BDI}_{i,t-1}^{C}$) | | -0.144** | | -0.030 |
| | | (0.053) | | (0.024) |
| BDI Cost, Second Lag ($\overline{BDI}_{i,t-2}^{C}$) | | | -0.124** | -0.084** |
| | | | (0.025) | (0.037) |
| First-stage adj. $R^2$ | 0.967 | 0.971 | 0.974 | 0.974 |
| First-stage F-Stat | 204 | 88 | 71 | 74 |
| Second-stage adj. $R^2$ | 0.966 | 0.969 | 0.974 | 0.974 |
| Country fixed effects | yes | yes | yes | yes |
| Year fixed effects | yes | yes | yes | yes |
| Countries | 48 | 48 | 48 | 48 |
| Observations | 760 | 712 | 664 | 664 |

*Note*: The regressions employ instruments that are based on an alternative BDI cost variable, defined as $\overline{BDI}_{i,t}^{C} = \theta_{i,t} \log(BDI_t)$, the interaction between country $i$'s contemporaneous primary products share of total trade and the log of the BDI. To instrument for trade, Column I uses the contemporaneous BDI cost ($\overline{BDI}_{i,t}^{C}$) defined in (8), Column II uses its first lag ($\overline{BDI}_{i,t-1}^{C}$), Column III uses its second lag ($\overline{BDI}_{i,t-2}^{C}$), and Column IV uses all three variables. Cluster robust standard errors are reported in the parenthesis. Statistical significance at the 10, 5 and 1 percent levels are indicated by *, ** and *** respectively.

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Table 8: 2SLS regression using other BDI cost variables (2nd robustness check)

| | I | II | III | IV |
|---|---|---|---|---|
| | $k = 2$ | $k = 3$ | $k = 4$ | $k = 5$ |
| *Dependent Variable* (2nd Stage): log(GDP per Capita) | | | | |
| log(Trade) | 0.524*** | 0.470*** | 0.465*** | 0.583*** |
| | (0.168) | (0.144) | (0.154) | (0.209) |
| *Dependent Variable* (1st Stage): log(Trade) | | | | |
| BDI Cost ($\widetilde{BDI}_{i,t}^{C,k}$) | -0.129** | -0.134*** | -0.130*** | -0.096** |
| | (0.054) | (0.050) | (0.042) | (0.040) |
| First-stage adj. $R^2$ | 0.974 | 0.977 | 0.981 | 0.984 |
| First-stage F-Stat | 74 | 84 | 75 | 80 |
| Second-stage adj. $R^2$ | 0.974 | 0.979 | 0.981 | 0.980 |
| Country fixed effects | yes | yes | yes | yes |
| Year fixed effects | yes | yes | yes | yes |
| Countries | 48 | 48 | 48 | 48 |
| Observations | 664 | 616 | 568 | 520 |

*Note*: The regressions employ instruments that are based on other BDI cost variables, defined as $\widetilde{BDI}_{i,t}^{C,k} = \theta_{i,t-k}\log(BDI_t)$, the interaction between the $k$th lag of country $i$'s primary products share of total trade and the log of BDI. To instrument for trade, Column I uses $\widetilde{BDI}_{i,t}^{C,2}$ ($k = 2$), Column II uses $\widetilde{BDI}_{i,t}^{C,3}$ ($k = 3$), Column III uses $\widetilde{BDI}_{i,t}^{C,4}$ ($k = 4$), and Column IV uses $\widetilde{BDI}_{i,t}^{C,5}$ ($k = 5$). Cluster robust standard errors are reported in the parenthesis. Statistical significance at the 10, 5 and 1 percent levels are indicated by *, ** and *** respectively.

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Table 9: 2SLS regression excluding financial crisis years (3rd robustness check)

| | I | II | III | IV |
|---|---|---|---|---|
| *Dependent Variable* (2nd Stage): log(GDP per Capita) | | | | |
| log(Trade) | 0.496*** | 0.541*** | 0.494*** | 0.490*** |
| | (0.158) | (0.143) | (0.124) | (0.126) |
| *Dependent Variable* (1st Stage): log(Trade) | | | | |
| BDI Cost ($BDI^C_{i,t}$) | -0.171*** | | | -0.061 |
| | (0.063) | | | (0.038) |
| BDI Cost, First Lag ($BDI^C_{i,t-1}$) | | -0.152*** | | -0.026 |
| | | (0.057) | | (0.031) |
| BDI Cost, Second Lag ($BDI^C_{i,t-2}$) | | | -0.162*** | -0.127*** |
| | | | (0.053) | (0.040) |
| First-stage adj. $R^2$ | 0.971 | 0.974 | 0.977 | 0.977 |
| First-stage F-Stat | 57 | 63 | 65 | 127 |
| Second-stage adj. $R^2$ | 0.972 | 0.976 | 0.981 | 0.981 |
| Country fixed effects | yes | yes | yes | yes |
| Year fixed effects | yes | yes | yes | yes |
| Countries | 48 | 48 | 48 | 48 |
| Observations | 568 | 520 | 472 | 472 |

*Note*: Financial crisis years from 2008 to 2010 are excluded. To instrument for trade, Column I uses the contemporaneous BDI cost ($BDI^C_{i,t}$) defined in (1), Column II uses its first lag ($BDI^C_{i,t-1}$), Column III uses its second lag ($BDI^C_{i,t-2}$), and Column IV uses all three variables. Cluster robust standard errors are reported in the parenthesis. Statistical significance at the 10, 5 and 1 percent levels are indicated by *, ** and *** respectively.

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Table 10: 2SLS regression of income on trade controlling for democracy, FDI and foreign aid (4th robustness check)

| | I | II | III |
|---|---|---|---|
| Additional Control | Polity | log(FDI) | log(Foreign aid) |
| *Dependent Variable* (2nd Stage): log(GDP per Capita) | | | |
| log(Trade) | 0.471*** | 0.509*** | 0.465*** |
| | (0.139) | (0.171) | (0.143) |
| *Dependent Variable* (1st Stage): log(Trade) | | | |
| BDI Cost ($BDI^C_{i,t}$) | -0.023 | -0.012 | -0.043 |
| | (0.043) | (0.031) | (0.034) |
| BDI Cost, First Lag ($BDI^C_{i,t-1}$) | -0.016 | -0.028 | -0.023 |
| | (0.026) | (0.025) | (0.028) |
| BDI Cost, Second Lag ($BDI^C_{i,t-2}$) | -0.136*** | -0.101** | -0.117*** |
| | (0.044) | (0.040) | (0.041) |
| First-stage adj. $R^2$ | 0.966 | 0.977 | 0.977 |
| First-stage F-Stat | 111.12 | 137.75 | 124.56 |
| Second-stage adj. $R^2$ | 0.978 | 0.976 | 0.980 |
| Country fixed effects | yes | yes | yes |
| Year fixed effects | yes | yes | yes |
| Countries | 43 | 48 | 48 |
| Observations | 540 | 578 | 568 |

*Note*: Column I controls for democracy using the Polity2 score. Column II controls for the log of inward real FDI flows denominated in million U.S. dollars. Column III controls for the log of real foreign aid denominated in million U.S. dollars. The regressions instrument for trade using both contemporaneous and lagged BDI cost variables. Cluster robust standard errors are reported in the parenthesis. Statistical significance at the 10, 5 and 1 percent levels are indicated by *, ** and *** respectively.

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Figure 1: The Baltic Dry Index, 1985–2010

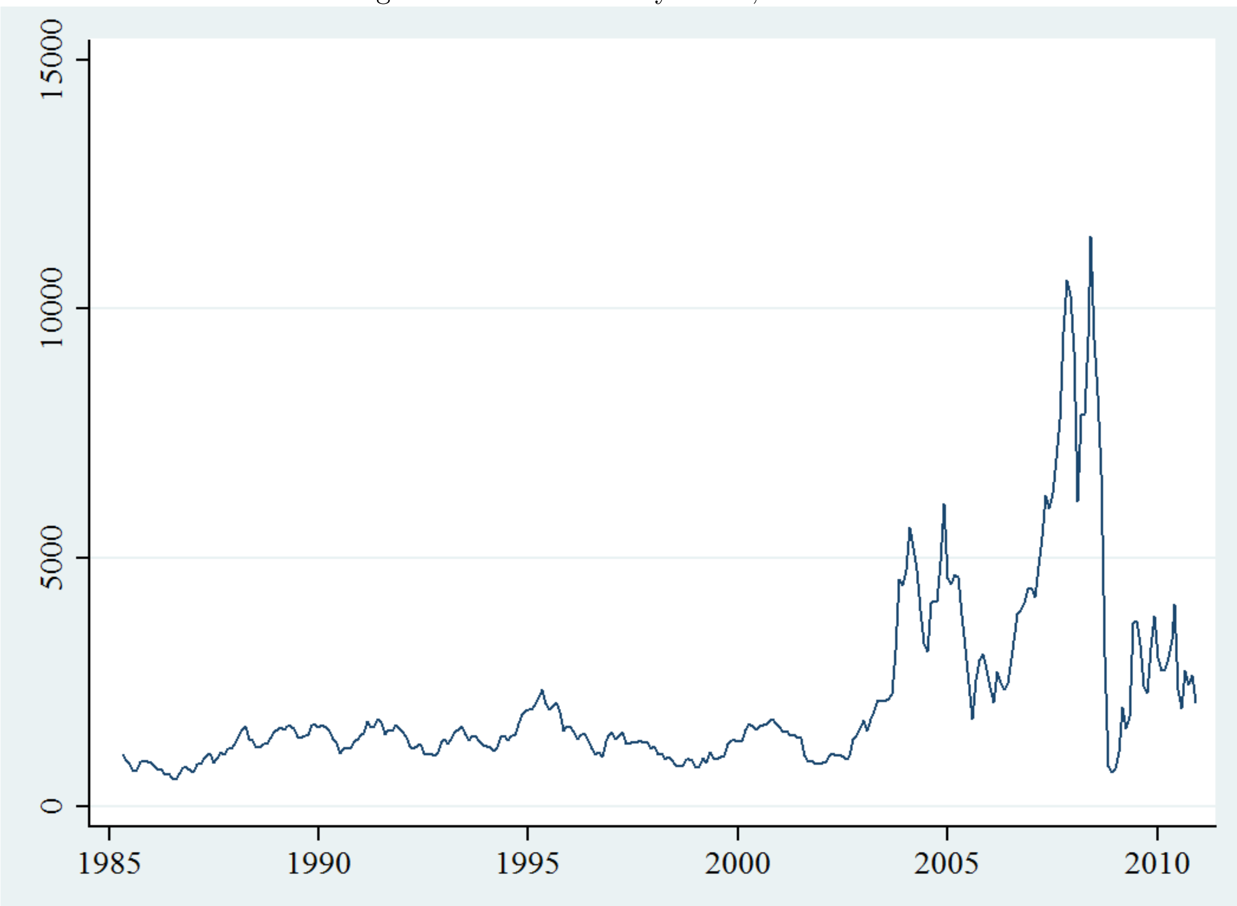


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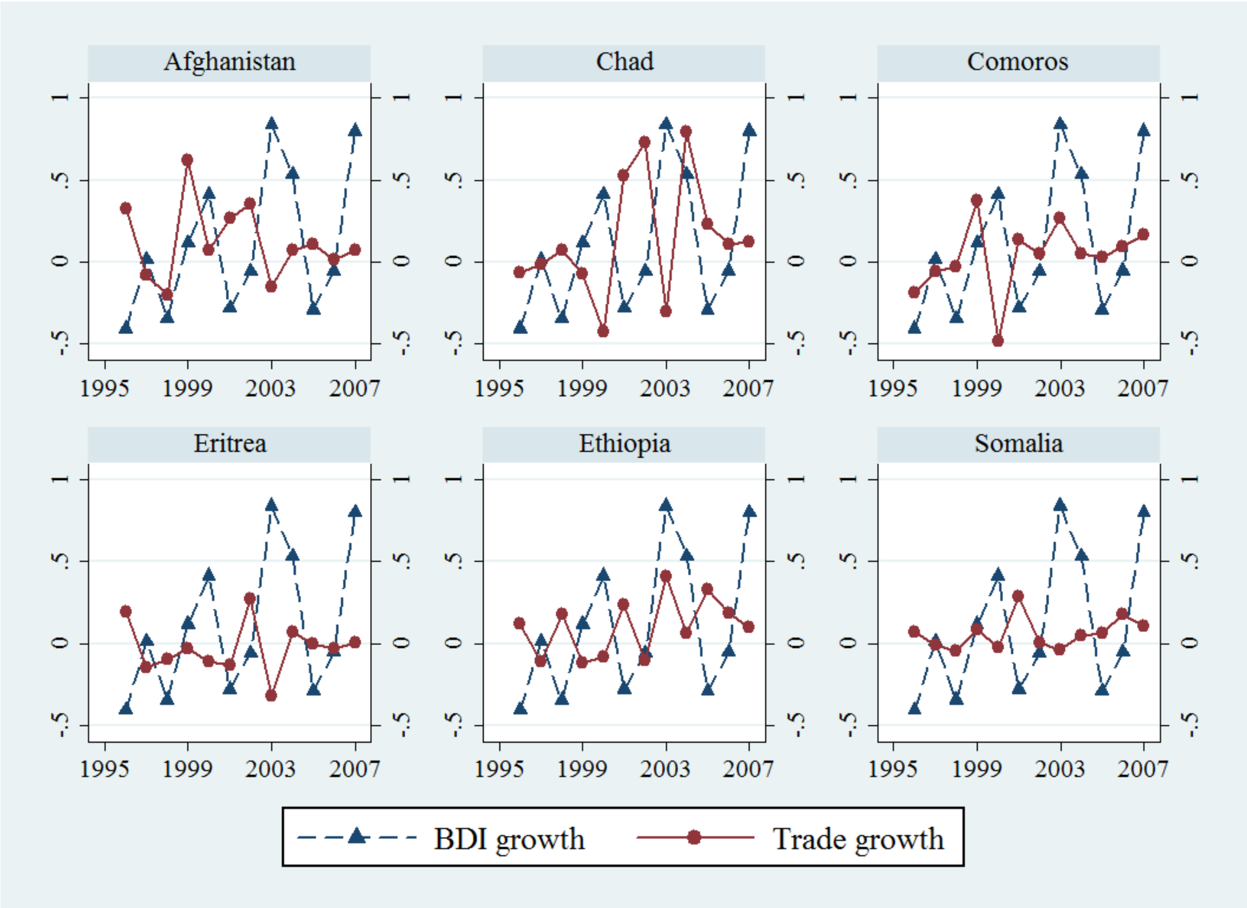
Figure 2: BDI growth and trade growth for a sample of LDCs




*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. The growth variables are constructed as the first difference of their respective values in logs.

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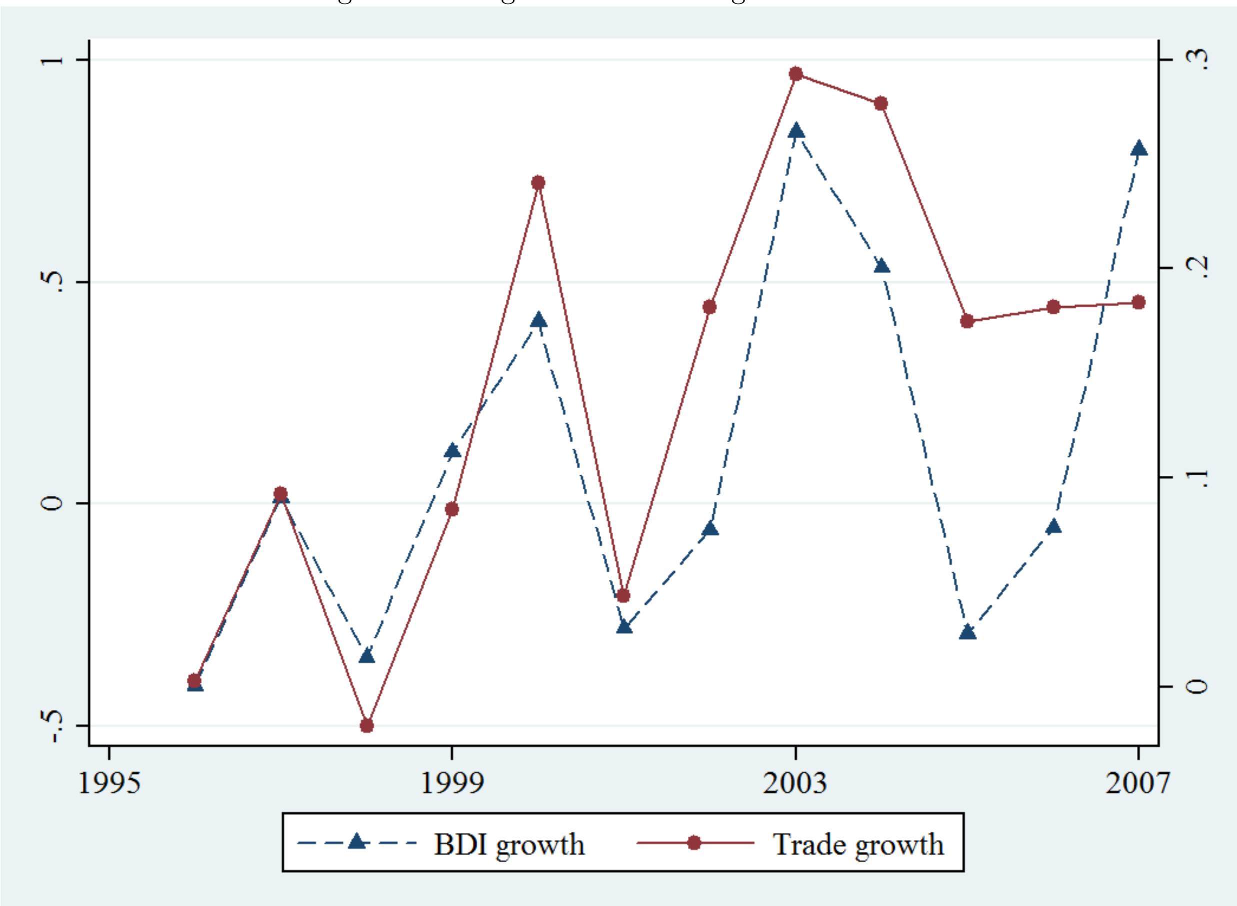
Figure 3: BDI growth and trade growth of China




*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. The growth variables are constructed as the first difference of their respective values in logs.

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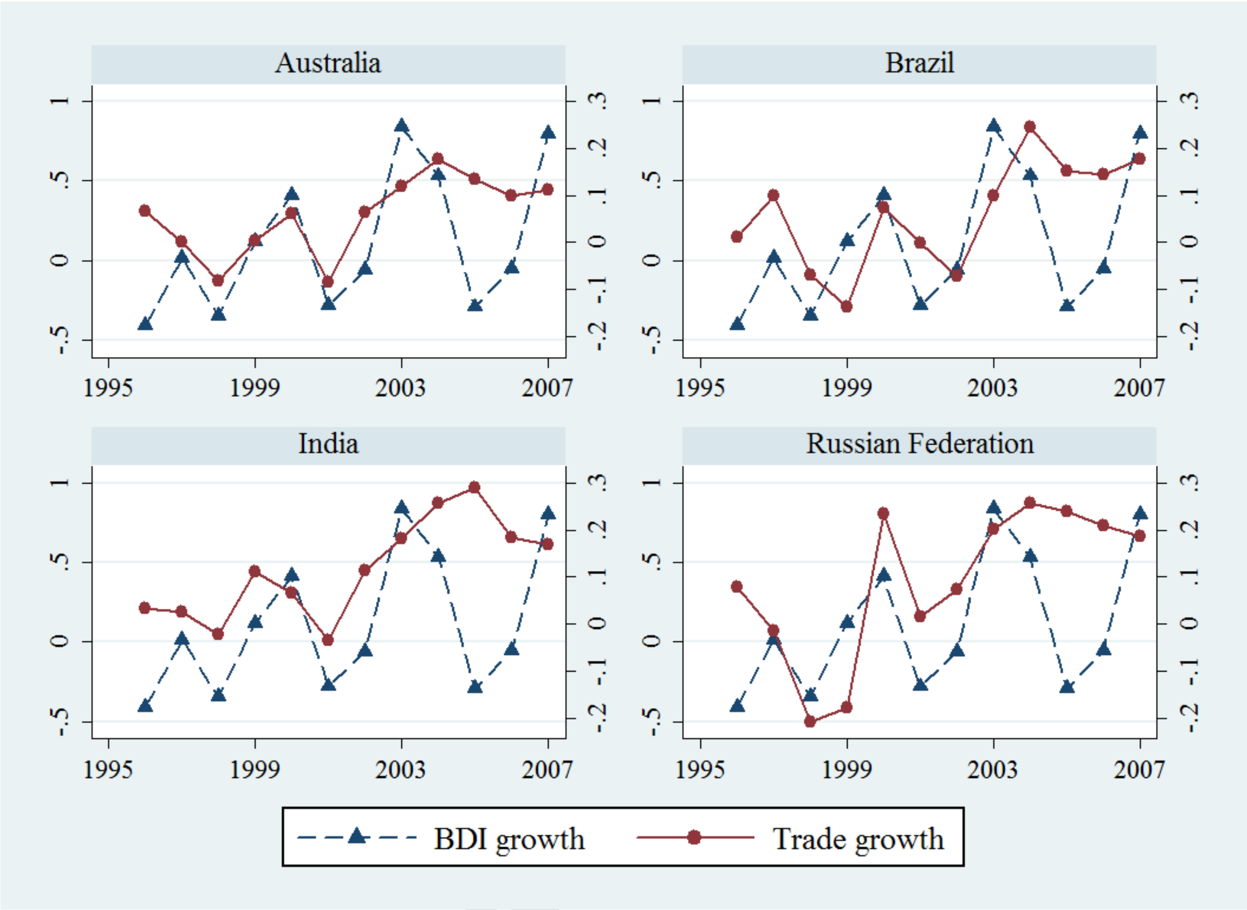
Figure 4: BDI growth and trade growth of Brazil, Russia, India and Australia




*Note*: This figure plots the growth in the BDI and the growth in trade of Brazil, Russia, India and Australia. The left vertical axis measures the growth in the BDI and the right vertical axis measures the growth in trade. The growth variables are constructed as the first difference of their respective values in logs.

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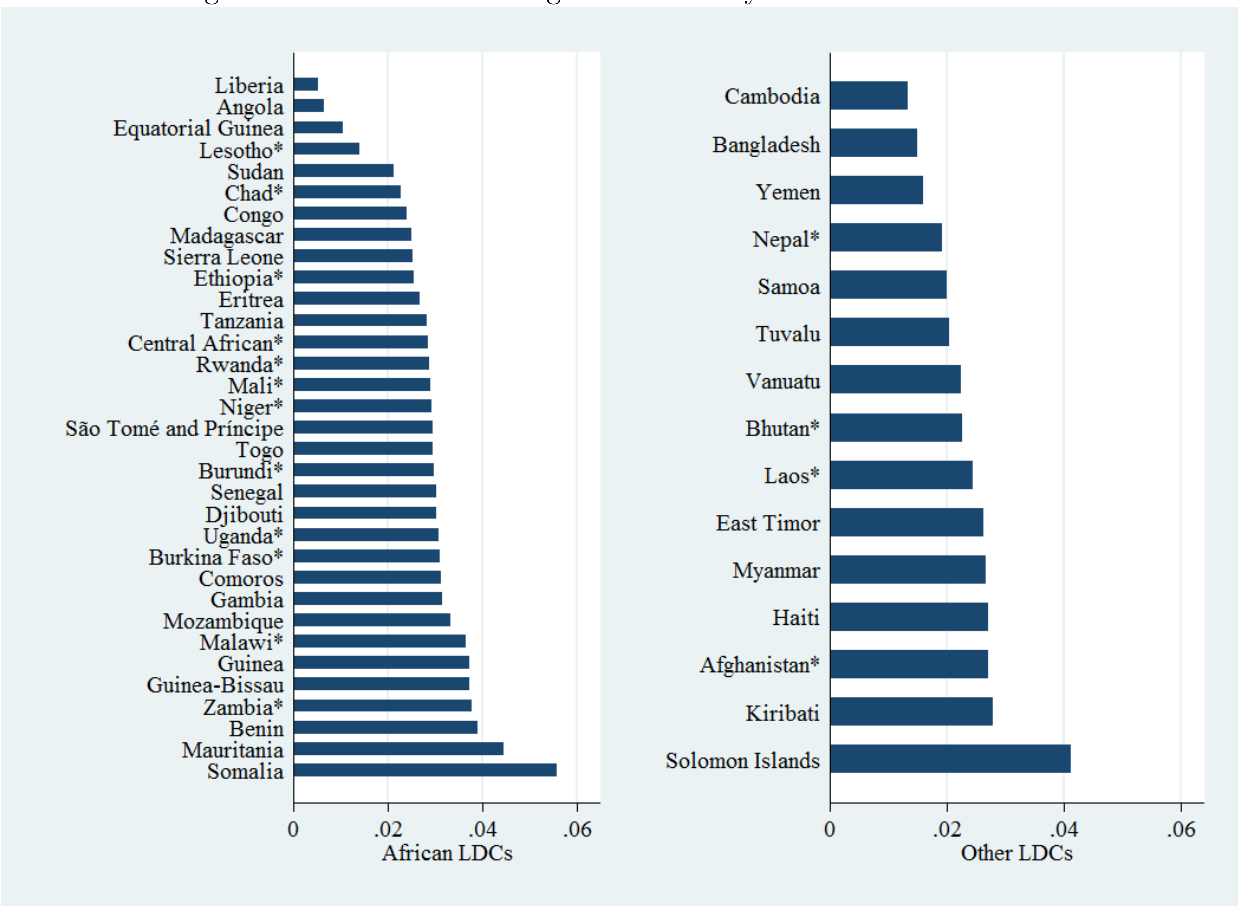
Figure 5: The absolute average BDI elasticity of income for each LDC




*Note*: This figure plots the absolute value of the (time) average BDI elasticity of income per capita for each LDC. This elasticity is computed based on equation (5). It shows the average percentage decline in GDP per capita in each country following a one percent increase in the BDI. The asterisk denotes landlocked countries.

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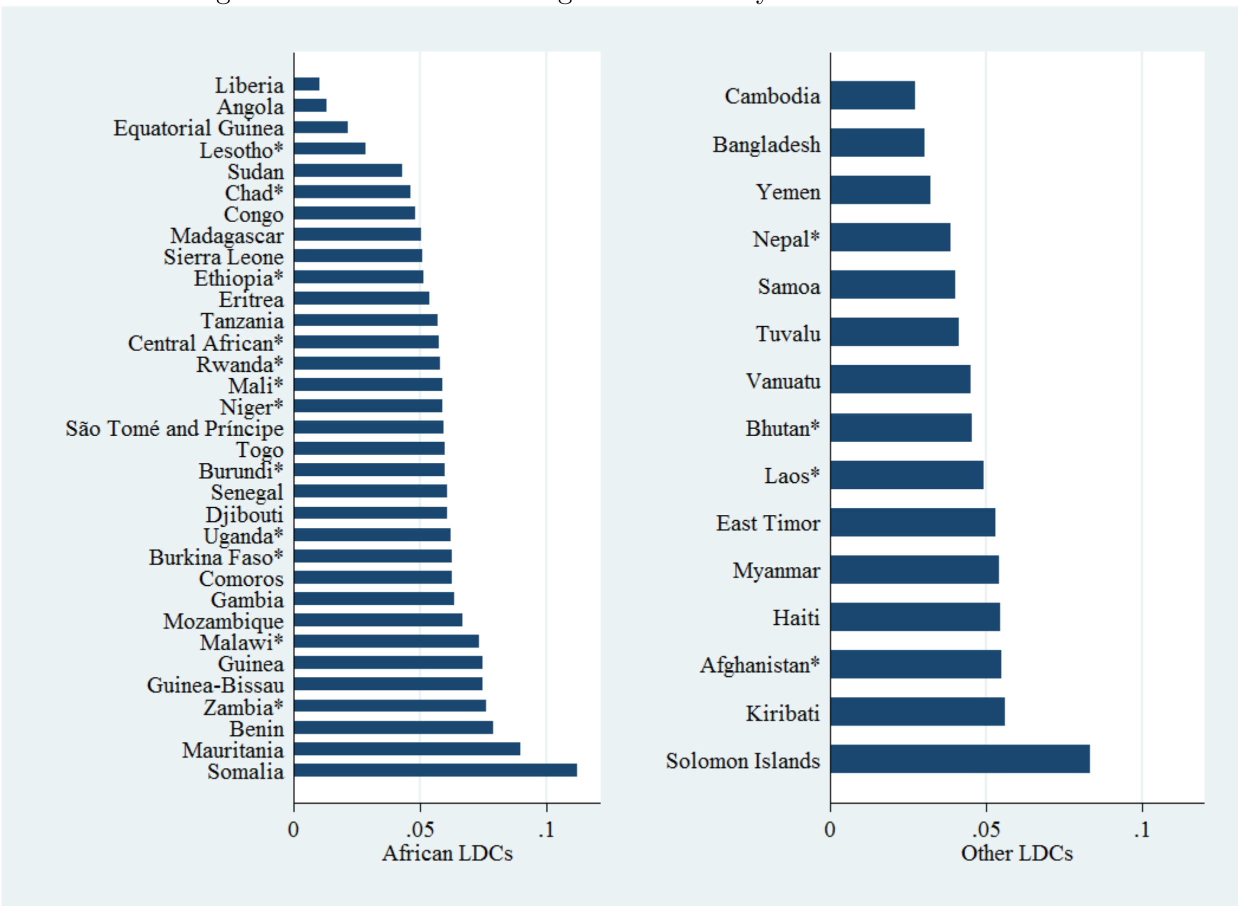
Figure 6: The absolute average BDI elasticity of trade for each LDC




*Note*: This figure plots the absolute value of the (time) average BDI elasticity of trade for each LDC. This elasticity is computed based on equation (6). It shows the average percentage decline in trade in each country following a one percent increase in the BDI. The asterisk denotes landlocked countries.

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# Appendix

Table A: List of 48 least developed countries (LDCs)

| Africa, 33 Countries | | | |
|---|---|---|---|
| Angola | crude oil, diamonds, refined petroleum products, coffee, sisal, fish and fish products, timber, cotton | Madagascar | coffee, vanilla, shellfish, sugar, cotton cloth, chromite, petroleum products |
| Benin | cotton, cashews, shea butter, textiles, palm products, seafood | Malawi# | tobacco, tea, sugar, cotton, coffee, peanuts, wood products, apparel |
| Burkina Faso# | cotton, livestock, gold | Mali# | cotton, gold, livestock |
| Burundi# | coffee, tea, sugar, cotton, hides | Mauritania | iron ore, fish and fish products, gold, copper, petroleum |
| Central African Republic | diamonds, timber, cotton, coffee, tobacco | Mozambique | aluminum, prawns, cashews, cotton, sugar, citrus, timber |
| Chad# | oil, cattle, cotton, gum arabic | Niger# | uranium ore, livestock, cowpeas, onions |
| Comoros* | vanilla, ylang-ylang (perfume essence), cloves, copra | Rwanda# | coffee, tea, hides, tin ore |
| Congo, Democratic Republic | diamonds, gold, copper, cobalt, wood products, crude oil, coffee | Sao Tome and Principe* | cocoa, copra, coffee, palm oil |
| Djibouti | reexports, hides and skins, coffee (in transit) | Senegal | fish, groundnuts (peanuts), petroleum products, phosphates, cotton |
| Equatorial Guinea | petroleum products, timber | Sierra Leone | diamonds, rutile, cocoa, coffee, fish |
| Eritrea | livestock, sorghum, textiles, food, small manufactures | Somalia | livestock, bananas, hides, fish, charcoal, scrap metal |
| Ethiopia# | coffee, qat, gold, leather products, live animals, oilseeds | Sudan | oil and petroleum products, cotton, sesame, livestock, groundnuts, gum arabic, sugar |
| Gambia | peanut products, fish, cotton lint, palm kernels | Tanzania | gold, coffee, cashew nuts, manufactures, cotton |
| Guinea | bauxite, alumina, gold, diamonds, coffee, fish, agricultural products | Togo | reexports, cotton, phosphates, coffee, cocoa |
| Guinea-Bissau | fish, shrimp; cashew nuts, peanuts, palm kernels, sawn lumber | Uganda# | coffee, fish and fish products, tea, cotton, flowers, horticultural products, gold |
| Lesotho# | manufactures (clothing, footwear, road vehicles), wool and mohair, food and live animals | Zambia# | copper, cobalt, electricity, tobacco, flowers, cotton |
| Liberia | rubber, timber, iron, diamonds, cocoa, coffee | | |

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| Asia and Oceania, 14 Countries | | | |
|---|---|---|---|
| Afghanistan# | opium, fruits and nuts, handwoven carpets, wool, cotton, hides and pelts, precious and semi-precious gems | Nepal# | clothing, pulses, carpets, textiles, juice, pashima, jute goods |
| Bangladesh | garments, frozen fish and seafood, jute and jute goods, leather | Samoa* | fish, coconut oil and cream, copra, taro, automotive parts, garments, beer |
| Bhutan# | electricity (to India), ferrosilicon, cement, calcium carbide, copper wire, manganese, vegetable oil | Solomon Islands* | timber, fish, copra, palm oil, cocoa |
| Burma | natural gas, wood products, pulses, beans, fish, rice, clothing, jade and gems | Timor-Leste* | coffee, sandalwood, marble |
| Cambodia | clothing, timber, rubber, rice, fish, tobacco, footwear | Tuvalu* | copra, fish |
| Kiribati# | copra, coconuts, seaweed, fish | Vanuatu* | copra, beef, cocoa, timber, kava, coffee |
| Laos# | wood products, coffee, electricity, tin, copper, gold | Yemen | crude oil, coffee, dried and salted fish, liquefied natural gas |
| **Americas and the Caribbean, 1 Country** | | | |
| Haiti* | apparel, manufactures, oils, cocoa, mangoes, coffee | | |

*Note*: * denotes an island state, # denotes a landlocked country. The list of LDCs is taken from the UN website `http://www.unohrlls.org/en/ldc/25` and information about exports is obtained from the CIA World Factbook `https://www.cia.gov/library/publications/the-world-factbook/`.

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Table B: List of high income developing and small-open economies

| | |
|---|---|
| 1. Anguilla | 2. Antigua and Barbuda |
| 3. Cayman Islands | 4. Cook Islands |
| 5. Guam | 6. Montserrat |
| 7. Niue | 8. Northern Mariana Islands |
| 9. Palau | 10. Saint Kitts and Nevis |
| 11. Saint Lucia | 12. Seychelles |
| 13. Turks and Caicos Islands | |

*Note*: This is a sample of "high income" countries, classified by the World Bank as countries whose gross national income per capita exceeds 12,276 U.S. Dollars in 2010.

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Highlights.txt

The Self-Organizing Map analysis is compared with the cluster analysis methods.
The EOF is used to reduce the data dimension and data noises.
The SOM is the most insensitive to the cut-off EOF mode number.

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