# Natural Disasters and the Effect of Trade on Income: A New IV Approach

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**Abstract**

Does trade openness cause higher GDP per capita? Since the seminal IV estimates of Frankel and Romer [F&R](1999) important doubts have surfaced. Is the correlation spurious and driven by omitted geographical and institutional variables? Does the instrument satisfy the exclusion restriction? In this paper, we generalize F&R's empirical strategy to a panel setting. We observe that natural disasters increase openness. Interacted with geographical variables, natural disasters can be used to construct an instrument that varies across countries *and* time. It can, therefore, be used in panel setups where unobserved country characteristics can be controlled for. Our results confirm the original findings.

**Keywords**: per capita income, openness, natural disasters, instrumental variable estimation, panel econometrics

**JEL-Classification**: C23, C26, F15, F43, O4, Q54

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# 1. Introduction

Does openness to trade result in higher per capita income? Virtually all workhorse models of trade theory predict gains from trade, in particular in the long-run. However, many observers, in the academia and outside, remain unconvinced by the empirical evidence. The central econometric problem lies in the joint endogeneity of openness and income. Using a cross-section of countries, Frankel and Romer (1999), henceforth F&R, have used a geography-based instrument to analyze the empirical relationship between trade and per capita income. Their approach has gained enormous popularity[1], but has also drawn important criticism. Rodriguez and Rodrik (2001) argue that F&R's instrument is correlated with other geographic variables that directly affect income. For example, the effect of openness is not robust to the inclusion of distance to the equator. Rodrik, Subramanian and Trebbi (2004) show that institutional quality matters more than geography (and geography-induced trade openness). Despite a rapidly increasing body of literature, the debate is not closed yet.

The issues with the F&R-approach discussed above essentially relate to (i) omitted variable bias, and (ii) to the validity of the exclusion restriction. In order to deal with (i), authors have turned to *panel* regressions, where unobserved time-invariant idiosyncratic country characteristics - such as distance to the equator, historical factors going back to colonialism, or climatic conditions - can be fully controlled for by first-differencing or within transformation of the data. However, the F&R-instrument is not applicable in the panel setup, since geography does not vary across time.[2] Until now, there is no convincing instrument for trade openness that has time variation and is applicable in a broad cross-section of countries.[3] In this study we come up with a generalization of the F&R-approach that can be used in a panel of countries. Problem (ii) is directly related to problem (i) since the exclusion restriction needs to hold conditional on controls. If country-specific characteristics can be controlled for by exploiting the panel structure of the data, there is less room for the exclusion restriction to fail. Moreover, one of the advantages of the original F&R instrument, which was lost in some of the subsequent research, is that the instrument is constructed from bilateral geographical variables (country-pairs) and their interactions, so that country-specific geographical features can still be included in the regression.

Our approach starts with the following consideration: when a country is hit by a major natural disaster, such as an earthquake, a volcano eruption, or a storm, its productive capacity is temporarily reduced. Increased investment and lower consumption are required to build up destroyed capital again. If the economy has access to international markets, imports surge after the disaster. When capacity is restored, imports decline again, but exports have to rise so that the economy may meet the intertemporal budget constraint. Therefore, everything else equal,

[1] Dollar and Kraay (2002), Irwin and Teviö (2002), Easterly and Levine (2003), Alcalá and Ciccone (2004), Redding and Venables (2004), Noguer and Siscart (2005), Frankel and Rose (2005), Cavallo and Frankel (2008), as well as Felbermayr, Hiller and Sala (2010) to name only a few studies that draw on F&R's instrument.

[2] Alternatively GMM-based approaches are used, e.g. Greenaway, Morgan and Wright (2002), Lederman and Maloney (2003), or Felbermayr (2005).

[3] See for instance Buch and Toubal (2009), who study the case of Germany, Romalis (2007), or Feyrer (2009) for interesting but not universally applicable approaches.

after a natural disaster, the economy should have a higher degree of openness (exports plus imports over GDP) than before. In fact, the degree of bilateral openness of an economy is, amongst other things, a function of natural catastrophes. We argue that the timing and geographical location of natural disasters are exogenous to income per capita so that their occurrence can be used to instrument openness.[4] The advantage of this instrument is its time-varying nature. Hence, it can be used in a panel of countries where the F&R-strategy would not be applicable.

Our framework generalizes the F&R instrument to the panel setup. Hence, its construction and many of its features can be maintained. We use natural disasters in a gravity model of bilateral trade from which income terms are omitted. We find that the effect of disasters on openness is conditioned by geographical factors, such as distance to financial centers, trade facilitating factors between country-pairs, such as proximity, and variables that describe the size of the country's internal market, such as population or area. We use Poisson Pseudo Maximum Likelihood regressions to predict bilateral trade volumes and employ their country-level aggregates as instruments.[5] Using country- and time-fixed effects in the cross-country income regression eliminates all geographical, climatic, historical or other time-invariant country-specific observed or unobserved influences. The inclusion of natural disasters as a control in the second stage regression makes sure that it is the *interaction* between countries' geographical location and natural disasters which identifies the effect of openness on GDP per capita.

We document three important results. First, a major natural disaster increases imports by about 0.07%-points on impact and exports after a lag. This finding is in line with Gassebner, Keck and Teh (2010), who suggest that imports increase, while exports contract due to a major disaster. Bilateral openness remains higher by 0.3%-points. Second, the IV strategy works well: The correlation between our constructed measure of openness and observed trade openness is 79%. Third, we employ our instrument to estimate the effect of openness on per capita income, using country- and time-fixed effects and controlling both for internal market size and the direct effect of natural disasters. Our results confirm the insights of F&R; the findings are qualitatively robust in a panel setup. In terms of economic significance, we find that a one standard deviation increase in openness increases income per capita by 45% (12% under standard fixed-effects OLS without instrumentation). Developing countries benefit more strongly from trade openness than developed countries.

We use the proposed instrument in a canonical growth regression. But it can be easily employed in many other setups where the researcher is interested in understanding the role of trade openness for macroeconomic outcomes.

**Literature**. Our paper is related to at least three strands of research: (i) the empirical literature on the relationship between international trade openness and per capita income, (ii) the gravity literature, and (iii) research on the effect of natural disasters.

Whether trade liberalization enhances GDP per capita has been subject to a debate among

[4]Controlling for fixed country specific characteristics (such as countries' geographical location) is important to deal with the fact that economic activity may be a function of perceived riskiness.

[5]Poisson models allow better out-of-sample prediction and are therefore preferable to OLS. Results do not depend on this choice.

empirical growth researchers. F&R (1999) were the first to implement an instrument for openness based on the exogenous geographic attributes of trade for the year 1985. Several papers applied and refined the instrument of F&R to various aspects of international trade, while others strongly criticized the approach[6]. Irwin and Terviö (2002) confirm the result of F&R that countries more open to trade hold higher incomes even after controlling for endogeneity. Yet, they criticize that this result is not robust to the inclusion of distance from the equator. Nagour and Siscart (2005) re-examine the relation between trade volumes and income levels using the proposed geography-based instrument. In contrast to earlier studies the authors use a richer data set that allows them to estimate the effect of openness on domestic income more precisely. Their result of income enhancing trade is remarkably robust to a wide array of geographical and institutional controls. Buch and Toubal (2009) examine whether openness causes higher growth for Germany after the fall of the Berlin Wall. They rule out endogeneity in a German state-country panel for 1991-2004 using exogenous time-invariant geographic and time-varying policy parameters. The authors find that geographic coefficients exert a strong effect on regional openness in Germany, and that regional GDP per capita surges with the degree of trade integration. An excellent paper close to ours is Feyrer (2009). He exploits the inherent distance-bias of technological change in transport systems (air transport) to generate a time-varying F&R instrument and employs it in a fixed-effect estimation. His country sample is considerably smaller than ours. However, in terms of results, our results compare well with Feyrer's.

The second strand of literature relates to well known research on the gravity equation. A formal theoretical derivation can be traced back to Anderson (1979). Further influential research applying the gravity setup has been undertaken by Baier and Bergstrand (2001, 2004, 2007, 2009), Anderson and van Wincoop (2003), Baltagi, Egger and Pfaffermayr (2003), as well as Santos Silva and Tenreyro (2006), henceforth SS&T.

Regarding research on disasters, our paper relates to a number of recent studies on the macroeconomic consequences of calamities, including work by Skidmore and Toya (2002, 2007), Kahn (2005), as well as Cuaresma (2008), Yang (2008), Noy (2009), and Cavallo et al. (2010). A recent paper by Gassebner, Keck and Teh (2010) is the first to quantify the effect of technological and natural catastrophes on real bilateral import flows.

The remainder of the paper is structured as follows. Section 2 motivates our instrumental variable strategy by discussing the role of natural disasters for imports and exports in a gravity model of bilateral trade flows. Section 3 constructs the instrument and discusses its properties. Section 4 employs it in our cross-country income regression for 1950-2008. Section 5 concludes.

# 2. Disasters and the Gravity Equation

## 2.1. Data

Nominal import and export values measured in current USD come from the IMF's *Direction of Trade Statistics* (2009). Nominal income data in current USD and total population data combine

[6]See e.g. Rodrik, Subramanian and Trebbi (2004), or Rodriguez and Rodrik (2001).

two sources: the World Bank's *World Development Indicators* database as the primary source, supplemented by Barbieri (2002).[7] Trade openness is defined as imports plus exports divided by GDP.

Geographic and bilateral trade impediments and facilitating factors - land area, great circle distance, common border, and colonial relation - are taken from the CEPII's *Geographic and Bilateral Distance Database* (2005). As a measure of international financial remoteness the natural logarithm of the great-circle distance to the closest offshore major financial center - London, New York, or Tokyo - is used, which is provided by Rose and Spiegel (2009).[8]

The primary source on natural disasters is the *Emergency Events Database* (EM-DAT 2010) maintained by the Center for Research on the Epidemiology of Disasters. The database differentiates two main categories: natural and technological catastrophes. The EM-DAT data are compiled from various sources, including UN agencies, NGOs, insurance companies, research institutes and press agencies. Priority is given to data from UN agencies, governments and the International Federation of Red Cross and Red Crescent Societies. This prioritization is not only a reflection of the quality or value of the data, it also reflects the fact that most reporting sources do not cover all disasters or have political limitations that could affect figures. In this paper we focus on *natural disasters* only, as such are considered to be exogenous.[9] [10] Theory suggests that disasters must not be too "small" to exert a notable effect on trade liberalization. The incident needs to be of a dimension that directly causes damage to production facilities, public infrastructure and affect a substantial number of people. Hence, its large-scale effects indirectly affect macroeconomic activity and cause damage or loss that triggers reconstruction expenditures or induces a large inflow of foreign assistance. We adapt a categorization of a study by Munich Re (2006) on natural catastrophes also used by Gassebner, Keck and Teh (2010) to filter disasters that eventually will enter the equation of interest. The Munich Re (2006) study defines a *great natural catastrophe* as involving more than 1,000 deaths plus extreme monetary damage. Hence, events entering the bilateral trade equation have to meet at least one of the following conditions[11]: (i) 1,000 or more deaths; or (ii) 1,000 or more persons injured; or (iii) 100,000 or more persons affected. We exclude the incurred costs of losses sustained condition as this might not be entirely exogenous.[12] Higher monetary losses are more likely in indus-

[7] As the WDI data span only over the 1960-2009 period, we use Katherine Barbieri's data, who uses the same primary source for this period, to extend the data until 1950.

[8] Note that we adapt this measure to a zero distance for the UK, the USA, and Japan. While the original Rose and Spiegel (2009) measure would give us a relatively remote UK, USA and Japan, measuring their distance to London or NY respectively. This approach does not fit our purpose in measuring a country's ability to smooth consumption in case of a disaster. We consider it very unlikely that the financial centers will be completely destroyed by a natural catastrophe. Hence, as these countries incorporate major financial centers they should not be treated as financially remote but rather as being able to smooth consumption quickly in case of a natural catastrophe.

[9] Technological disasters may be bound to the development status of an economy. Nations with a low development stage may experience more technological catastrophes due to lower technological standards, work ethic, or poor infrastructure.

[10] Natural disasters comprise droughts, earthquakes, epidemics, extreme temperature, floods, insect infestations, (mud)slides, volcanic eruptions, waves or surges, wildfires and windstorms. In this paper, though, epidemics are excluded, as such are suspected to comply with other mechanisms - such as poor infrastructure - intensifying their spread, and as their economic effects may differ systematically from those of other disasters.

[11] The decision rule is driven by data availability. The rather fragmentary structure of the EM-DAT database constrains us to an "or" rather than an "and" rule.

[12] Yet, including the monetary losses does not significantly change the results.

trialized nations due to the presence of infrastructure and production facilities, thus physical capital. Hence, the value of damage is in our case not a good measure of the scope of a disaster since it depends on per capita income of an economy, which is endogenous. As a consequence we construct a measure of natural disasters not considering the monetary costs of a catastrophe.[13]

The decision rule decreases the number of natural disasters from a total of 8,980 to 1,636 large-scale natural catastrophes in the dataset over 1950 to 2008. Counting all disasters that strike a nation in a specific year, a frequency variable is created. Nations with no observation fulfilling the decision rule criteria are allotted a zero that year.[14] Presumably, the frequency variable contains more precise information than a simple dummy variable.

But are natural disasters really exogenous? It is fairly convincing that natural catastrophes are not caused by GDP per capita but rather depend on the geographic location of a nation state. Still, we have to be careful, since disasters might actually depend on specific countries' levels of economic development. As countries move up the development ladder, their economic vulnerability tends to increase. For instance, if forests are cut down or rivers are rectified, flooding or landslides become more likely. Therefore, it may be wise to concentrate on specific disasters that are more likely to be truly exogenous (earthquakes, volcanic eruptions) or on catastrophes that cannot be human-induced or caused by country-specific development levels (tsunamis, storms, droughts, storm floods). This is a point that cannot be tested directly but we will use robustness checks to support our findings. Further, economic activity may concentrate in 'safe' places to avoid disasters. However, this possibility would be controlled for by the inclusion of country dummies.

## 2.2. Empirical Strategy

How disasters affect trade depends on the relative position of countries in geographical space and on their access to financial markets. Hence, the bilateral dimension matters as trade costs are affected by the multilateral position of a country (Anderson and van Wincoop, 2003, and Baier and Bergstrand, 2009). The more remote the economy, the less it will be able to rely on foreign imports to smooth domestic consumption. Also, if disasters have geographical correlation, substituting imports for domestic production may be more expensive as close-by trade partners may also be hit by the shock. Hence, it is important to move beyond the multilateral picture and study bilateral trade flows.

We estimate a gravity model of trade using a Poisson Pseudo Maximum Likelihood (PPML) approach based on SS&T (2006)

$$M_t^{ij} = exp[\beta_0 + \beta_1 \ln G_t^i G_t^j + \beta_2 \ln P_t^i + \beta_3 \ln P_t^j + \beta_4 \Omega_t^i + \beta_5 \Omega_t^j + \beta_6 \Gamma_t^{ij} + \beta_7 \Gamma_t^{ji}]\nu_{ij}\nu_t\varepsilon_t^{ij} \qquad (1)$$

[13]As a robustness check we will consider *all* natural disasters, large and small in impact. Results in the bilateral trade equation give us a similar instrument for when considering all natural disasters, while the estimates are of a similar magnitude and significance in the trade-income equation, which supports our findings.

[14]This is possible as EM-DAT captures data on the occurrence and effects of catastrophes worldwide dating from 1900.

where $M_t^{ij}$ relates to bilateral imports flows at point $t$ between country $i$ and $j$, $\ln G_t^i G_t^j$ is the log of the product of the GDP of country $i$ and of country $j$, while the log of population, $\ln P_t^i$ and $\ln P_t^j$, is used as a proxy of the economies' sizes. $\Gamma_t^i$ and $\Gamma_t^j$ denote interaction terms between the disaster frequency variables, $\Omega_t^i$ and $\Omega_t^j$[15], and geographic components. Additionally, we include theoretically-motivated multilateral resistance terms à la Baier and Bergstrand (2009). $\nu_{ij}$ denotes the full country-pair specific vector of fixed effects. These capture time-invariant pair-specific determinants of trade such as geographical distance, and historical or cultural. The $\nu_{ij}$ nest exporter- and importer dummies $\nu_i, \nu_j$ so that variables such as a country's geographical position relative to other countries is coltrolled for. $\nu_t$ are time-fixed effects, controlling for the global business cycle or the price of oil, while $\varepsilon_t^{ij}$ constitutes an error term. We estimate the variance-covariance matrix using a heteroskedasticity-robust estimator that also allows for clusters at the dyadic level. This is strongly recommended by Stock and Watson (2008) to void inconsistent estimates due to serial correlation.

The standard procedure would be to take the log of $M_t^{ij}$ in equation (1) and estimate the vector $\beta$ using OLS, yet, loosing a lot of information by dropping all zeros from the trade matrix. We tackle this matter by following SS&T (2006) and estimate the gravity using PPML. As a matter of fact, this leads to stronger estimates since we do not have to omit the information contained in the zero trade observations.

**Gravity Results**. Results from testing the gravity equation of bilateral trade for 1950-2008 are depicted in table (1). All coefficients incorporate robust residuals that are clustered at the country-pair level calculated using a conditional fixed-effects PPML model. Following F&R, nations with a population of less than 100,000 citizens are excluded from the panel as those economies' trade flows may be dominated by idiosyncratic facts. As explained above, we apply a conditional fixed-effects PPML approach as it represents a non-negligible share of country pairs (SS&T, 2006) and we need not resort to out-of-sample preconditions (Noguer and Siscart, 2005).

Estimates in table (1) show the typical gravity results found in the literature. The higher a country pair's joint GDP the stronger the trade ties between them (1% significance). Coefficients on bilateral import (export) flows are significantly decreasing in the size of the home (partner) country in all specifications. PPML estimates are in line with findings by SS&T (2006). Multilateral resistance terms on distance and proximity are constructed in accordance to Baier and Bergstrand (2009).

Estimation results on the disaster frequency variable are of particular interest. When an economy is hit by a natural disaster, its productive capacity is temporarily reduced, we expect a negative sign on exports. If the economy has access to international markets, imports surge after the disaster, we expect a positive sign on import flows. When capacity is restored imports decline again, but exports have to rise so that the economy may meet the intertemporal budget constraint. In table (1), estimates on the importing country are positive, even though to a great

[15]We also run the regression using cumulated disasters $CumDis_t^i = \sum_{s=0}^{T} \Omega_s^i$, which are always cut-off after 5 years, as the impact of previous disasters on trade patterns may cumulate over time.

Table 1: Conditional Fixed-Effects PPML Gravity Results, 1950-2008

| Dependent Variable: | bilateral import flows | | | | | |
|---|---|---|---|---|---|---|
| | yearly disasters | | | cumulated disasters | | |
| | FE PPML | FE PPML | FE PPML | FE PPML | FE PPML | FE PPML |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| # large-scale disasters,i | 0.036*** | 0.073 | 0.146 | 0.014*** | 0.041 | 0.073 |
| | (0.00) | (0.11) | (0.09) | (0.00) | (0.08) | (0.07) |
| # large-scale disasters,j | 0.053*** | -0.282*** | -0.322*** | 0.012*** | -0.107** | -0.099** |
| | (0.01) | (0.09) | (0.10) | (0.00) | (0.04) | (0.04) |
| disaster x financial (ln),i | | -0.010 | -0.008 | | -0.011 | -0.010 |
| | | (0.02) | (0.01) | | (0.01) | (0.01) |
| disaster x financial (ln),j | | 0.067*** | 0.065*** | | 0.022*** | 0.022*** |
| | | (0.01) | (0.01) | | (0.01) | (0.01) |
| disaster x MultRes,i | | -0.012 | -0.011 | | -0.003 | -0.003 |
| | | (0.01) | (0.01) | | (0.01) | (0.01) |
| disaster x MultRes,j | | 0.026** | 0.026* | | 0.010* | 0.010* |
| | | (0.01) | (0.01) | | (0.01) | (0.01) |
| dis. x fin (ln)x MultRes,i | | 0.002 | 0.002 | | 0.001 | 0.001 |
| | | (0.00) | (0.00) | | (0.00) | (0.00) |
| dis. x fin (ln)x MultRes,j | | -0.006*** | -0.006*** | | -0.002*** | -0.002*** |
| | | (0.00) | (0.00) | | (0.00) | (0.00) |
| disaster x distance (ln),i | | | -0.009** | | | -0.004 |
| | | | (0.00) | | | (0.00) |
| disaster x distance (ln),j | | | 0.005 | | | -0.001 |
| | | | (0.04) | | | (0.00) |
| gdp,i * gdp,j (ln) | 0.788*** | 0.787*** | 0.786*** | 0.803*** | 0.804*** | 0.802*** |
| | (0.03) | (0.02) | (0.02) | (0.03) | (0.03) | (0.03) |
| population (ln),i | -0.106*** | -0.093** | -0.093*** | -0.102*** | -0.103*** | -0.100** |
| | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) |
| population (ln),j | -0.093** | -0.093** | -0.092*** | -0.088** | -0.092** | -0.089** |
| | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) |
| MR: distance (ln) | 0.070* | 0.121*** | 0.121*** | 0.084* | 0.100** | 0.102** |
| | (0.04) | (0.04) | (0.04) | (0.05) | (0.04) | (0.04) |
| MR: contiguity | 0.257 | 0.272 | 0.295 | 0.203 | 0.154 | 0.207 |
| | (0.41) | (0.38) | (0.36) | (0.44) | (0.39) | (0.39) |
| Fixed Effects | | | | | | |
| Pair | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES |
| Loglikelihood | -1.21e+07 | -1.19e+07 | -1.19e+07 | -1.23e+07 | -1.22e+07 | -1.22e+07 |
| Chi2 | 35034.93 | 43563.77 | 46903.36 | 34078.24 | 40729.35 | 40932.24 |
| Observations | 821177 | 821177 | 821177 | 821177 | 821177 | 821177 |

Note: Constant, importer-, exporter-, and time-fixed effects are not reported. Country-pair clustered robust standard errors are reported in parenthesis. Multilateral resistance terms à la Baier and Bergstrand (2009).* p<0.05, ** p<0.01, *** p<0.001

deal insignificant, except for column (1) and (4). This is in line with Gassebner, Keck and Teh (2010), who point out that the impact of a catastrophe might be transmitted indirectly through a reduction in macroeconomic activity induced by a contraction in investment and output and a worsening in fiscal balances. Reconstruction or rebuilding of damaged infrastructure in the disaster struck state, probably including external financial assistance, is likely to increase imports as there must be a corresponding inflow of goods and services. Disasters in the partner country $j$ decrease exports significantly in column (2), (3), (5), and (6) in table (1). The positive coefficient on the exporter disaster frequency parameter in column (1) and (4) switches its sign due to omitted information as financial distance and thus the ability to smooth consumption in case of a shock is decisive for the effect of disasters on trade flows. From the results we can conclude that bilateral export flows are reduced due to a calamity either through direct (losses in human resources and destruction of production facilities) or indirect (disruption of transportation facilities) channels. The findings are largely in line with those of Gassebner, Keck and Teh (2010) in a related framework looking at real import flows under OLS.

Further, considering the interaction between financial remoteness and natural calamities, we expect the positive effect of disasters on imports to be reduced if a country is less integrated financially. Interactions remain insignificant for the importer, but show the right sign, hence we believe this to be economically plausible. Beyond that, the contracting effect on exports of a catastrophe is less strong if the country is financially remote, thus cannot smoothen consumption easily (1% significance). We introduce further interaction terms of disasters, as well as disaster and financial remoteness, with the multilateral resistance of distance calculated according to Baier and Bergstrand (2009). The more multilaterally remote an economy is the less strong the increase (decrease) of imports (exports) in case of a disaster. From the tripple interaction term we can conclude that the more financially and multilaterally remote a country, the stronger the surge (contraction) in import (export) flows. In column (3) and (6), we ad interaction terms between disasters and geographic distance to the specification. Coefficients remain robust compared to the previous specification. The further apart a country pair when hit by a natural catastrophe, the less strong the increase (decrease) in imports (exports). This result is as expected. Remote country pairs trade in general less than proximate pairs, which is a well established result in the gravity literature. If a country in a remote pair is hit by a shock it cannot easily exploit trade ties to smooth consumption as such are generally weeker between distant pairs.

In general, we can support the proposition that natural catastrophes vary substantially and considerably over time. Further, we can underpin the conjecture that natural disasters exert an economically significant impact on observed bilateral trade flows. Hence, disasters might be used in a bilateral setting to construct an instrument for trade openness.

## 3. The IV strategy

## 3.1. Empirical Strategy

**Background.** To assess the effect of trade liberalization on income per capita, we run a regression that explains the log of real GDP per capita as a function of an economy's trade share and other components of income that can be controlled for by including country-fixed effects.

$$\ln y_t^i = \alpha + \beta \omega_t^i + \gamma X_t^i + \nu_i + \nu_t + \varepsilon_t^i \quad (2)$$

where $y_t^i$ denotes real per capita GDP at time $t$ in country $i$, $\omega_t^i$ reflects the aggregate of trade openness share of an economy, $X_t^i$ is a vector of time-varying covariates (such as the log of population, or the incidence of a natural disaster), $\nu_i$ captures time-invariant country-specific factors affecting income, $\nu_t$ controls for time-specific components that affect all economies simultaneously, and $\varepsilon_t^i$ represents the error term.

International trade $\omega_t^i$ is specified as a function of an economy's size, $\ln P_t^i$, the frequency of disasters that hit a nation, $\Omega_t^i$, geographical components interacted with natural disasters, $\Gamma_t^i$, country-specific factors $\nu_i$, time-fixed effects $\nu_t$, and other unobserved parameters affecting trade $\epsilon_t^i$:

$$\omega_t^i = \phi + \rho \ln P_t^i + \delta \Omega_t^i + \theta \Gamma_t^i + \nu_i + \nu_t + \epsilon_t^i \quad (3)$$

The error terms in equation (2) and (3) are presumably correlated, as causality runs both ways. An economy with a well-developed infrastructure or an economic policy that encourages competition and confidence in markets will probably experience high trade shares given its country characteristics, while acquiring high growth rates given its trade patterns. Testing the link between openness to trade and real per capita GDP thus cannot be considered in isolation, as it constitutes a salient endogeneity problem. It is a well known issue that if international trade is correlated with the error term in equation (2), trade estimates may be biased and inconsistent (Helpman, 1997). The crucial assumption of our analysis hinges on the fact that relevant variables are conditionally uncorrelated with the error term in equation (2), and thus exogenous.[16] On this basis, equation (2) can be estimated using limited maximum likelihood instrumental variable methods, henceforth LIML, instrumenting trade through a time-varying variable constructed from a modified bilateral trade equation, comprising only exogenous parameters of trade.

**Bilateral Trade Specification.** The equations above study a multilateral setup. However, in reality, the bilateral dimension matters as trade costs are affected by the multilateral position of a country. The more remote an economy is, the less it will be able to rely on foreign imports to smooth domestic consumption. Further, if disasters have geographical correlation, substituting imports for domestic production may be more expensive as proximate trade partners may also be hit by the shock. Hence, it is insightful to run a modified gravity regression for bilateral trade

[16] Additionally, we control for natural disasters in the income equation directly to show that the effect of trade on income is not driven by the effect of natural disasters on a country's GDP per capita but rather by the bilateral components of the gravity. Further, it is difficult to think of ways through which the interaction of disasters with financial remoteness, and other geographic parameters may affect income, other than trade.

- defined as imports plus exports divided by GDP

$$\omega_t^{ij} = exp[\beta_0 + \beta_1 \ln P_t^i + \beta_2 \ln P_t^j + \beta_3 \Omega_t^i + \beta_4 \Omega_t^j + \beta_5 \Gamma_t^i + \beta_6 \Gamma_t^j] \nu_i \nu_j \nu_t \varepsilon_t^{ij} \quad (4)$$

where $\omega_t$ relates to bilateral trade openness, while the corresponding log of population is used as a measure of the economies sizes. $\Gamma_t^i$ and $\Gamma_t^j$ denote interaction terms between the disaster frequency variables, $\Omega_t^i$ and $\Omega_t^j$, and geographic parameters - such as common borders, the distance to the nearest financial center, land area or total population - as those might affect the impact of disasters on bilateral trade patterns. $\nu_i$ and $\nu_j$ control for importer- and exporter-specific characteristics, while $\nu_t$ reflects time-fixed effects. $\varepsilon_t^{ij}$ captures a robust error term clustered at the dyadic level in accordance to Stock and Watson (2008).

**Implications for Aggregate of Trade.** The instrument generated from the bilateral trade equation will be time-varying, as the coefficients collected in the regression sufficiently change over time. An economy's size, geographic components, and its ability to smooth consumption after a shock account for the variation in trade openness on the bilateral basis. Predicting trade - for observations where all explanatory variables are available - and summing the estimated coefficients over all other trading partners $j$

$$\text{constructed trade share} = \hat{\omega}_t^i = \sum_j [\hat{\beta}_t{}' X_t^i] \quad (5)$$

where $\hat{\beta}_t{}'$ denotes the vector of the estimates' fitted values in equation (4), gives us the overall trade potential of country $i$ due to exogenous parameters only.

## 3.2. Construction of the instrument

We now apply the methodology described above regarding the bilateral trade specification. We follow to a great extend F&R. Our strategy, however, reaches beyond their setup as we redefine their approach to apply it to a panel framework by introducing natural disasters and a set of interaction terms as exogenous time-varying components of trade. This approach may be subject to omitted variable bias, since we are in a panel setup. To mediate this problem, we exploit the sample's panel structure by utilizing importer-, exporter-, and time-fixed effects. Thus, we control for business cycles and country specifics. Beyond that, keep in mind that a valid instrument does *not* require the estimates corresponding to $X_t^i$ to be *consistent* estimates of a gravity model. The predicted openness parameters $\hat{\omega}_t^i$ are by construction orthogonal to $y_t^i$, thus constitute a valid instrument.

As mentioned above, the standard procedure would be to take the log of $\omega_t^{ij}$ in equation(4) and estimate the vector $\beta_t$ using OLS, yet, loosing a lot of information by dropping all zeros from the trade matrix. As data quality in explanatory variables is decisive for countries experiencing change, omitting information is generally expected to bias the estimates concerned toward zero in absolute terms. If the process toward a shift in a variable of interest is long-lasting, estimated parameters are in the long-run poorly quantified. Since $\omega_t^{ij} = 0$ for about 26% of our observations, we tackle this matter by following SS&T (2006) and construct the instrument using a PPML approach. As a matter of fact, the PPML approach leads to a stronger prediction as we include the information contained in zero trade flows and need not resort to out-of-sample preconditions to construct the instrument (Noguer and Siscart, 2005).[17]

**Results of IV Construction.** Table (2) column (1) to (3) motivate that disasters also affect bilateral trade openness significantly, while column (4) depicts the preferred specification for predicting the instrument under the disaster decision rule. Gravity coefficients are in line with the extensive literature. With increasing bilateral distance trade openness contracts, while a common border, or a similar cultural background lead to an increase in bilateral trade openness holding everything else constant. Beyond that, we find that an economy's bilateral trade share significantly augments if the nation is hit by a natural disaster, ceteris paribus, while it decreases in column (3) if more interaction terms with the multilateral resistance of distance are included. If a calamity strikes a partner country $j$ the bilateral openness of $i$ decreases significantly, presumably due to a higher loss in imports from $j$ than the increase in exports to $j$. However, in column (1) and (2) the direct bilateral openness share effect increases due to a disaster in the partner country. This is not implausible as imports might as well contract more than exports increase due to the shock in the partner economy. The effect of natural catastrophes on the access to international markets is quite stable in magnitude and over specifications. Hence, as disasters significantly affect bilateral openness it is perspicuous to deploy them in estimating an instrument for trade.

In the preferred specification in column (4), geographic and historic components enter either due to their bilateral composition (distance, common border, and cultural ties) or through interaction with the disaster frequency parameter (area, financial remoteness, population, and adjacency). Beyond this, interaction results enter with the expected signs in column (4). For instance, if countries are less integrated into financial markets they cannot easily smooth consumption in case of a disaster and thus mitigate the positive (negative) bilateral trade effect of a disaster in country $i$ ($j$).

PPML estimates contain significant explanatory power with over 800,000 observations from 1950-2008 when predicting the instrument from our preferred specification in column (4). The occurrence of a catastrophe directly enhances bilateral integration according to the PPML regression in table (2) column (4). The null that $H_0 : \beta_3 = 0$, or $H_0 : \beta_4 = 0$, or $H_0 : \beta_3 = \beta_4 = 0$ can be rejected on basis of the F-Test. Further, we can also rejected the hypothesis that $H_0 : \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$. Hence, we conclude that our disaster frequency variables and the interaction terms do comprise substantial predictive power.

The next step is to aggregate predicted trade potentials from the bilateral regression across all trading partners, as explained in equation (5) and examine whether bilateral components, natural disaster occurrence, and the interactions contain sufficient information on overall trade.[18]

[17] A linear OLS gravity model produces a weak instrument and thus biases IV estimation results, while constructing an instrument using PPML works rather well, as can be seen in section 4..

[18] All further specification results needed for the robustness checks can be found in table (7) in the Appendix. The

Table 2: Preferred Specification for the Instrument, 1950-2008

| Dependent Variable: | bilateral trade openness | | | |
|---|---|---|---|---|
| | yearly disasters | | | |
| | FE PPML | FE PPML | FE PPML | PPML |
| | (1) | (2) | (3) | (4) |
| # large-scale disasters,i | 0.019 | 0.271*** | -0.517*** | 0.328*** |
| | (0.01) | (0.05) | (0.20) | (0.10) |
| # large-scale disasters,j | 0.082*** | -0.015 | 0.459** | -0.911*** |
| | (0.01) | (0.03) | (0.23) | (0.19) |
| disaster x financial (ln),i | | -0.035*** | 0.086*** | -0.032*** |
| | | (0.01) | (0.03) | (0.01) |
| disaster x financial (ln),j | | 0.015*** | 0.063** | 0.020*** |
| | | (0.01) | (0.04) | (0.00) |
| disaster x MultRes,i | | | 0.090*** | |
| | | | (0.02) | |
| disaster x MultRes,j | | | -0.061** | |
| | | | (0.03) | |
| dis. x fin (ln)x MultRes,i | | | -0.014*** | |
| | | | (0.00) | |
| dis. x fin (ln)x MultRes,j | | | -0.003 | |
| | | | (0.00) | |
| disaster x area (ln),i | | | | -0.021*** |
| | | | | (0.01) |
| disaster x area (ln),j | | | | -0.003 |
| | | | | (0.01) |
| disaster x pop (ln),i | | | | 0.011* |
| | | | | (0.01) |
| disaster x pop (ln),j | | | | 0.045*** |
| | | | | (0.01) |
| disaster x border (ln),i | | | | 0.116*** |
| | | | | (0.04) |
| disaster x border (ln),j | | | | -0.001 |
| | | | | (0.02) |
| distance (ln) | | | | -0.954*** |
| | | | | (0.04) |
| contiguity | | | | 0.219** |
| | | | | (0.10) |
| colonial relation | | | | 0.564*** |
| | | | | (0.16) |
| common colonizer | | | | 0.712*** |
| | | | | (0.18) |
| col. rel. post 1945 | | | | 1.228*** |
| | | | | (0.21) |
| were/are same country | | | | 0.499*** |
| | | | | (0.13) |
| population (ln), i | -0.179*** | -0.178*** | -0.177*** | -0.174*** |
| | (0.04) | (0.04) | (0.04) | (0.04) |
| population (ln),j | 0.495*** | 0.485*** | 0.496*** | 0.150*** |
| | (0.15) | (0.15) | (0.16) | (0.04) |
| MR: distance (ln) | -0.224** | -0.199* | -0.187 | |
| | (0.11) | (0.11) | (0.11) | |
| MR: contiguity | 1.556** | 1.612** | 1.579** | |
| | (0.73) | (0.74) | (0.72) | |
| Fixed Effects | | | | |
| Pair | YES | YES | YES | - |
| Importer | - | - | - | YES |
| Exporter | - | - | - | YES |
| Year | YES | YES | YES | YES |
| Loglikelihood | -1.12e+04 | -1.12e+04 | -1.12e+04 | -1.70e+04 |
| Chi2 | 1494.111 | 1612.269 | 1783.573 | 36095.94 |
| Observations | 787324 | 787324 | 787324 | 833529 |

Note: Constant, pair-, importer-, exporter-, and time-fixed effects are not reported. Country-pair clustered robust standard errors are reported in parenthesis. Multilateral resistance terms à la Baier and Bergstrand (2009). * p<0.05, ** p<0.01, *** p<0.001

### 3.3. Quality of the instrument

In the above section we have seen that disasters exert a considerable effect on countries' trade patterns. As we are interested in the effect of openness $\omega_t^i$ on domestic income growth $y_t^i$, we can now use the aggregated predicted trade share $\hat{\omega}_t^i$ as an instrument for actual trade $\omega_t^i$. For constructed openness to be a qualitatively good and valid instrument, $\omega_t^i$ and $\hat{\omega}_t^i$ need to be positively and strongly correlated. The correlation between the level of the predicted and the actual trade share - the latter of which we obtain from the PWT 7.0 - amounts to 79%. The change in predicted and actual openness is depicted in Figure (1).

Figure 1: Actual versus Constructed Trade Share

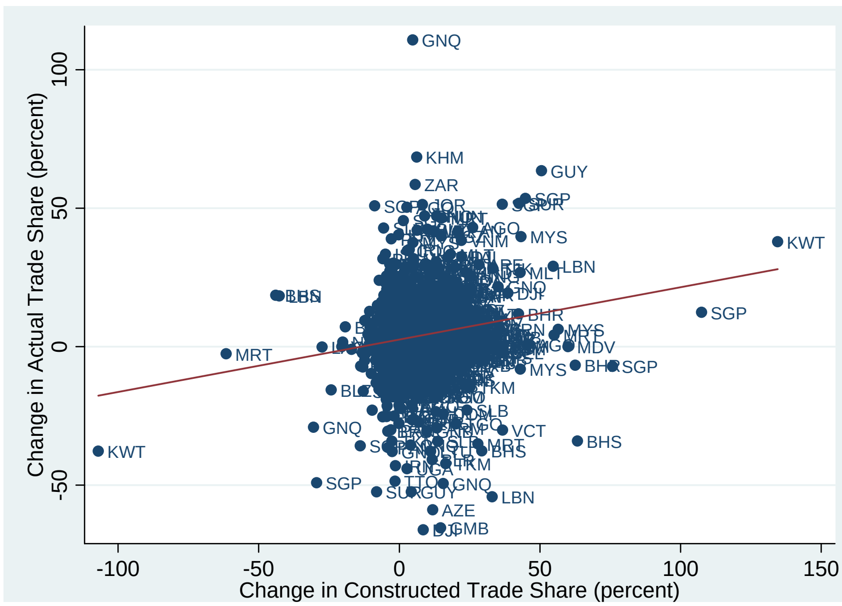


Table (3) assess the quality of the instrument in more detail. Estimations are undertaken for 5-year averages in a within transformation, including time-fixed effects and robust clustered residuals. The estimation of actual openness on predicted trade liberalization, constructed under PPML, yields strong and highly significant coefficients on $\hat{\omega}_t^i$. We focus on three different samples: (i) a sample that excludes countries for which oil production is the dominant industry suggested by Mankiew et al. (1992), (ii) the intermediate sample of Mankiew et al. (1992), where countries are identified whose income data are likely to be subject to measurement error, and (iii) the full sample for which data is available.

As the constructed trade share is in fact highly correlated with the size of an economy and natural disasters, we need to examine whether the aggregated instrument provides information beyond that contained by these parameters. Column (2), (5), and (8) show estimations controlling for the log of population, the frequency of natural disasters, and the lag thereof on observed

definitions employed range from large-scale to all natural disasters, from the 5-year cumulative of calamities to only non-human induced exogenous catastrophes, as defined in the data section.

Table 3: Quality of the Instrument (1950-2008), 5-year averages

| Dependent variable: | Actual trade share | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Non-oil Sample | | | Intermediate Sample | | | Full Sample | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| constructed trade share | 0.500*** | | 0.628*** | 0.493*** | | 0.654*** | 0.306*** | | 0.368*** |
| | (0.07) | | (0.11) | (0.07) | | (0.11) | (0.09) | | (0.12) |
| population (ln) | | -0.052 | -0.018 | | -0.030 | -0.008 | | -0.068 | -0.040 |
| | | (0.07) | (0.07) | | (0.08) | (0.07) | | (0.07) | (0.07) |
| # of disasters | | 0.005 | 0.001 | | 0.005 | 0.002 | | 0.005 | 0.001 |
| | | (0.02) | (0.01) | | (0.02) | (0.01) | | (0.01) | (0.01) |
| # of disasters, t-1 | | 0.028 | 0.035* | | 0.022 | 0.027 | | 0.032** | 0.034** |
| | | (0.02) | (0.02) | | (0.02) | (0.02) | | (0.01) | (0.01) |
| Fixed Effects | | | | | | | | | |
| Country | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| $R^2$ (within) | 0.465 | 0.403 | 0.497 | 0.510 | 0.447 | 0.554 | 0.306 | 0.292 | 0.328 |
| $R^2$ (between) | 0.833 | 0.210 | 0.855 | 0.845 | 0.202 | 0.861 | 0.722 | 0.410 | 0.705 |
| $R^2$ (overall) | 0.637 | 0.201 | 0.732 | 0.644 | 0.153 | 0.743 | 0.527 | 0.344 | 0.624 |
| F-Test | 26.52 | 17.80 | 29.24 | 25.79 | 16.35 | 28.95 | 14.53 | 13.89 | 15.23 |
| Observations | 1007 | 919 | 919 | 804 | 736 | 736 | 1448 | 1311 | 1311 |

Note: * p<0.1, ** p<0.05, *** p<0.01; Constant, within- and time-fixed effects are not reported. Country clustered robust standard errors in parenthesis. Column (1) to (3), non-oil sample of Mankiew et al. (1992) ,column (4) to (6) Intermediate Mankiew et al. (1992), and the full sample in column (7) to (9).

aggregated trade patterns, additionally including the constructed instrument in column (3), (6), and (9). The estimates on the constructed trade share remain significant and increase slightly in magnitude due to the inclusion of the lag of disasters, and thus the omission of one period.[19] As expected, this gives us some evidence that natural calamities might positively affect aggregated trade openness, yet coefficients are for the most part insignificant. The coefficient on population is insignificant in all settings. Beyond that the within explanatory power of the estimation remains quite strong and stable within the setups. From this we can conclude that the information contained in the aggregated instrument on actual trade reaches beyond that contained in natural disasters and total population, hence, constitutes particular information from the bilateral setting.

Most importantly, in the LIML approach we need to be able to exclude $\hat{\omega}_t^i$ from the second-stage regression. Even though the exclusion restriction cannot be tested for directly, it is fairly convincing that predicted trade cannot be caused by real income per capita as the instrument is constructed in the bilateral setting from exogenous components only. Population, natural disasters, bilateral components and the interactions thereof account for a major part in the variation of the overall trade share. Hence, the predicted trade openness can be considered exogenous. Still, we have to be careful. As calamities and population growth might plausibly cause economic outcomes, it is straight forward to directly control for them in the second-stage IV regression. By this we mitigate a potential omitted variables bias and avoid a violation of the exclusion restriction.

# 4. Results

## 4.1. Main results

**Specification and Sample**. To rule out endogeneity when evaluating the impact of trade on income over time, we can now utilize the instrument constructed in section 3.2. to assess the causal relation between trade liberalization and per capita income in a setting with 162 nations for 1950 to 2008. As we can draw on meaningful time-variance, we deploy panel methods to clarify the trade-income nexus. In all cases we conduct regressions on the basis of 5-year averages as means to compensate for output gaps or cyclic patterns. The basic estimation setup consists of the log of GDP per capita as the dependent parameter at time $t$ in country $i$, while the right-hand side variables are specified as before.

$$\ln y_t^i = \alpha + \beta\omega_t^i + \delta\Omega_t^i + \gamma \ln P_t^i + \nu_i + \nu_t + \varepsilon_t^i$$

Additional independent determinants of domestic income are not expected to be correlated with the predicted trade share. The disaster frequency parameter and its lag, as well as total population are included in the setup to determine their direct effect on the growth process. All

[19]Estimates on the trade share remain similar in magnitude throughout the settings when not including the lagged disaster parameter and thus not omitting one period.

regressions are estimated using country-fixed effects to control for any time-invariant country-specific characteristics that might affect a country's income. Additionally, we include time-fixed effects and allow for a robust clustered error term. Data on real per capita income stem from the PWT 7.0. We focus on three samples: a non-oil producing country sample suggested by Mankiew et al. (1992), a sample that excludes countries with a potential large measurement error in the data by Mankiew et al. (1992), and the full sample of 162 countries for which data is available. In the following we are able to support the proposition that the constructed instrument from PPML proves to be valid and feasible in the panel setup.

**Basic Results**. Table (4), column (1), (4), and (7) report coefficients from the OLS within transformation regression of the actual trade share on real GDP per capita for 1950 to 2008 for the various samples. The magnitude of estimates is comparable to earlier cross-sectional findings by F&R (1999), Irwin and Terviö (2002), as well as Noguer and Siscart (2005). An increase in the trade share of 1 %-point points toward a surge in income by 0.5% in column (1), holding everything else constant. Total population has a significant impact on domestic income as well, while natural disasters have a significant impact only in the full sample. Nevertheless, due to the endogeneity problem the approach might be significantly biased.

In column (2)-(3), (5) to (6), and (8)-(9) we account for the endogeneity problem and deploy the constructed trade share as an instrument for observed openness. The coefficient of trade on income increases sharply when IV methods are applied. Yet, this result is in also line with previous research. According to the Non-oil producing and the intermediate sample, an increase in trade openness of 1%-point causes income to increase by 1.2 percent (1% significance level), ceteris paribus, in the full sample in column (9) by 1.5 percent. A 1% increase in population contracts real GDP per capita by about 0.6 percent (1% significance), while the occurence of a further large-scale natural disaster has no effect in the non-oil and the intermediate sample, but augments income by an additional 0.07 percent (1% significance) in the full sample.[20] The latter finding is in line with empirical observations made by Skidmore and Toya (2002, 2007), who found that geological disasters, such as earthquakes and volcanic erruptions, stir economic activity in affected nation states in contrast to less disaster-prone countries. Cuaresma (2008) also supports this view. He found that infrastructure will be reconstructed and expanded, particularly in transformation economies, after a calamity has struck a nation. Further, Noy (2009) explains that external aid money and materials tend to flow into disaster struck developing economis.[21]

Above all, our instrument is reasonable on basis of the partial explanation power of 16% for the non-oil, 19 percent for the intermediate, and 5% for the full sample, as well as the F-Test on the excluded instrument, which is larger than the Stock-Yogo 15% value for the weak identification, based on LIML size. Stock and Yoko (2005) point out that the rule of thumb of

[20]Note that the positive impact of disasters on growth is not in line with the prediction of intertemporal trade models. However, Keynesian growth models would predict that disasters tackle investment demand, which in the end increases real GDP per capita.

[21]Noy (2009) also points out that private money is leaving the country after a catastrophe at the same time that aid money and materials are entering.

Table 4: Trade Openness and Real GDP per Capita (1950-2008), 5-year averages

Dependent Variable: ln real GDP per capita
Dependent Variable (First-stage): Actual Trade Share
Instrument: Predicted Trade Share

| | Non-oil Sample | | | Intermediate Sample | | | Full Sample | | |
|---|---|---|---|---|---|---|---|---|---|
| | FE | FE LIML | | FE | FE LIML | | FE | FE LIML | |
| | | First-Stage | Second-Stage | | First-Stage | Second-Stage | | First-Stage | Second-Stage |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| actual trade share | 0.545*** | | 1.177*** | 0.622*** | | 1.152*** | 0.399*** | | 1.543*** |
| | (0.12) | | (0.22) | (0.13) | | (0.21) | (0.09) | | (0.37) |
| population (ln) | -0.705*** | -0.018 | -0.672*** | -0.629*** | -0.008 | -0.614*** | -0.595*** | -0.040 | -0.518*** |
| | (0.10) | (0.07) | (0.11) | (0.10) | (0.07) | (0.11) | (0.10) | (0.07) | (0.12) |
| # of large-scale disasters | 0.033 | 0.001 | 0.031 | 0.024 | 0.002 | 0.022 | 0.075*** | 0.001 | 0.069*** |
| | (0.03) | (0.01) | (0.03) | (0.03) | (0.01) | (0.03) | (0.02) | (0.01) | (0.03) |
| # of large-scale disasters, t-1 | -0.011 | 0.035* | -0.028 | -0.021 | 0.027 | -0.033 | 0.029 | 0.034** | -0.007 |
| | (0.03) | (0.02) | (0.04) | (0.03) | (0.02) | (0.04) | (0.02) | (0.01) | (0.03) |
| constructed trade share | | 0.628*** | | | 0.654*** | | | 0.368*** | |
| | | (0.11) | | | (0.11) | | | (0.12) | |
| Fixed Effects | | | | | | | | | |
| Country | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| $R^2$ | 0.944 | 0.497 | 0.935 | 0.956 | 0.554 | 0.951 | 0.924 | 0.328 | 0.880 |
| F-Test | 207.41 | 29.27 | 193.25 | 205.35 | 28.99 | 182.38 | 256.66 | 15.24 | 184.17 |
| Observations | 919 | 919 | 919 | 736 | 736 | 736 | 1311 | 1311 | 1311 |
| Countries | 94 | 94 | 94 | 72 | 72 | 72 | 162 | 162 | 162 |
| Partial $R^2$ | | | 0.16 | | | 0.19 | | | 0.05 |
| F-Test on excl. Instrument | | | 31.93 | | | 32.88 | | | 9.22 |
| Stock-Yogo weak ID test | | | 8.96 | | | 8.96 | | | 8.96 |
| Under ID Test | | | 3.99 | | | 3.31 | | | 3.63 |
| Under ID p-Value | | | 0.05 | | | 0.07 | | | 0.06 |

Note: * p<0.1, ** p<0.05, *** p<0.01; Constant, country- and time-fixed effects are not reported. Country clustered robust standard errors in parenthesis. Column (1) to (3), non-oil sample of Mankiew et al. (1992) ,column (4) to (6) Intermediate Mankiew et al. (1992), and the full sample in column (7) to (9). Stock-Yoko (2005) critical values of 15% for the weak instrument test (5-percent significance) based on LIML size reported. Stock and Yogo (2005) criticize that the rule of thumb of Staiger and Stock (1997) of an F-value>10 is too narrow if LIML is used and provide critical values for the weak instrument test. As the F-Test on the exlcuded instrument is equal or larger than the critical value, the weak instruments hypothesis is rejected with the second stringent criterion. Hence, we can conclude that the instrument is not weak.

Staiger and Stock (1997) of an F-value larger that 10 is too narrow if LIML is used. They provide critical values for the weak instrument test. The instrument works particularly well for the sample where oil productin states are excluded, and for the intermediate sample specified by Mankiew et al. (1992), where the excluded F-Test strongly exceeds even the Stock-Yogo 10% weak instrument value. On this basis, the weak instruments hypothesis is rejected with the second stringent criterion of Stock and Yogo (2005) for the full sample, and the stongest criterion for the other two samples. Hence, we can conclude that the suggested instrument is not weak. Note that the instrument is also feasable as its variation origniates from the bilateral trade relation. By including population and disasters directly in the IV estimation we can show that the validity of the instrument premises on its bilateral construction and holds information beyond that contained in country $i$'s disaster and population parameters.[22]

To sum up, trade integration causes an increase in GDP per capita by about 1.5% in the overall and by 1.2% for the non-oil and the intermediate sample. The conditional fixed-effects LIML estimates overstate FE coefficients by 2.2 for the sample excluding oil producers, by 1.8 for the intermediate sample, while those for the full sample are 3.8 times larger. F&R (1999) find the IV estimate to be 2.3 times bigger than the OLS estimate in 1985, while Irwin and Terviö (2002) find an averaged factor of 2.6 over their cross-sectional settings. We can thus conduct that our estimates are reasonable, as they are in line with previous findings.

## 4.2. Robustness checks

We perform four robustness tests focusing on a sample division suggested by Subramanian and Wei (2007) and the decision rule on disasters. First, we split the sample in industrialized and developing countries. Second, we use all natural disasters to construct the instrument and apply this on the endogenous trade income nexus. Third, we utilize only disasters considered free from any human influence. Fourth, we perform the same regressions using cumulated disasters to catch the effect that past and present disasters have an effect on trading patterns and thus might potentially alter our results.

We begin with the industrialized - developing specification. From column (1)-(2) of table (5), we perceive that openness does not significantly affect real GDP per capita in industrialized countries, as expected, even though the instrument remains technically valid. Looking at developing nations in column (3) to (4) we can conclude that an income growth effect is realized from trade openness, with a significant positive coefficient, a excluded F-Test very close to the Stock-Yogo 15% value, and partial explanation power of 5 percent.

In a second robustness test, we use all natural disasters that occurred between 1950 and 2008, to check whether our results are driven by our decision rule regarding large-scale catastrophes. We construct the instrument as before, now applying all natural calamities. Results on the gravity-type estimation from which the instrument is predicted can be found in table (7), Appendix. Table (5) column (5) and (6) report results on the income-trade regression. We find

[22] We also controlled for the interaction terms in the IV framework. Results are not reported as the coefficients on the interaction terms are insignificant and do not change the magnitude or significance of the trade coefficient at all.

Table 5: Robustness: Trade Openness and Real GDP per Capita (1950-2008), 5-year averages

Dependent Variable: ln real GDP per capita
Dependent Variable (First-stage): Actual Trade Share
Instrument: Predicted Trade Share

| | Industrialized Countries | | Developing Countries | | all disasters | | exog. large disasters | | exog. all disasters | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FE LIML | | FE LIML | | FE | FE LIML | FE | FE LIML | FE | FE LIML |
| | First-Stage | Second-Stage | First-Stage | Second-Stage | | Second-Stage | | Second-Stage | | Second-Stage |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| actual trade share | | -0.242 | | 1.715*** | 0.408*** | 1.511*** | 0.403*** | 1.517*** | 0.410*** | 1.530*** |
| | | (0.44) | | (0.45) | (0.09) | (0.32) | (0.09) | (0.38) | (0.09) | (0.34) |
| population (ln) | -0.214 | -0.320 | 0.015 | -0.562*** | -0.561*** | -0.497*** | -0.590*** | -0.517*** | -0.554*** | -0.492*** |
| | (0.22) | (0.39) | (0.10) | (0.19) | (0.09) | (0.12) | (0.10) | (0.12) | (0.09) | (0.12) |
| # of disasters | 0.007 | -0.057 | 0.003 | 0.062** | 0.013 | 0.003 | 0.097** | 0.078 | 0.023 | 0.011 |
| | (0.04) | (0.03) | (0.01) | (0.03) | (0.01) | (0.01) | (0.04) | (0.05) | (0.02) | (0.02) |
| # of disasters, t-1 | 0.047 | -0.130 | 0.034** | -0.004 | 0.019* | 0.020** | 0.040 | 0.002 | 0.025* | 0.023* |
| | (0.03) | (0.11) | (0.01) | (0.04) | (0.01) | (0.01) | (0.03) | (0.05) | (0.01) | (0.01) |
| constructed trade share | 0.873*** | | 0.358*** | | | | | | | |
| | (0.29) | | (0.13) | | | | | | | |
| Fixed Effects | | | | | | | | | | |
| Country | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| $R^2$ | 0.716 | 0.989 | 0.283 | 0.825 | 0.923 | 0.882 | 0.923 | 0.881 | 0.923 | 0.881 |
| F-Test | 26.94 | 1177.13 | 10.35 | 107.22 | 253.12 | 190.87 | 252.26 | 181.78 | 259.54 | 192.86 |
| Observations | 240 | 240 | 1071 | 1071 | 1311 | 1311 | 1311 | 1311 | 1311 | 1311 |
| Countries | 23 | 23 | 139 | 139 | 162 | 162 | 162 | 162 | 162 | 162 |
| Partial $R^2$ | | 0.19 | | 0.05 | | 0.06 | | 0.05 | | 0.06 |
| F-Test on excl.Instrument | | 8.89 | | 7.89 | | 13.14 | | 8.55 | | 11.53 |
| Stock-Yogo weak ID test | | 8.96 | | 8.96 | | 8.96 | | 8.96 | | 8.96 |
| Under ID Test | | 3.94 | | 3.08 | | 4.36 | | 3.56 | | 4.21 |
| Under ID p-Value | | 0.05 | | 0.08 | | 0.04 | | 0.06 | | 0.04 |

Note: * p<0.1, ** p<0.05, *** p<0.01; Constant, country- and time-fixed effects are not reported. Country clustered robust standard errors in parenthesis. Industrialized and Developing country classification according to Subramanian and Wei (2007). Stock-Yoko (2005) critical values of 15% for the weak instrument test (5-percent significance) based on LIML size reported. Stock and Yogo (2005) criticize that the rule of thumb of Staiger and Stock (1997) of an F-value>10 is too narrow if LIML is used and provide critical values for the weak instrument test. As the F-Test on the exlcuded instrument is equal or larger than the critical value, the weak instruments hypothesis is rejected with the second stringent criterion. Hence, we can conclude that the instrument is not weak.

the instrument to be valid and feasible due to increased excluded F-Tests and a similar partial $R^2$. Further, regression coefficients are essentially similar as to when applying the large-scale disaster decision rule.

Our third robustness test uses utterly non-human induced natural catastrophes following our reflections in section 2.1., last paragraph. Results are reported in table (5) column (7) to (8) for large-scale, and column (9) to (10) for all natural catastrophes. LIML results state an increase in per capita GDP by 1.5% due to a 1%-point increase in trade integration. Excluded F-Tests and partial $R^2$s again signal the validity of the instrument. Hence, results on excluding flooding, landslides, and wildfires are not materially different.

As a last robustness check we perform regressions using the above mentioned categorizations of natural disasters but now considering 5-year cumulated catastrophes to see whether the frequency of disasters, as well as past and present disasters cumulate to a different result. Regression coefficients are depicted in table(8), Appendix. We again find a positive effect on per capita GDP within a small range to the original findings. LIML estimates overstate FE coefficients by a threefold when using cumulated large-scale disasters. The F-Test on the excluded instrument compare to results in table (4) and (5).

Overall, results remain robust under several disaster specifications and the instrument constructed from PPML remains significantly valid and feasible in all setups. Industrialized countries seem not to experience any income growth from increased trade openness, while we find a significant effect for developing economies.

## 5. Conclusions

This paper constructs a valid instrument for trade openness in the panel framework and subsequently underpins an empirical fact: countries that are more integrated with respect to trade tend to have a higher income per capita in the long-run. This is in line with earlier cross-sectional findings by F&R (1999), Irwin and Terviö (2002), or Nagour and Siscart (2005). Ruling out endogeneity in the panel, we find substantial evidence of a beneficial effect of trade on GDP per capita in the 162 country sample for 1950-2008. This finding is robust to the categorization of natural disasters.

Our analysis redefines the F&R approach. We show that natural disaster substantially enhance trade integration. Thereupon, we construct an instrument for trade openness, including natural disasters and its interaction with country characteristics as a time-varying component of trade in a modified bilateral trade setting to be able to exploit the panel structure of our data. In all cases, we use yearly bilateral data including importer-, exporter-, and time-fixed effects in a PPML approach to predict the instrument. This setting considers zero trade flows and thus predicts trade as a proportion of a country's GDP more precisely. We consider the components of bilateral trade to be truly exogenous. In fact, as the occurrence of disasters is conditioned on the geographic location of a country, there is no likely channel through which these parameters impact income other than bilateral trade interaction. Thus, we find that the constructed trade share contains sufficient information about actual aggregated trade patterns to be able to rule out endogeneity in the trade-income nexus. We control for the direct effects of disasters and population on domestic income in the IV approach.

To assess the effect of openness on GDP per capita we use data that is averaged over 5 years including country- and time-fixed effects. We deal with the possible endogeneity of trade by using the geography-disaster based instrument developed in the third part of the paper. The results we get for the LIML model is stable and robust over all disaster specifications when using the PPML constructed instrument. Moreover, we have sufficient evidence to conclude that openness causally increases domestic income. This result is not changed due to the direct inclusion of population or natural catastrophes. Nicely, our instrument remains valid and feasible over all setups with a sufficiently high partial $R^2$ and a F-Test on the excluded instrument roughly above the 15% Stock-Yogo critical value for the full sample and exceeding the 10% value for the samples suggested by Mankiew et al. (1992). Frankly, we conclude that the constructed instrument varies significantly over time, thus works well in the panel framework, and can be applied to many other setups to understand the role of trade openness for macroeconomic outcomes.

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# A Appendix

Table 6: Summary Statistics and Data Sources

**Gravity Section**

| Variable | Observations | Mean | St. Dev. | Data Source |
|---|---|---|---|---|
| bilateral openness $(M_{ij}^t + M_{ji}^t / Y_i^t)$ | 833529 | 0.005 | 0.053 | DoTS (2009) |
| nominal import flows | 859319 | 177.407 | 2433.911 | DoTS (2009) |
| population (ln), i | 833529 | 15.515 | 2.318 | WDI (2009) & Barbieri (2002) |
| population (ln), j | 833529 | 15.427 | 2.457 | WDI (2009) & Barbieri (2002) |
| # of large-scale disasters, i | 833529 | 0.262 | 0.949 | EM-DAT (2010), decision rule |
| # of large-scale disasters, j | 833529 | 0.259 | 0.940 | EM-DAT (2010), decision rule |
| distance to financial center (ln), i | 833529 | 7.361 | 1.420 | Rose & Spiegel (2009), adaption |
| distance to financial center (ln), j | 833529 | 7.398 | 1.391 | Rose & Spiegel (2009), adaption |
| were or are the same country | 833529 | 0.011 | 0.105 | CEPII (2005) |
| colonial relation post 1945 | 833529 | 0.010 | 0.099 | CEPII (2005) |
| common colonizer | 833529 | 0.096 | 0.295 | CEPII (2005) |
| ever in colonial relation | 833529 | 0.017 | 0.129 | CEPII (2005) |
| contiguity | 833529 | 0.025 | 0.155 | CEPII (2005) |
| great circle distance (ln) | 833529 | 8.677 | 0.802 | CEPII (2005) |
| MR: distance (ln) | 859319 | 9.778 | 0.713 | CEPII (2005), own calculations á la Baier & Bergstrand (2009) |
| MR: contiguity | 859319 | -0.009 | 0.072 | CEPII (2005), own calculations á la Baier & Bergstrand (2009) |
| GDP,i*GDP,j (ln) | 859319 | 46.116 | 3.420 | WDI (2009) & Barbieri (2002) |

**Trade-Openness Section**

| Variable | Observations | Mean | St. Dev. | Data Source |
|---|---|---|---|---|
| trade openness share | 1448 | 0.702 | 0.450 | PWT 7.0 |
| population (ln) | 1448 | 8.828 | 1.764 | PWT 7.0 |
| real GDP per capita (ln) | 1448 | 7.586 | 1.544 | PWT 7.0 |
| # of large-scale disasters | 1448 | 0.234 | 0.769 | EM-DAT (2010), decision rule |
| # of all disasters | 1448 | 1.282 | 2.603 | EM-DAT (2010), decision rule |
| # of exogenous large-scale disasters | 1448 | 0.143 | 0.489 | EM-DAT (2010), decision rule |
| # of all exogenous disasters | 1448 | 0.763 | 1.6942 | EM-DAT (2010), decision rule |
| constructed trade share, PPML | 1448 | 0.543 | 0.349 | own calculations |
| constructed trade share, OLS | 1443 | 1.201 | 3.961 | own calculations |

Table 7: PPML Specification to Construct Instrument, 1950-2008, Robustness

Dependent Variable: bilateral trade openness

| | yearly disaster frequency | | | cumulated disaster frequency | | | |
|---|---|---|---|---|---|---|---|
| | exog. large disasters | all disasters | all exog. disasters | large-scale disasters | exog. large disasters | all disasters | all exog. disasters |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| # disasters,i | 0.292** | 0.084* | 0.031 | 0.342*** | 0.491*** | 0.017 | 0.011 |
| | (0.13) | (0.05) | (0.07) | (0.06) | (0.10) | (0.02) | (0.03) |
| # disasters,j | -0.836*** | -0.172*** | -0.160*** | -0.100 | 0.080 | -0.007 | 0.004 |
| | (0.12) | (0.03) | (0.05) | (0.07) | (0.11) | (0.01) | (0.02) |
| disaster x financial (ln),i | -0.022*** | -0.002 | 0.001 | -0.018*** | -0.012** | -0.001 | 0.000 |
| | (0.01) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) |
| disaster x financial (ln),j | 0.018*** | 0.007*** | 0.010*** | 0.006** | 0.008*** | 0.002*** | 0.002*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| disaster x area (ln),i | -0.023*** | -0.014*** | -0.013*** | -0.006 | -0.008* | -0.005*** | -0.006*** |
| | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| disaster x area (ln),j | -0.018 | -0.002 | 0.000 | -0.005 | -0.007 | 0.001* | 0.001 |
| | (0.01) | (0.00) | (0.01) | (0.01) | (0.01) | (0.00) | (0.00) |
| disaster x pop (ln),i | 0.012 | 0.007* | 0.008 | -0.006 | -0.012** | 0.003*** | 0.004* |
| | (0.01) | (0.00) | (0.01) | (0.00) | (0.01) | (0.00) | (0.00) |
| disaster x pop (ln),j | 0.054*** | 0.010*** | 0.007 | 0.008** | -0.002 | -0.001** | -0.001*** |
| | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| disaster x border,i | 0.181*** | 0.028* | 0.043* | 0.034*** | 0.048*** | 0.009** | 0.013** |
| | (0.05) | (0.02) | (0.02) | (0.01) | (0.01) | (0.00) | (0.01) |
| disaster x border,i | 0.005 | 0.009 | 0.011 | 0.001 | 0.008 | 0.003 | 0.004 |
| | (0.03) | (0.01) | (0.01) | (0.01) | (0.01) | (0.00) | (0.00) |
| population (ln),i | -0.173*** | -0.170*** | -0.169*** | -0.174*** | -0.174*** | -0.161*** | -0.163*** |
| | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) |
| population (ln),j | 0.157*** | 0.121*** | 0.143*** | 0.153*** | 0.166*** | 0.176*** | 0.179*** |
| | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.05) |
| distance (ln) | -0.954*** | -0.952*** | -0.953*** | -0.955*** | -0.955*** | -0.954*** | -0.953*** |
| | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) |
| contiguity | 0.218** | 0.176* | 0.188* | 0.212** | 0.209** | 0.157 | 0.174 |
| | (0.10) | (0.11) | (0.11) | (0.10) | (0.10) | (0.11) | (0.11) |
| ever in colonial rel | 0.562*** | 0.563*** | 0.563*** | 0.565*** | 0.562*** | 0.569*** | 0.567*** |
| | (0.17) | (0.17) | (0.16) | (0.16) | (0.17) | (0.17) | (0.17) |
| com col post 1945 | 0.710*** | 0.713*** | 0.711*** | 0.711*** | 0.718*** | 0.708*** | 0.709*** |
| | (0.18) | (0.18) | (0.18) | (0.18) | (0.18) | (0.18) | (0.18) |
| colonial rel post 1945 | 1.230*** | 1.224*** | 1.225*** | 1.229*** | 1.233*** | 1.217*** | 1.220*** |
| | (0.21) | (0.21) | (0.21) | (0.21) | (0.21) | (0.21) | (0.21) |
| same country | 0.498*** | 0.511*** | 0.508*** | 0.497*** | 0.491*** | 0.509*** | 0.508*** |
| | (0.13) | (0.13) | (0.13) | (0.13) | (0.13) | (0.13) | (0.13) |
| Fixed Effects | | | | | | | |
| Importer | YES | YES | YES | YES | YES | YES | YES |
| Exporter | YES | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES | YES |
| Log likelihood | -1.71e+04 | -1.70e+04 | -1.70e+04 | -1.71e+04 | -1.71e+04 | -1.71e+04 | -1.71e+04 |
| Chi2 | 35863.29 | 37539.83 | 37780.33 | 35736.97 | 35857.98 | 36409.94 | 36414.73 |
| Observations | 833529 | 833529 | 833529 | 833529 | 833529 | 833529 | 833529 |

Note: Constant, importer-, exporter-, and time-fixed effects are not reported. Trading pair clustered robust standard errors in parenthesis. * p<0.05, ** p<0.01, *** p<0.001

Table 8: Robustness: Trade Openness and Real GDP per Capita (1950-2008), 5-year averages

Dependent Variable: ln real GDP per capita
Dependent Variable (First-stage): Actual Trade Share
Instrument: Predicted Trade Share

| | large disasters | | all disasters | | exogenous large disasters | | all exogenous disasters | |
|---|---|---|---|---|---|---|---|---|
| | FE | FE LIML Second-Stage | FE | FE LIML Second-Stage | FE | FE LIML Second-Stage | FE | FE LIML Second-Stage |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| actual trade share | 0.397*** | 1.220*** | 0.407*** | 1.560*** | 0.401*** | 1.077*** | 0.409*** | 1.579*** |
| | (0.09) | (0.34) | (0.09) | (0.36) | (0.09) | (0.34) | (0.09) | (0.38) |
| population (ln) | -0.597*** | -0.541*** | -0.560*** | -0.493*** | -0.591*** | -0.546*** | -0.554*** | -0.488*** |
| | (0.10) | (0.11) | (0.09) | (0.12) | (0.10) | (0.10) | (0.09) | (0.12) |
| # cumulated disasters | 0.016*** | 0.015*** | 0.003 | 0.001 | 0.019** | 0.017** | 0.005 | 0.002 |
| | (0.01) | (0.01) | (0.00) | (0.00) | (0.01) | (0.01) | (0.00) | (0.00) |
| # cumulated disasters , t-1 | 0.007* | 0.002 | 0.004* | 0.004** | (0.01) | (0.01) | 0.005* | 0.005* |
| | (0.00) | (0.01) | (0.00) | (0.00) | (0.01) | (0.01) | (0.00) | (0.00) |
| Fixed Effects | | | | | | | | |
| Country | YES | YES | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES | YES | YES |
| $R^2$ | 0.924 | 0.901 | 0.923 | 0.879 | 0.923 | 0.908 | 0.923 | 0.877 |
| F-Test | 255.56 | 211.11 | 254.18 | 185.38 | 249.24 | 214.40 | 264.16 | 186.06 |
| Observations | 1311 | 1311 | 1311 | 1311 | 1311 | 1311 | 1311 | 1311 |
| Countries | 162 | 162 | 162 | 162 | 162 | 162 | 162 | 162 |
| Partial $R^2$ | | 0.05 | | 0.06 | | 0.05 | | 0.05 |
| F-Test on excl. Instrument | | 10.14 | | 10.38 | | 9.75 | | 9.53 |
| Stock-Yogo weak ID test | | 8.96 | | 8.96 | | 8.96 | | 8.96 |
| Under ID Test | | 4.20 | | 4.21 | | 4.22 | | 4.03 |
| Under ID p-Value | | 0.04 | | 0.04 | | 0.04 | | 0.04 |

Note: * p<0.1, ** p<0.05, *** p<0.01; Constant, country- and time-fixed effects are not reported. Country clustered robust standard errors in parenthesis. Stock-Yoko (2005) critical values of 15% for the weak instrument test (5-percent significance) based on LIML size reported. Stock and Yogo (2005) criticize that the rule of thumb of Staiger and Stock (1997) of an F-value>10 is too narrow if LIML is used and provide critical values for the weak instrument test. As the F-Test on the exlcuded instrument is equal or larger than the critical value, the weak instruments hypothesis is rejected with the second stringent criterion. Hence, we can conclude that the instrument is not weak.

Table 9: Beta Coefficients

Dependent Variable: ln real GDP per capita

Dependent Variable (First-stage): Actual Trade Share

Instrument: Predicted Trade Share

| | large-scale disasters | | |
|---|---|---|---|
| | | First-Stage | Second-Stage |
| Standardized value: | FE | FE LIML | |
| | (1) | (2) | (3) |
| actual trade share | 0.116*** | | 0.450*** |
| | (0.03) | | (0.11) |
| population (ln) | -0.684*** | -0.159 | -0.595*** |
| | (0.11) | (0.26) | (0.14) |
| # disasters | 0.036*** | 0.002 | 0.034*** |
| | (0.01) | (0.01) | (0.01) |
| # disasters, t-1 | 0.014 | 0.057** | -0.004 |
| | (0.01) | (0.02) | (0.02) |
| constructed trade share | | 0.283*** | |
| | | (0.09) | |
| Fixed Effects | | | |
| Country | YES | YES | YES |
| Year | YES | YES | YES |
| $R^2$ (within) | 0.924 | | |
| $R^2$ (between) | 0.047 | | |
| $R^2$ (overall) | 0.157 | | |
| F-Test | 256.66 | 15.24 | 184.17 |
| Observations | 1311 | 1311 | 1311 |

Note: Constant, country-, and time-fixed effects are not reported. Robust clustered standard errors in parenthesis. * p<0.05, ** p<0.01, *** p<0.001

## Table 10: OLS Specification and Growth-Income Regression, 1950-2008

| Dependent Variable: bilateral trade openness | | Dependent Variable: ln real GDP per capita<br>Dependent Variable (First-stage): Actual Trade Share<br>Instrument: Predicted Trade Share | | | |
|---|---|---|---|---|---|
| | OLS | | FE | FE LIML<br>First-Stage | Second-Stage |
| | (1) | | (2) | (3) | (4) |
| # of disasters,i | -0.275*** | actual trade share | 0.401*** | | 0.282 |
| | (0.06) | | (0.09) | | (0.80) |
| # of disasters,i | -0.882*** | population (ln) | -0.618*** | -0.059 | -0.626*** |
| | (0.06) | | (0.10) | (0.07) | (0.10) |
| disaster x financial (ln),i | -0.002 | # of disasters | 0.075*** | 0.005 | 0.076*** |
| | (0.00) | | (0.02) | (0.01) | (0.02) |
| disaster x financial (ln),j | -0.003 | # of disasters, t-1 | 0.029 | 0.030** | 0.030 |
| | (0.00) | | (0.02) | (0.01) | (0.03) |
| disaster x area (ln),i | -0.024*** | constructed trade share | | 0.017** | |
| | (0.01) | | | (0.01) | |
| disaster x area (ln),j | -0.025*** | | | | |
| | (0.01) | | | | |
| disaster x pop (ln),i | 0.037*** | | | | |
| | (0.00) | | | | |
| disaster x pop (ln),j | 0.070*** | | | | |
| | (0.00) | | | | |
| disaster x border,i | -0.034 | | | | |
| | (0.03) | | | | |
| disaster x border,j | -0.036 | | | | |
| | (0.03) | | | | |
| poopulation (ln), i | -0.187*** | | | | |
| | (0.03) | | | | |
| population (ln), j | -0.288*** | | | | |
| | (0.02) | | | | |
| distance (ln) | -1.408*** | | | | |
| | (0.02) | | | | |
| contiguity | 0.358*** | | | | |
| | (0.09) | | | | |
| ever in colonial rel | 0.701*** | | | | |
| | (0.11) | | | | |
| com col post 1945 | 1.021*** | | | | |
| | (0.04) | | | | |
| colonial rel post 1945 | 1.575*** | | | | |
| | (0.16) | | | | |
| same country | 0.997*** | | | | |
| | (0.13) | | | | |
| Fixed Effects | | Fixed Effects | | | |
| Importer | YES | Country | YES | YES | YES |
| Exporter | YES | | | | |
| Year | YES | Year | YES | YES | YES |
| Log likelihood | -1.71e+04 | $R^2$ | 0.924 | 0.294 | 0.923 |
| Chi2 | 35709.91 | F-Test | 249.49 | 13.62 | 281.98 |
| Observations | 833547 | Observations | 1285 | 1282 | 1282 |
| | | Countries | 162 | 162 | 162 |
| | | Partial $R^2$ | | | 0.01 |
| | | F-Testonexcl.Instrument | | | 4.56 |
| | | Stock-Yogo weak ID test | | | 8.96 |
| | | Under ID Test | | | 7.43 |
| | | Under ID p-Value | | | 0.01 |

Note: Constant, importer-, exporter-, and time-fixed effects are not reported. Trading pair clustered robust standard errors in parenthesis. * p<0.05, ** p<0.01, *** p<0.001