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Abstract

We examine how trade openness influences income inequality within countries. The sample includes 139 countries over the period 1970–2014. We employ predicted openness as instrument to deal with the endogeneity of trade openness. The effect of trade openness on income inequality differs across countries. Trade openness tends to disproportionately benefit the relative income shares of the very poor, but not necessarily all poor, in emerging and developing economies. In most advanced economies, trade openness increased income inequality, an effect that is driven by outliers. Our results suggest a strong effect of trade openness on inequality in China and transition countries.

JEL Code: C26, D31, D63, F02, F60, H11, H20
Keywords: Trade openness, globalization, income inequality, instrumental variable estimation, panel econometrics, development levels, transition economies

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1 Introduction

How trade openness relates to income inequality has been examined in many empirical studies since the mid-1990s (e.g., Wood, 1995; Cragg and Epelbaum, 1996; Feenstra and Hanson, 1996; Borjas et al., 1997; Leamer, 1998; Meschi and Vivarelli, 2009; Jaumotte et al., 2013; Roser and Cuaresma, 2016). The empirical evidence is mixed. These studies use macrodata at the country level and hardly report causal effects. We therefore investigate how trade openness influences income inequality by employing a new identification strategy and considering heterogeneity across countries. The sample includes up to 139 countries over the period 1970-2014.

We use an instrumental variable (IV) approach to identify the causal effect of trade openness on inequality. Our IV is predicted openness based on a gravity equation using a time-varying interaction of geography and exogenous large-scale natural disasters as proposed by Felbermayr and Gröschl (2013). The results do not suggest that trade openness influences income inequality in the full country sample. There is a good reason why: The Stolper-Samuelson theorem (Stolper and Samuelson, 1941) predicts that trade openness decreases inequality in developing countries and increases inequality in developed countries.

We examine whether the effect of trade openness on income inequality differs across developing and developed countries. In emerging and developing countries, our results suggest that trade openness disproportionately benefits the very poor (not necessarily all poor), as predicted by the Stolper-Samuelson theorem. This finding is in line with previous studies indicating that globalization, and in particular trade liberalization, reduces inequality and poverty in developing countries (see Winters et al., 2004; Jaumotte et al., 2013; Bergh and Nilsson, 2014). In our sample of 34 advanced economies, upper deciles disproportionately gain from trade openness at the expense of the income shares of the bottom deciles of the income distribution. The relationship, however, is driven by outliers. Our results therefore do not confirm, as predicted by the Stolper-Samuelson theorem, that trade openness increases inequality in developed countries.

Our results, moreover, suggest a strong effect of trade openness on inequality within transition countries. These countries have experienced a particularly fast change towards trade openness accompanied by large-scale market-oriented reforms and an economic transition process in our period of observation. The market-oriented reforms likewise promoted integration in the global market and increased income inequality. The impact on income distribution during the transition period was hardly cushioned by either labor market institutions or welfare states, which characterize many advanced economies (see Milanovic, 1999; Myant and Drahokoupil, 2010; Perugini and Pompei, 2015b).

2 Theoretical predictions and empirical evidence

2.1 Theoretical predictions

The classical theoretical framework for examining the relationship between trade openness and distributional market outcomes is the Heckscher-Ohlin (HO) model (Ohlin, 1933). It explains the inequality effect of trade openness as a result of productivity differences and the relative factor endowment of countries, and the extent to which individuals depend on labor or capital income. Countries specialize in production within their relatively abundant factor and export these goods when they open up to trade. The Stolper-Samuelson theorem (Stolper and Samuelson, 1941) shows that the subsequent trade-induced relative changes in product prices increase the real return to the factors used intensively in the production of the factor-abundant export goods and decrease the returns to the other factors. As a consequence, the country's abundant production factors gain from openness, while scarce factors lose. Because capital and skilled labor are relatively abundant in advanced economies, income inequality and income concentration towards the top incomes is expected to increase. In developing countries, unskilled labor, which is intensively used in local production, would benefit from economic openness by increasing wages and income. In developing countries, income inequality is therefore expected to decrease. Based on the HO model assumptions, how trade openness influences income inequality depends on a country's development level. Following the Stolper-Samuelson theorem, trade openness is expected to decrease income inequality in developing countries and to increase income inequality in developed countries (with almost leveling effects in a full sample including both groups).

Since the 1990s, several studies have pointed to limitations of the standard HO model implications and provided mechanisms to explain why inequality patterns of country case studies do not necessarily follow the predictions of the Stolper-Samuelson theorem. For instance, offshoring and outsourcing of less-skilled production

decreases the wages and bargaining power of less-skilled workers in advanced economies, but offshored and outsourced activities might be relatively skill-intensive from the perspective of the workforce in developing countries (see Feenstra and Hanson, 1996, 1999). Along the same lines, scholars discuss how rising exposure of sectors to international trade competition (e.g., Cragg and Epelbaum, 1996; Munch and Skaksen, 2008; Egger and Kreickemeier, 2009; Sampson, 2014), import of capital goods (e.g., Feenstra and Hanson, 1997; Acemoglu, 2003), and trade-induced technological transfers and catch-up processes (e.g., Berman and Machin, 2000; Zhu and Trefler, 2005; Burstein et al., 2013; Bloom et al., 2016) may increase the skill intensity and relative demand for skilled labor in the developing world. In short, these mechanisms may explain why the skill premium of workers and thus income inequality may rise in countries of all income groups when they opening to international trade.

2.2 Empirical evidence

How trade openness relates to income inequality has been examined in many empirical studies in the 1990s (e.g., Wood, 1995; Cragg and Epelbaum, 1996; Feenstra and Hanson, 1996; Borjas et al., 1997; Leamer, 1998) and has been revisited since the early 2000s (e.g., Meschi and Vivarelli, 2009; Jaumotte et al., 2013; Roser and Cuaresma, 2016). The empirical evidence is mixed.[1]

Roser and Cuaresma (2016) use data for 32 developed countries and employ panel models over the period 1963-2002. They show that—in line with the Stolper-Samuelson theorem—trade openness is positively related to income inequality. Their findings suggest that imports from developing countries are positively correlated with income inequality in the developed world. This is a result that seems to be driven by the group of liberal market economies but lacks statistical significance for other developed countries. The results by Meschi and Vivarelli (2009) suggest, in contrast to the HO model predictions, that trade is positively associated with income inequality in a sample of 65 developing countries. Their results are based on panel models over a rather short period from 1980 to 1999. The positive relationship between trade and income inequality within developing (Meschi and Vivarelli, 2009) and within developed countries (Roser and Cuaresma, 2016) corroborates that international trade gives rise to income inequality. By contrast, Jaumotte et al. (2013) suggest that trade openness is associated with lower income inequality, a result that is based on a small sample of 31 developing and 20 developed countries over the period 1981 to 2003. Their study does not, however, decompose the relationship between trade and inequality within the subsamples of developing or developed countries. These empirical studies use macrodata at the country level and hardly report causal effects.

Other studies use microdata to identify how trade openness influences local incomes across regions and workers within individual countries. Empirical evidence on the effect with a focus on individual advanced economies is mixed (e.g., Autor et al., 2013; Dauth et al., 2014). Reviews based on country case studies in the developing world also conclude that the effect of trade on income inequality and poverty is context specific (e.g., Goldberg and Pavcnik, 2007; Pavcnik, 2017). Microdata-based case studies are useful to understand causal mechanisms but cannot predict external validity with respect to the overall effect of trade openness on income inequality.

Another strand of related studies examines the relationship of (economic) globalization and income inequality (or poverty) (e.g., Dreher and Gaston, 2008; Bergh and Nilsson, 2010; Dorn and Schinke, 2018; Dorn et al., 2018; Lang and Tavares, 2018; Sturm et al., 2019; Bergh et al., 2020).[2] Overall, these studies find a positive relationship between (economic) globalization and income inequality, although the results are mixed in advanced economies. The findings, moreover, suggest a poverty-reducing effect of (economic) globalization in developing countries (e.g., Bergh and Nilsson, 2010; Dorn et al., 2018; Lang and Tavares, 2018).[3] These studies, however, often do not decompose the effect of trade from financial indicators of economic globalization, and do not allow conclusions to be inferred on the predictions of the HO trade model.[4] We examine how trade openness influences inequality and provide new empirical evidence on the HO theory predictions.[5]

[1] Winters et al. (2004) review early empirical studies of the trade-inequality nexus and conclude that "there can be no simple general conclusion about the relationship between trade liberalization and poverty" (p.106).

[2] Some of these studies also use clever new identification strategies. For example, Lang and Tavares (2018) use instrumental variables based on the geographical distribution of globalization.

[3] Consequences of globalization are surveyed by Potrafke (2015).

[4] There is no encompassing theory describing how overall (economic) globalization influences income inequality. Scholars often use trade-based theories to describe how overall (economic) globalization influences income inequality.

[5] The same issue examined here was suggested, independently, by Siddique (2021).

3 Data

We use an unbalanced panel for up to 139 countries over the period 1970-2014. The data are averaged over five years in nine periods between 1970 and 2014. We follow related literature and use five-year averages to reduce the possibility of outliers, measurement errors, missing observations in individual years and short-term movements in the business cycle influencing the inferences (see Felbermayr and Gröschl, 2013).

3.1 Variables

Income inequality

We use the Gini household income inequality indices of Solt's (2016) Standardized World Income Inequality Database (SWIID, v5.1) as the primary measure of income inequality. SWIID provides standardized Gini income inequality measures for market and net outcomes based on the same concept, and thus allows the comparison of income inequality before and after redistribution by taxation and transfers over time. We use both the market and net income Gini indices.

The high coverage across countries and time and the adjustment procedure for achieving possible comparability is the major reason for preferring SWIID to other secondary source datasets (see Dorn, 2016, for a discussion). SWIID uses the Luxembourg Income Study (LIS) as a baseline. To predict missing observations in the LIS series, data from other secondary data sources and statistical offices are standardized to LIS by using systematic relationships of different Gini types and model-based multiple imputation estimates. When estimating missing observations, Solt (2016) considers that adjustments cannot be constant across countries and time by relying on information from proximate years in the same country as the best solution, and on information on countries in the same region and with similar development level as the second-best solution. There are, however, concerns over the reliability of SWIID's imputed estimates in data-poor regions (Ferreira et al., 2015; Jenkins, 2015).

A shortcoming of Gini indices is that they do not show which parts of a country's income distribution disproportionately gain or lose and cause changes in the Gini index. We therefore also employ the released data on relative net income shares of the Global Consumption and Income Project (GCIP) by Lahoti et al. (2016) as a measure of post tax and transfer income inequality. In a similar vein as SWIID, they estimate standardized measures based on the available data sources to increase comparability across countries and time, and increase the coverage of the data by using interpolation methods for missing country-year observations.

Trade openness and covariates

We measure trade openness by the sum of imports and exports as a share of GDP. Trade data are taken from the World Development Indicators (World Bank, 2017).

We include the following control variables: real GDP per capita to control for any distributional effect due to different income levels. Economic growth and the GDP per capita level have been shown to be positively related to globalization and international trade (see Dreher, 2006; Dreher et al., 2008; Feyrer, 2009; Felbermayr and Gröschl, 2013; Gygli et al., 2019) and to the development of the income distribution over time (see Berg et al., 2012). Demographic changes and shifts in the size of population are also likely to influence both international trade and the income distribution (OECD, 2008). We therefore add the age dependency ratio and the logarithm of total population. The dependency ratio measures the proportion of dependents per 100 of the working age population, where citizens younger than 15 or older than 64 are defined as the dependent (typically non-productive) part. A higher share of dependent citizens is usually associated with higher income inequality and higher redistribution activities within countries. Shifts in the size of the population affect the dependency ratio as well as a country's labor and skill endowment. Trade openness is likely to be correlated with other indicators of globalization such as FDIs, migration or political globalization. Other globalization indicators might also influence inequality within countries (Borjas et al., 1997; Bergh and Nilsson, 2010; Jaumotte et al., 2013; Dorn et al., 2018; Lang and Tavares, 2018; Sturm et al., 2019). We therefore use the KOF globalization subindices for political and social globalization as well as an index for FDIs as controls in our baseline models (Dreher, 2006, update KOF 2016). Our instrument *predicted openness* is constructed by using a gravity model including exogenous large-scale natural disasters in other countries. Natural disasters themselves are shown to influence trade openness and the per capita income level of countries (see Felbermayr and Gröschl, 2013, 2014). Some natural disasters are registered across borders. Natural disasters registered in the home country might have a direct impact on the home country's income distribution (see Keerthiratne and Tol, 2018). To make sure that our estimated relationship between trade and inequality is not driven by the correlation between disasters registered in the home country and income

inequality, we directly control for the effect of large-scale natural disasters on the income distribution within countries. We included the one-period lagged large-scale natural disasters as a baseline control variable. Table A1 in the Appendix describes summary statistics and data sources of all variables.

3.2 Country subsamples

Full and benchmark samples

Next to our *full sample* of 139 countries, we also use a sample for high and upper middle income countries as our *benchmark sample*. High and upper middle income countries are classified by the criterion of the World Bank as of 2015 and include 82 countries having a gross national income (GNI) per capita of USD 4,126 or more. The 57 countries in our dataset below the GNI per capita threshold of USD 4,126 are classified as low income and lower middle income countries (lower income countries). Lower income countries are more likely than high and middle income countries to have few period observations per country due to a lack of data availability. Data in lower income countries are, moreover, more likely to be subject to measurement errors. There are serious concerns about the quality of the income inequality data from less developed countries. Jenkins (2015), for example, shows that source data on inequality of high quality, in which the income concept and the survey can be verified, are rare in less developed and in particular in sub-Saharan African countries. The lack of data quality is also reflected in the imputed Gini estimates in SWIID, as the imputation variability of imputed country-period observations is large in some countries, especially in lower income countries (Ferreira et al., 2015; Jenkins, 2015). To address potential biases in the estimates because of data quality, our benchmark sample excludes the 57 lower income countries that are in the full sample. 29 of the 57 excluded countries are sub-Saharan African countries.

Development levels

We use subsamples for the most *advanced economies* and *emerging markets & developing economies (EMD)*.[6] To distinguish between advanced economies and emerging markets and developing economies we apply the classification of the International Monetary Fund (IMF, 2016). This classification is based on per capita income levels. However, it also considers export diversification and the degree of integration into the global financial system to classify advanced economies.[7] The 34 countries fulfilling the criterion of the advanced economies sample are also included in our benchmark sample (high and upper middle income countries). The subsample of emerging markets and developing economies includes 105 countries taken from both income groups, the full set of lower income countries and the countries of the benchmark sample, which are not classified as advanced economies.

Transition economies

Transition economies are another important country sample when examining the trade openness-inequality nexus. Transition economies have experienced a large shift in trade openness since the fall of the Iron Curtain. The globalization shock for transition countries was, however, hardly cushioned by either labor market institutions, education systems or welfare states, which characterize many advanced economies in the rest of the world. The transition countries had limited capabilities in the education system and higher labor market frictions at the beginning of their transition. The education and social systems rather deteriorated in the transition period (e.g., Campos and Coricelli, 2002). The transition to an open and competitive market economy, FDI-induced new technologies and equipment, and the overall skill-biased technological shift in the 1990s suddenly required other skills than the working age population and the education systems were prepared for (see Aghion and Commander, 1999). During the simultaneous period, transition countries also experienced many structural and institutional changes in political institutions and their economy, such as privatizations of state-owned enterprises, deindustrialization, price liberalizations, financial development, labor and product market deregulation, new models of corporate governance, or shrinking and reforming of the public sector during their transformation from centrally planned to market-based economies (Milanovic, 1999; Roland, 2000; Flemming and Micklewright, 2000; Ivanova, 2007; Myant and Drahokoupil, 2010; Perugini and Pompei, 2015b). One of the most visible outcomes of the systematic change and complex interplay of several forces is a remarkable increase in income inequality (see Campos and Coricelli, 2002; Ivanova, 2007; Perugini and Pompei, 2015a). The market-oriented reforms, moreover, promoted the inflow of FDI and the countries' integration in the global market. The transition toward market economies might therefore be an omitted driver of trade openness and inequality in transition countries. The systemic change

[6] See Appendix for the list of countries by development levels.

[7] Several oil exporters that have high per capita GDP but almost no export diversification, for example, would not make the IMF classification for advanced economies.

and restructuring of the economy and governance has likely influenced the speed of globalization and the rise of income inequality (Milanovic, 1999; Milanovic and Ersado, 2011; Aristei and Perugini, 2014).

We use a sample of the (new) European Union member states from Central and Eastern Europe (East EU) and China. These countries have already been shown to contribute to a large extent to changes in the global income distribution since the fall of the Berlin Wall (see Lakner and Milanovic, 2016).

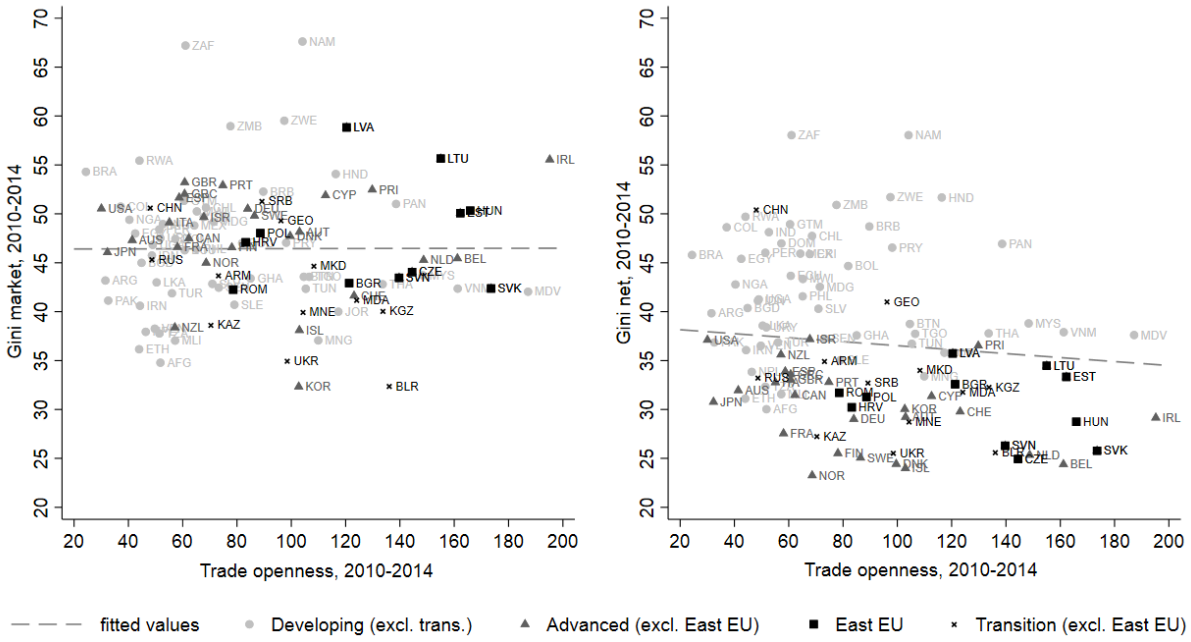
4 Descriptive statistics

4.1 Trade openness and income inequality across countries

We examine the correlation between trade openness and income inequality across countries in the most recent five-year period of observation, 2010-2014: Income inequality before taxes and transfers is hardly correlated with trade openness (see Figure 1). The coefficient of correlation is 0.01.

The Gini index after tax and transfers is on average 9.8 index points lower than the Gini index value before redistribution in the period 2010-14. Net income inequality in open countries is, however, lower than in less open countries. The correlation coefficient between trade openness and the Gini net index is -0.17, indicating that more developed and open countries have larger welfare states. EU member states and other advanced economies are among the most open countries and have the world's lowest levels of income inequality after redistribution.

Figure 1: Trade openness and Gini income inequality, 2010-2014



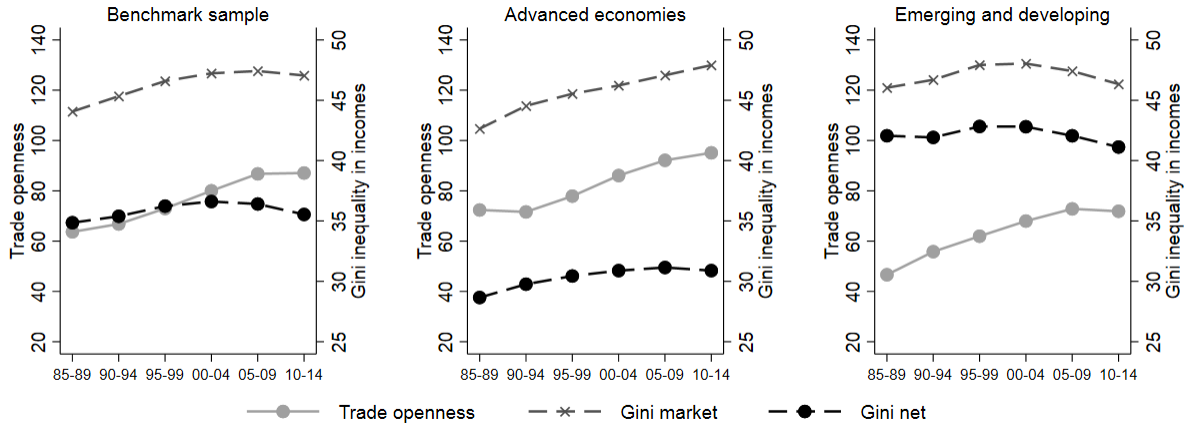
Source: SWIID 5.1, World Bank (2017), own calculations.
Notes: Figure 1 relates to the full country sample within the period 2010-2014. The figure excludes Luxembourg and Singapore as outliers. Transition (excl. East EU) relate to former members of the Soviet Union (FSU, non-EU), Western Balkan (non-EU) states, and China. Unconditional correlations: $\beta_{market} = 0.005$; $\beta_{net} = -0.171^{*}$ ($^{*}p < 0.1$).

4.2 Trends across samples and countries

Trade openness and income inequality both increased quite rapidly between the late 1980s and the late 1990s; that is the first decade after the fall of the Berlin Wall in 1989 (Figure 2). There was a further increase in trade openness around the world in the 2000s. The pre tax/transfer and post tax/transfer Gini indices, however, decreased from the early 2000s in EMD economies. In advanced economies, the Gini net index has been around 31 since 2000, while market income inequality has increased in the same period of time. The differing trends in the mean values of the Gini indices before and after taxation and transfers indicate a rise of redistribution in the sample of advanced economies since the early 2000s. Before taxation and transfers, income inequality is at a

similar level in advanced and EMD economies. After taxation and transfers, inequality is much lower in advanced economies than in the emerging and developing world.[8]

Figure 2: Global trends in trade openness and Gini income inequality



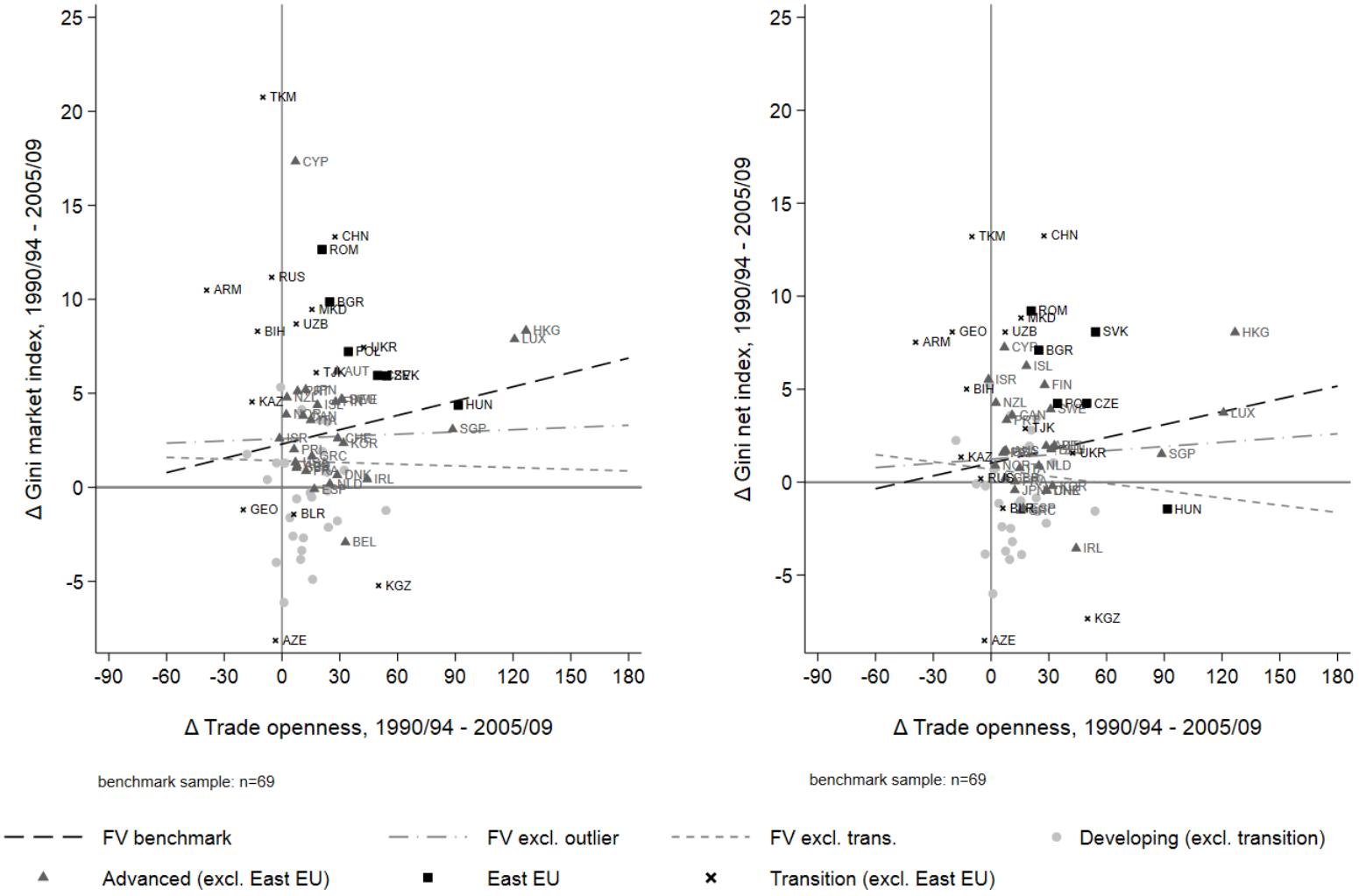
Source: SWIID 5.1, World Bank (2017), own calculations.
Notes: Trends between the periods 1985-1989 and 2010-2014. Unweighted mean of balanced samples. In the full sample, 63 of 140 countries have observations in all six periods, in the benchmark sample 47 of 82 countries, 24 of 34 countries within the sample of advanced economies, and 39 of 106 countries in the sample of emerging and developing economies (EMD).

In Figure 3 we focus on changes in income inequality and trade openness in individual countries of our benchmark sample between the periods 1990-1994 and 2005-2009 (based on 69 countries from the benchmark sample having observations in both periods 1990-1994 and 2005-2009). The unconditional correlation between the changes in trade openness and the market and net income inequality is positive. The coefficients of correlation are 0.025 and 0.023. There are, however, two groups of countries that are the key drivers of the linear relationship between the late 1980s and late 2000s: First, Hong Kong, Luxembourg and Singapore are outliers regarding trade openness. Second, the transition countries in Eastern Europe and China experienced a huge opening process (globalization shift) and a huge rise in income inequality during that time.[9] The other countries from the benchmark sample also enjoyed rapidly increasing trade openness but experienced less pronounced increases in income inequality than Eastern European countries and China. When we exclude the outliers Hong Kong, Luxembourg and Singapore, the unconditional correlation between the change in trade openness and income inequality is almost zero (the coefficients are 0.004 and 0.008). After excluding outliers and transition countries, the unconditional correlation between the change in trade openness and income inequality is negative instead. The coefficients of correlation are -0.003 and -0.013 when we exclude transition countries and outliers from the benchmark sample. Within the sample of advanced economies, the changes in trade openness and income inequality outcomes are hardly correlated between the periods 1990-1994 and 2005-2009. The coefficients of correlation are 0.027 and 0.024. After excluding transition countries and outliers, the relationship between trade and the Gini inequality indices turns out to be negative. The coefficients of correlation are -0.072 and -0.078 in the remainder sample of advanced economies.

[8] In the EU15, post tax/transfer inequality is lower than in other advanced regions such as the western offshores. The trends in inequality reflect the fact that countries of the western offshores such as the United States do have more market-oriented economic systems and less generous welfare states than their Scandinavian and continental European counterparts (see Fuest et al., 2010; Doerrenberg and Peichl, 2014; Dorn and Schinke, 2018). Empirical research has shown how inequality dynamics differ among advanced economies during the last wave of globalization, with larger increases in income inequality in Anglo-Saxon countries such as the United States and less pronounced trends in Continental Europe (see Atkinson and Piketty, 2007; Dorn, 2016; Roser and Cuaresma, 2016; Dorn and Schinke, 2018).

[9] Post-communist countries from Central and Eastern Europe (East EU) and the former Soviet Union (FSU) had relatively low levels of trade openness and income inequality before 1990. During their first stage of transition from centrally planned to market-based economies in the 1990s, both groups experienced a large rise in trade openness and income inequality (see Dorn et al., 2018). While trade openness increased in both groups during the 2000s, inequality increased in new EU member countries from Central and Eastern Europe but decreased in the other countries of the former Soviet Union such as the Russian Federation (see Gorodnichenko et al., 2010; Aristei and Perugini, 2014).

Figure 3: Changes in trade openness and Gini income inequality, between 1990/94 and 2005/09



Source: SWIID 5.1, World Bank (2017), own calculations.
Notes: Figure 3 describes countries within the benchmark sample including high and middle income countries having observations in periods 1990-1994 and 2005-2009. Transition (excl. EU) captures former members of the Soviet Union, Western Balkan (Non-EU) states, and China. The balanced benchmark sample includes 69 countries. Hongkong, Luxembourg and Singapore are extreme outliers. After excluding outliers and transition countries, the balanced sample consists of 52 countries. Unconditional correlations in the benchmark sample: $\beta_{market} = 0.025, \beta_{net} = 0.023$, after excluding outliers $\beta_{market} = 0.004, \beta_{net} = 0.008$, and after excluding outliers and (EU and Non-EU) transition economies $\beta_{market} = -0.003, \beta_{net} = -0.013$; significance level: $^{*}p < 0.1$. FV = fitted values.

5 Empirical strategy

5.1 OLS panel fixed effects model

We estimate the baseline panel model by ordinary least squares (OLS), where countries are described by i and five-year periods by τ:

$$Y_{i,\tau} = \beta \times TRADE_{i,\tau} + \boldsymbol{\Theta}' \times \boldsymbol{\chi_{i,\tau}} + \upsilon_i + \upsilon_\tau + \epsilon_{i,\tau} \quad (1)$$

$Y_{i,\tau}$ describes the measure of income inequality (Gini index, or relative income share by decile) of country i in period τ. The explanatory variable $TRADE_{i,\tau}$ describes the trade openness of country i in period τ. The vector $\chi_{i,\tau}$ includes control variables as described in Section 3.1, υ_i describes the country fixed effects, υ_τ describes the fixed period effects, and $\epsilon_{i,\tau}$ is the error term. All variables are included as averages in each of the nine periods (t = 1,...,9).

By estimating OLS in a fixed effects (FE) model we exploit the within-country variation over time, eliminating any observable and unobservable country-specific time-invariant effects. We also include fixed time effects to control for other confounding factors (e.g., period-specific shocks) that influence multiple countries simultaneously. We use standard errors robust to heteroscedasticity clustered at the country level.

5.2 2SLS panel IV model

Endogeneity problem and IV approach

There are two reasons for potential endogeneity of trade openness in our model: omitted variable bias and reverse causality.

We included many control variables, but other unobserved omitted variables may give rise to biased estimates. The omitted variable bias indicates that there is still a third (or more) variable(s), which influence(s) both trade openness and income inequality. For example, increasing mobility may induce countries to reduce (capital) taxes and cut welfare benefits, which, in turn, will influence disposable income and probably also employment. If competition from countries with cheap labor induces companies in high income countries to specialize in the production of high-tech goods and services, which requires highly skilled labor, this will have an impact on the skill premium. It is difficult to disentangle these effects from the 'direct' influence of trade openness on income inequality, that is the influence of trade openness, given other factors.

Second, reverse causality may occur because changes in income inequality are likely to influence policies that affect trade openness. The debate on the Transatlantic Trade and Investment Partnership (TTIP), for instance, is also influenced by the perception that gains from trade may be distributed rather unevenly. Shifts in the income distribution within a country may also have direct effects on the trade openness level of the country, for example if more people are able to travel, to buy more expensive import goods or to make international investments and savings.

To deal with the endogeneity problem of trade openness, we use predicted openness based on a gravity equation as an IV. Frankel and Romer (1999) apply predicted openness in a cross-sectional approach. We want to exploit exogenous time variation in predicted openness using the IV in a panel model and controlling for unobserved country effects (see Feyrer, 2009; Felbermayr and Gröschl, 2013). We employ the exogenous component of variations in openness predicted by geography and time-varying natural disasters in foreign countries, as proposed by Felbermayr and Gröschl (2013) for a panel data model, as an IV for trade openness. The incidence of natural disasters such as earthquakes, hurricanes or volcanic eruptions in one country influences the openness of its trading partners, depending on the two countries' geographic proximity.[10] An earthquake hitting Mexico, for example, will increase international trade of other countries with Mexico. The rise in a country's trade openness level will be larger, the closer a country is located to Mexico.

Instrument construction

The predicted openness is constructed in two steps: First, exogeneous natural disasters are included in a gravity model to predict bilateral trade openness. Bilateral openness $\hat{\omega}_t^{i,j}$ describes trade flows between country i and

[10] For example, the effect of an earthquake in Mexico will be stronger for trade flows of Honduras or the United States than those of India.

country j in year t and is predicted by a reduced gravity model using a Poisson Pseudo Maximum Likelihood (PPML) estimation to account for zero trade flows and standard errors clustered by country pairs.

Bilateral openness $\hat{\omega}_t^{i,j}$ is regressed on variables exogenous to income inequality such as largescale natural disasters in foreign countries j, interactions of the incidence of natural disasters in foreign countries j and bilateral geographic variables, or population:

$$\hat{\omega}_t^{i,j} = exp[\delta \times D_t^j + \boldsymbol{\gamma}' \times \boldsymbol{Z_t^{i,j}} + \boldsymbol{\lambda}' \times (\boldsymbol{\Phi_t^{i,j}} \times D_t^j) + \upsilon^i + \upsilon^j + \upsilon_t + \epsilon_t^{i,j}] \tag{2}$$

where $Z_t^{i,j} = [lnPOP_t^i; lnPOP_t^j; lnDIST^{i,j}; BOR^{i,j}]$ includes exogenous controls such as population (POP) in countries i and j in year t, and the bilateral geographic variables distance $DIST$, and a common border dummy BOR, based on Frankel and Romer (1999). D_t^j denotes exogenous large-scale natural disasters in country j, while $\Phi_t^{i,j} = [lnFINDIST_t^j; lnAREA^j; lnPOP_t^j; BOR^{i,j}]$ describes the exogenous variables interacting with D_t^j, such as the international financial remoteness $FINDIST$, the surface area $AREA$, or population POP of country j.[11] Country and time fixed effects are captured by υ^i, υ^j, υ_t, while $\epsilon_t^{i,j}$ accounts for the idiosyncratic error. The bilateral openness equation (2) is designed to maximize conditional correlation between observed trade openness and the constructed instrument (see relevance of the instrument below).

We follow the approach preferred by Felbermayr and Gröschl (2013) and use exogenous "large" scale natural disasters (as D_t^j) to make sure that a disaster is of a sufficiently large dimension and caused not by local determinants or the development level of the country but rather by exogenous global phenomena. This classification of natural disasters includes "large" earthquakes, droughts, storms, storm floods and volcanic eruptions that (i) caused 1,000 or more deaths; or (ii) injured 1,000 or more people; or (iii) affected 100,000 or more people. In our robustness checks, we use alternative definitions of disasters to construct the instrument, such as a broader specification of disasters that includes all kinds of natural disasters or counting all sizes of disasters (see Section 6.4). The data on natural disasters is taken from the Emergency Events database (EM-DAT).

In the second step of constructing the IV, Felbermayr and Gröschl (2013) use an exogenous proxy for multilateral openness $\Omega_{i,t}$ by aggregating the obtained predicted bilateral openness values $\hat{\omega}_t^{i,j}$ of country i over all bilateral country pairs and years t:

$$\Omega_{i,t} = \sum\nolimits_{i \neq j} \hat{\omega}_t^{i,j} \tag{3}$$

Based on our underlying data, we obtain values for all years from 1966 to 2008. Averaging over nine periods τ and using one-period lags of predicted openness $\Omega_{i,\tau-1}$, we obtain our instrument for $TRADE_{i,\tau}$ in equation (1).

Relevance of the instrument

The relevance of the IV predicted openness $\Omega_{i,\tau-1}$ depends on its conditional correlation with trade openness $TRADE_{i,\tau}$. The first stage regression has the following form:

$$TRADE_{i,\tau} = \alpha \times \Omega_{i,\tau-1} + \boldsymbol{\varphi}' \times \boldsymbol{\chi_{i,\tau}} + \upsilon^j + \upsilon_t + \epsilon_t^{i,j} \tag{4}$$

The model is estimated by applying the FE estimator, controlling for any time-invariant country characteristics, and using robust standard errors clustered at the country level. The first stage also includes all control variables $\boldsymbol{\chi_{i,\tau}}$ as in equation (1) and period dummies to control for common period effects.

The first stage regression results show that the IV is relevant (see Appendix, Table A2). Our predicted openness variable correlates positively with trade openness ($TRADE$). The relationship is statistically significant at the 1% level in the full sample, the benchmark sample and in the sample of advanced economies. In the sample of developing economies, the statistical significance is at the 10% level. The Cragg-Donald Wald F-statistics on the excluded instrument are well above the 10% critical value ($F \geq 16.38$) of the weak instrument test by Stock and Yogo (2005). The partial R^2 of lagged predicted openness ranges between 2.4% in the sample of developing economies and 23.3% in the sample of advanced economies.

Exclusion restriction

Income inequality does not influence predicted openness because the instrument is constructed from exogenous

[11] As large-scale natural disasters may hit both bordering countries, the interaction of disasters and the common border dummy is included. Interactions of the disaster variable with surface area and population in country j consider the fact that economic and population density matters for the aggregate damage caused by large-scale natural disasters.

components, such as large-scale natural disasters and bilateral geographic components. We do not believe that predicted openness influences income inequality directly or through other explanatory variables that we did not include in our model. Predicted openness is an arguably excludable instrument. Foreign natural disasters are expected to have no effect on income inequality other than through the extent of trade openness or other indicators of globalization, e.g., international transactions and migration. We control for other globalization indicators such as FDIs and social and political globalization in our regression models. Migration is included in the social globalization index and we control for migration as an individual variable in our robustness tests.[12]

Large-scale natural disasters may give rise to changes in the income distribution. Felbermayr and Gröschl (2013, 2014) have shown, for example, that natural disasters influence overall per capita income. Some natural disasters are registered across borders. Natural disasters registered in the home country might have a direct impact on the home country's income distribution (see Keerthiratne and Tol, 2018). To mitigate any potential omitted variable bias because of cross-border natural disasters we directly control for the effect of large-scale natural disasters in the home country.

6 Results

6.1 Baseline results

We examine the average effect of trade openness on Gini income inequality in our full and benchmark sample. Our results in Table 1 do not suggest a statistically significant relationship between trade openness and income inequality in the full sample and benchmark sample—estimating the models by OLS (columns 1-4) and 2SLS (columns 5-8) notwithstanding. The baseline specifications do not confirm that trade openness influences inequality within countries when we use large country samples—in line with predictions of the Stolper-Samuelson theorem.

The baseline results in Table 1 also show the coefficient estimates of the control variables. FDIs and large-scale natural disasters increase income inequality both before and after redistribution. The Gini market index increases when the share of dependents increases. Population and inequality are negatively correlated before tax and transfers.

Table 2 shows the baseline 2SLS results when we use the relative net income shares (by deciles) as the dependent variables. The results in Table 2 corroborate our baseline results when using the Gini index as the dependent variable in the full sample (panel a), indicating that the relationship between trade openness and income inequality lacks statistical significance. The relationship between trade openness and relative income shares in the benchmark sample is more pronounced (panel b). The coefficient estimate of trade openness is negative when the relative income shares of the lower income deciles 1 to 7 are used as the dependent variables and positive when the relative income shares of the three highest income share deciles are used as the dependent variables. But the coefficient estimates are rather small. The effect of trade openness, however, is only statistically significant for the upper middle class in the 9th decile (column 9 of Table 2). The coefficient is significant at the 5% level and indicates that the income share of decile (9) increased by 0.12 percentage points when trade openness increased by ten percentage points.

6.2 The role of development levels

The effect of trade openness on income inequality is expected to differ depending on the development level of countries. The Stolper-Samuelson theorem (Stolper and Samuelson, 1941) predicts that trade openness increases inequality in developed countries and decreases inequality in developing countries. We examine two subsamples depending on the development level of countries: the sample of 34 advanced economies and the sample of 102 emerging markets and developing economies (see Table 2, panel c and d). The instrument is relevant within both subsamples. The Cragg-Donald Wald F-statistic is above the 10% and 15% critical values.

[12] One may argue that the exclusion restriction is not fulfilled because natural disasters that occur in the trading partner countries (which are often direct geographical neighbors) give rise to migration. For example, when a natural disaster occurs in Mexico, especially poor Mexican citizens are likely to leave Mexico and migrate to a neighboring country such as Honduras. If this is true, the natural disaster that hit Mexico (and gave rise to the exogenous variation in our instrumental variable predicted openness) influenced trade openness and income inequality in Honduras. Empirical studies show, however, that natural disasters hardly give rise to international migration in the medium and long term (see Gröschl and Steinwachs, 2017).

Table 1: Trade openness and income inequality – baseline results (OLS and 2SLS)

	OLS				2SLS			
	Full sample		Benchmark sample		Full sample		Benchmark sample	
	(1) Gini market	(2) Gini net	(3) Gini market	(4) Gini net	(5) Gini market	(6) Gini net	(7) Gini market	(8) Gini net
Trade openness	0.00817	0.0110	-0.00872	-0.00107	-0.0658	-0.0276	0.000943	0.0232
	(0.0133)	(0.0106)	(0.0153)	(0.0113)	(0.0692)	(0.0563)	(0.0418)	(0.0339)
GDP p.c.	0.0952	0.0235	0.0955	0.00434	0.150	0.0522	0.0880	-0.0146
	(0.0590)	(0.0500)	(0.0575)	(0.0460)	(0.0916)	(0.0673)	(0.0743)	(0.0517)
Population (log)	-5.322*	-2.298	-2.873	1.146	-5.964**	-2.633	-2.660	1.682
	(2.835)	(2.203)	(3.969)	(3.075)	(2.842)	(2.204)	(3.858)	(3.186)
Age dependency	0.129**	0.0666	0.193***	0.140**	0.101	0.0518	0.197***	0.151***
	(0.0509)	(0.0436)	(0.0692)	(0.0597)	(0.0613)	(0.0513)	(0.0683)	(0.0578)
Social glob.	0.0618	0.0252	0.0431	0.000700	0.0604	0.0245	0.0435	0.00156
	(0.0507)	(0.0400)	(0.0522)	(0.0399)	(0.0498)	(0.0375)	(0.0508)	(0.0407)
Political glob.	-0.0346	-0.0173	-0.0102	0.00560	-0.0212	-0.0103	-0.0131	-0.00176
	(0.0369)	(0.0303)	(0.0464)	(0.0379)	(0.0395)	(0.0312)	(0.0467)	(0.0377)
FDI	0.0695***	0.0426***	0.0777***	0.0437***	0.0783***	0.0472***	0.0777***	0.0437***
	(0.0208)	(0.0154)	(0.0260)	(0.0162)	(0.0222)	(0.0168)	(0.0254)	(0.0159)
Nat. disasters (t-1)	2.103***	2.115***	2.390***	2.450***	2.255***	2.194***	2.377***	2.419***
	(0.377)	(0.478)	(0.315)	(0.392)	(0.345)	(0.445)	(0.317)	(0.403)
Fixed effects								
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries	139	139	82	82	139	139	82	82
Observations	794	794	516	516	794	794	516	516
Partial R^2					0.067		0.131	
F Test, weak ID					45.573		62.899	
F Test, p-value					0.000		0.000	

Notes: OLS and 2SLS panel fixed effects estimations based on nine periods using 5-year averages between 1970 and 2014. Clustered robust standard errors in parentheses. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical value: 16.38 (10 %). Significance levels: ***p < 0.01; **p < 0.05; *p < 0.1.

Table 2: Trade openness and income inequality – subsample results (2SLS)

(13)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	Gini market	Gini net
(a) Full sample												
Trade openness	-0.000703	-0.00229	-0.00168	-0.000640	0.000542	0.00174	0.00288	0.00384	0.00442	-0.00835	-0.0666	-0.0284
	(-0.08)	(-0.29)	(-0.23)	(-0.09)	(0.08)	(0.30)	(0.57)	(0.78)	(0.51)	(-0.20)	(-0.97)	(-0.51)
Countries	136	136	136	136	136	136	136	136	136	136	136	136
Observations	783	783	783	783	783	783	783	783	783	783	783	783
Partial R^2							0.067					
F Test, weak ID							45.593					
F Test pvalue							0.000					
(b) Benchmark sample												
Trade openness	-0.00707	-0.00861	-0.00826	-0.00735	-0.00600	-0.00411	-0.00137	0.00302	0.0117**	0.0280	0.000222	0.0228
	(-1.02)	(-1.41)	(-1.47)	(-1.42)	(-1.28)	(-0.99)	(-0.37)	(0.81)	(2.00)	(0.89)	(0.01)	(0.68)
Countries	81	81	81	81	81	81	81	81	81	81	81	81
Observations	513	513	513	513	513	513	513	513	513	513	513	513
Partial R^2							0.134					
F Test, weak ID							64.572					
F Test pvalue							0.000					
(c) Advanced econ.												
Trade openness	-0.00867**	-0.00779*	-0.00667	-0.00537	-0.00382	-0.00191	0.000522	0.00389	0.00942***	0.0204	-0.0287	0.00350
	(-2.12)	(-1.94)	(-1.51)	(-1.14)	(-0.81)	(-0.42)	(0.13)	(1.28)	(2.88)	(0.69)	(-0.79)	(0.16)
Countries	34	34	34	34	34	34	34	34	34	34	34	34
Observations	244	244	244	244	244	244	244	244	244	244	244	244
Partial R^2							0.233					
F Test, weak ID							58.875					
F Test pvalue							0.000					
(d) Developing econ.												
Trade openness	0.0317*	0.0240	0.0219	0.0203	0.0183	0.0148	0.00900	-0.00151	-0.0231	-0.117	-0.235	-0.212
	(1.71)	(1.41)	(1.25)	(1.13)	(1.03)	(0.88)	(0.61)	(-0.12)	(-1.07)	(-1.04)	(-1.09)	(-1.14)
Countries	102	102	102	102	102	102	102	102	102	102	102	102
Observations	539	539	539	539	539	539	539	539	539	539	539	539
Partial R^2							0.025					
F Test, weak ID							10.821					
F Test pvalue							0.072					

Notes: 2SLS panel fixed effects estimations based on nine periods using 5-year averages between 1970 and 2014. T-statistics in parentheses. Robust standard errors clustered at the country level. All specifications include country and year fixed effects, and baseline control variables (see Table 1): GDP per capita, population(log), dependecy ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical values: 16.38 (10 %), 8.96 (15 %). Significance levels: ***p $<$ 0.01; **p $<$ 0.05; *p $<$ 0.1.

We examine how trade openness influences Gini inequality. 2SLS results in Table 2 do not show that trade openness influences income inequality when we use Gini market and Gini net indices as the dependent variables (columns 11-12), neither within the most advanced economies (panel c) nor within the sample of emerging and developing economies (panel d).

We also examine how trade openness influences the relative net income shares in Table 2 (columns 1-10). Within the advanced economies, the results suggest that trade openness increased income inequality. Table 2 shows that trade openness decreased the relative net income shares of the lowest income deciles and increased the relative net income shares of the upper middle class income deciles (panel c). The effect is negative and significant for the two lowest income deciles (panel c, columns 1-2) and positive and statistically significant for the 9th decile (panel c, column 9). The coefficient, however, indicates a rather small effect. The income share of the upper middle class (decile 9) increased by 0.09 percentage points when trade openness increased by 10 percentage points. Within the emerging and developing world, our results suggest that trade openness tends to decrease income inequality. Trade openness tends to decrease income shares of the upper deciles and to increase income shares of the poor and middle class within the emerging and developing economies. Trade openness, however, also lacks statistical significance in almost all specifications in Table 2, panel (d). The exception is the coefficient estimate in panel (d), column (1), suggesting a rather positive effect of trade openness on the relative income share of the poorest in the income distribution of emerging and developing countries. The coefficient indicates that the bottom 10% income share (decile 1) increased by 0.3 percentage points when trade openness increased by 10 percentage points.

Our 2SLS results based on relative income shares as the dependent variable are again in line with predictions of the Stolper-Samuelson theorem. Within developing economies, our findings suggest that the poorest people disproportionately gain from trade openness at the expense of the relative income shares of higher income deciles. Within advanced economies, our findings suggest that the upper middle class disproportionately gain from trade openness at the expense of the relative income shares of bottom deciles.

The findings suggest that trade openness influences income inequality, both within our benchmark country sample and within advanced economies. The benchmark sample includes the advanced economies sample and the 48 emerging economies having a per capita income level above a minimum threshold (not including developing countries having a GNI per capita below USD 4,126, as of 2015). As coefficient estimates of trade openness in the benchmark sample are larger than in the sample of advanced economies, and 41.5 percent of countries in the benchmark sample are advanced economies, other countries within the benchmark sample might be the main drivers of the significant positive effect of trade openness on income inequality.

6.3 Outliers and transition countries

The unconditional relationship between the change in trade openness and income inequality seems to be driven by outliers in trade openness and by Central and Eastern European transition countries (East EU) and China (see Section 4). We therefore examine the effect of trade openness on income inequality when we exclude outliers and transition countries. The results are shown in Table 3.

First, we exclude Singapore as an outlier in trade openness from the sample of advanced economies (Table 3, panel a) and the benchmark sample of high and upper middle income countries (Table 3, panel b). The results in Table 3 show that all coefficient estimates lack statistical significance after excluding Singapore, both in the advanced economies and in the benchmark sample. Within the remaining 33 advanced economies, the coefficient estimates for trade openness are positive for the effect on the bottom 70% income share (panel a, columns 1-7) and negative for the effect on income shares of the upper 30% (panel a, columns 8-10) after excluding the nine observations for Singapore. Within the remaining benchmark sample of 80 countries, the coefficient estimates for trade openness have are positive for the bottom 20% and top 20% income shares (panel b, columns 1-2 and 9-10) and negative for the deciles in the middle class (panel b, columns 3-8) after excluding observations for Singapore. These findings, however, do not support the prediction by the Stolper-Samuelson theorem that trade liberalization increases inequality in developed countries.

Second, we exclude China and the East EU transition countries from the benchmark sample of high and upper middle income countries (Table 3, panel c). The coefficients of the trade openness variables become smaller and do not turn out to be statistically significant when we exclude China and the East EU transition countries. After excluding China and transition economies, the coefficient estimate of trade openness on the income share of the 9th decile in column (9) is 0.008 and lacks statistical significance—it is 0.012 at the 5% significance level when China and transition economies are included (Table 2, panel b). In a similar vein, the coefficient of trade

Table 3: The role of outliers and transition economies (2SLS)

(13)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	Gini market	Gini net
(a) Advanced, excl. outlier												
Trade openness	0.00728	0.00503	0.00386	0.00304	0.00231	0.00150	0.000403	-0.00131	-0.00432	-0.0178	-0.0306	-0.000956
	(0.95)	(0.72)	(0.55)	(0.44)	(0.36)	(0.26)	(0.08)	(-0.27)	(-0.60)	(-0.44)	(-0.49)	(-0.03)
Countries	33	33	33	33	33	33	33	33	33	33	33	33
Observations	235	235	235	235	235	235	235	235	235	235	235	235
Partial R^2							0.186					
F Test, weak ID							42.613					
F Test, p-value							0.000					
(b) Benchmark, excl. outlier												
Trade openness	0.00630	0.000605	-0.00177	-0.00316	-0.00404	-0.00452	-0.00449	-0.00348	0.000570	0.0140	-0.0227	-0.00786
	(1.26)	(0.11)	(-0.30)	(-0.51)	(-0.62)	(-0.68)	(-0.68)	(-0.55)	(0.09)	(0.31)	(-0.50)	(-0.21)
Countries	80	80	80	80	80	80	80	80	80	80	80	80
Observations	504	504	504	504	504	504	504	504	504	504	504	504
Partial R^2							0.126					
F Test, weak ID							58.531					
F Test, p-value							0.000					
(c) Excl. transition econ.												
Trade openness	-0.00174	-0.00316	-0.00313	-0.00274	-0.00209	-0.00111	0.000357	0.00279	0.00765	0.00317	-0.0454	-0.0120
	(-0.26)	(-0.54)	(-0.55)	(-0.50)	(-0.41)	(-0.24)	(0.09)	(0.75)	(1.33)	(0.09)	(-1.16)	(-0.39)
Countries	69	69	69	69	69	69	69	69	69	69	69	69
Observations	454	454	454	454	454	454	454	454	454	454	454	454
Partial R^2							0.139					
F Test, weak ID							59.729					
F Test, p-value							0.000					
(d) Transition effect												
Trade openness	-0.00333	-0.00538	-0.00540	-0.00485	-0.00390	-0.00251	-0.000453	0.00286	0.00939	0.0136	-0.0301	-0.00195
	(-0.48)	(-0.89)	(-0.95)	(-0.90)	(-0.79)	(-0.56)	(-0.12)	(0.74)	(1.56)	(0.41)	(-0.76)	(-0.06)
Trade*Transition	-0.0167*	-0.0145	-0.0128	-0.0112	-0.00938	-0.00716	-0.00412	0.000701	0.0106	0.0646	0.136**	0.111*
	(-1.90)	(-1.58)	(-1.44)	(-1.34)	(-1.24)	(-1.07)	(-0.72)	(0.13)	(1.10)	(1.41)	(2.00)	(1.79)
Countries	81	81	81	81	81	81	81	81	81	81	81	81
Observations	513	513	513	513	513	513	513	513	513	513	513	513
Partial R^2							0.131					
F Test, weak ID							30.608					
F Test, p-value							0.001					

Notes: Singapore excluded as outlier in panels (a) and (b). Transition economies include China and East-EU member states (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Romania). 2SLS panel fixed effects estimations based on nine periods using 5-year averages between 1970 and 2014. T- statistics in parentheses. Robust standard errors clustered at the country level. All specifications include country and year fixed effects, and baseline control variables (see Table 1): GDP per capita, population(log), dependecy ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical values: 16.38 (10 %). Significance levels: ***p $<$ 0.01; **p $<$ 0.05; *p $<$ 0.1.

openness for the effect on the top 10% income share is 0.003 for the remainder benchmark sample (column 10). It is 0.028 when China and transition economies are included (Table 2, panel b). This effect suggests that trade openness especially increased relative income shares of very rich citizens in China and Eastern European transition economies. After excluding China and transition economies, the coefficients even turn negative when we use Gini indices as dependent variables (columns 11-12).

The results suggest that China and the Eastern European countries drive the effect of trade openness on income inequality. We therefore include an interaction effect of trade openness and the sample of China and transition economies in Table 3, panel (d). The trade openness variable lacks statistical significance in any specification (columns 1-12). Trade openness, however, has a positive effect on Gini income inequality in transition countries (columns 11-12). The interaction effect is statistically significant at the 5% and 10% levels and suggests that Gini inequality in transition economies increases by an additional 1.4 index points (Gini market) and 1.1 points (Gini net) when trade openness increases by 10 percentage points. The negative interaction effect of trade openness on the income shares of the bottom 10% of transition countries is also statistically significant (Table 3, panel d, column 1).[13]

After excluding transition countries from the benchmark sample, we do not find an overall inequality-increasing effect of trade openness in a large sample of advanced and emerging economies—which is in line with HO model predictions (Stolper-Samuelson theorem).

6.4 Robustness checks

We tested the sensitivity of our baseline results in many ways. First, we follow related studies and use the ICT capital stock as a proxy to control for technological change (Jaumotte et al., 2013). While the ICT capital stock is positively related to changes in the Gini inequality outcomes in all OLS and 2SLS models, inferences about the relationship between trade openness and income inequality do not change (Appendix II, Table A4). ICT capital stock is only statistically significant in the full sample when we use Gini inequality after tax and transfers as the dependent variable.

Second, we followed related literature and used periods with five-year averages in our baseline models. We tested the robustness of the results by including a larger frequency with shorter time periods of three-year averages (Appendix II, Tables A5 and A6). Inferences do not change. Our results show that trade openness increased the income share of the 9th decile within the benchmark sample and the 8th and 9th decile within advanced economies. Within advanced economies, the negative effect on the poor is significant for the bottom 30% of the income distribution. Within emerging and developing economies, the trade openness variable lacks statistical significance in any specification. The coefficient for the bottom 10% is statistically significant when we use five-year averaged periods. The t-statistic of the coefficient estimate is 1.55 when we use three-year averaged periods (Appendix II, Table A6, panel d). The estimates in the sample of emerging and developing economies suffer from a weak ID when we use three-year averaged periods. The Cragg-Donald Wald F-statistic is 10.88 and below the 10% critical value identified by Stock and Yogo (2005). The p-value on the excluded instrument is above 0.1. Using five-year averaged periods is therefore preferred over three-year averaged periods to obtain valid IV results for the sample of emerging and developing economies.

Third, the descriptive statistics in Section 4 suggest that there are trends over time. We therefore used the trend rather than the period fixed effects in a robustness test (Appendix II, Tables A7 and A8). Inferences of our results on the trade-inequality nexus do not change.

Fourth, inequality measures might be persistent across periods. We therefore included lagged dependent variables to allow for dynamics that give rise to serial correlation. Our main results, however, do not change. In the benchmark sample, the trade openness coefficient turns out to have a positive and significant effect on Gini inequality after redistribution. The pro poor effect in developing economies and the pro upper middle class effect in advanced economies are more pronounced when we include lagged dependent variables. The effects in the benchmark sample and sample of advanced economies are again driven by outliers and transition countries.

Fifth, the relationship between trade openness and income inequality might be non-monotonic, where inequality first rises and later declines when trade openness increases (Helpman et al. (2010, 2017)). This would follow Kuznets (1955) hypothesis predicting a non-monotonic relationship where income inequality first increases and later decreases when the overall income level of a country increases. We examine whether the effect of trade

[13] We also examined the effect of trade openness on inequality within the sample of emerging and developing economies when we exclude transition countries (Appendix II, Table A3).

openness on inequality changes at different levels of the trade openness process. We include trade openness in levels and squared trade openness in our baseline model.[14] We do not find evidence for a non-monotonic relationship (Appendix II, Figures A1 – A2 for marginal trade openness effects on Gini indices depending on the level of trade openness).

Sixth, we used alternative definitions of natural disasters by constructing the instrument predicted openness in the panel model, such as broader specifications that include all kinds of natural disasters or counting all sizes of disasters (small and large), as suggested by Felbermayr and Gröschl (2013). Using the alternative instruments, inferences do not change (Appendix II, Table A9).

7 Conclusion

We examined how trade openness influences income inequality using predicted openness as an IV for trade openness. The baseline results do not show that trade openness influences income inequality in the full country sample. The effect of trade openness on income inequality differs across countries. In particular, our results using relative income shares as the dependent variable are in line with predictions of the Stolper-Samuelson theorem: Trade openness tends to disproportionately benefit relative income shares of the very poor (not necessarily all poor) in the sample of emerging and developing economies. In advanced economies, trade openness increased income inequality, an effect that is, however, driven by outliers. We therefore cannot confirm, as predicted by the Stolper-Samuelson theorem, that trade liberalization gives rise to income inequality in developed countries. The positive effect of trade openness on income inequality in our benchmark country sample is driven by China and transition countries from Central and Eastern Europe.

Why is there a positive relationship between trade openness and inequality in the transition countries including China and the countries of Central and Eastern Europe but hardly so in the group of advanced economies?

The transition countries from Eastern Europe and China have experienced a rapid process of trade openness, while the welfare states and labor market institutions in these countries were less developed than in many advanced countries in the rest of the world—in particular in Western Europe. Chinese reform programs were, for example, concentrated on economic growth that has not been moderated by large public education and redistribution programs. Participation in China's rise to a global economic power, therefore, is unequally distributed within the country (see Ravallion and Chen, 2007). Transition countries from Central and Eastern Europe have also experienced systematic structural and institutional changes towards market economies, which might be the drivers of rising trade openness levels and inequality outcomes in our results.

In the most advanced economies, established progressive tax and transfer systems, stable political and democratic institutions, and widely accessible opportunities for education may have moderated adverse effects of trade openness on income inequality. Our descriptive statistics suggest that redistribution programs in EU15 countries reduce income inequality to a much larger extent than equivalent tax/transfer programs in many other advanced economies. The United States, for example, is widely seen as the country that has experienced the most pronounced increase in income inequality, partly because competition from emerging economies such as China has destroyed jobs for medium and low-skilled labor (see Autor et al., 2013). Future research should examine in more detail how institutions influence income inequality when countries are active in trading goods and services.

[14] The models are estimated by OLS. We also estimated the 2SLS and instrumented the squared trade openness by the squared instrument, but the instruments turn out to be weak. We therefore elaborate on the OLS estimates.

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APPENDIX

Supporting Information for

Trade openness and income inequality: New empirical evidence

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List of countries (139)

Advanced Economies*: Australia, Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States

Emerging and Developing Economies: Albania*, Algeria*, Angola*, Argentina*, Armenia, Azerbaijan*, Bangladesh, Barbados*, Belarus*, Belize*, Benin, Bolivia, Bosnia and Herzegovina*, Brazil*, Bulgaria*, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Central African Republic, Chad, Chile*, China*, Colombia*, Comoros, Costa Rica*, Cote d'Ivoire, Croatia*, Djibouti, Dominican Republic*, Ecuador*, Egypt, El Salvador, Ethiopia, Fiji*, Gabon*, Gambia, Georgia, Ghana, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, Hungary*, India, Indonesia, Iran*, Jamaica*, Jordan*, Kazakhstan*, Kenya, Kyrgyz Republic, Lao, Lebanon*, Macedonia (FYR)*, Madagascar, Malawi, Malaysia*, Maldives*, Mali, Mauritania, Mauritius*, Mexico*, Moldova,, Mongolia*, Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama*, Paraguay*, Peru*, Philippines, Poland*, Romania*, Russian Federation*, Rwanda, Senegal, Sierra Leone, South Africa*, Sri Lanka, St. Lucia*, Suriname*, Syria, Tajikistan, Tanzania, Thailand*, Togo, Trinidad and Tobago*, Tunisia*, Turkey*, Turkmenistan*, Uganda, Ukraine, Uruguay*, Uzbekistan, Venezuela*, Viet Nam, Republic of Yemen, Zambia, Zimbabwe

Central and Eastern European EU Members*: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia

Former Members of the Soviet Union: Armenia, Azerbaijan*, Belarus*, Georgia, Kazakhstan*, Kyrgyz Republic, Moldova, Russian Federation*, Tajikistan, Turkmenistan*, Ukraine, Uzbekistan Western Balkan*: Albania, Bosnia and Herzegovina, Macedonia (FYR)

EU 15*: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom

*Countries and samples marked with * are high and middle income countries and included in our benchmark sample. The World Bank (2015) classified countries having a GNI per capita of USD 4,126 or more as high and middle income countries.*

Table A1: Summary statistics and data sources, 5-year averaged periods

Variable	Mean	Std. Dev.	Min.	Max.	N	Source	Definition
Dependent variables							
Gini market	45.86	7.09	23	74.46	808	Solt (2016), SWIID v5.1	Gini inc. inequality, pre tax & transfers
Gini net	37.7	8.85	18.15	61.84	808		Gini inc. inequality, post tax & transfers
Income shares (net)						Lahoti et al. (2016), GCIP	Relative net income share by decile
Decile 1	1.91	1.06	0.18	5.95	795		
Decile 2	3.06	1.3	0.54	6.53	795		
Decile 3	4.06	1.44	0.94	7.21	795		
Decile 4	5.07	1.51	1.43	8.1	795		
Decile 5	6.16	1.51	2.07	8.95	795		
Decile 6	7.42	1.45	2.95	9.92	795		
Decile 7	9.02	1.32	4.27	11.99	795		
Decile 8	11.28	1.08	6.53	14.71	795		
Decile 9	15.26	0.94	10.85	18.15	795		
Decile 10	36.76	10.36	18.48	69.55	795		
Trade variable							
Trade openness	75.23	49.53	6.79	410.25	808	World Bank(2017), WDI	Exports & imports as share of GDP
Instrument							
Ω^i_τ	59.32	35.95	0.47	322.62	710	Felbermayr & Gröschl (2013)	Predicted openness
$\Omega^i_{\tau-1}$	56.08	34.52	0.42	322.62	808		One period lag of predicted openness
Baseline controls							
GDP pc	12.65	13	0.44	90.5	800	Feenstra et al.(2015),	Real GDP per capita, in billions USD
ln POP	2.53	1.63	-1.89	7.21	800	PWT v9.0	Log of total population, in millions
Dependency	65.87	18.76	34.96	112.84	808	World Bank (2017), WDI	Age dependency ratio, young & old
Social GLOB	45.67	22.84	6.55	93	802	update KOF 2016	KOF index of social globalization 2016
Political GLOB	65.90	20.05	18.55	97.67	802		KOF index of political globalization 2016
FDI	59.75	23.77	5	100	806		KOF index of total FDI-to-GDP ratio 2016
$L.Disaster_{\tau-1}$	0.2	0.63	0	7.8	808		One period lag of large scale natural disasters
Robustness test controls							
ICT capital stock	0.19	0.81	0	12.71	571	Jorgenson and Vu (2017)	ICT capital stock, in 100'000 USD

References (not cited in the main text):
Feenstra, R., R. Inklaar, and M. Timmer (2015). "The Next Generation of the Penn World Table." *American Economic Review*, 105(10), 3150-3182.
Jorgenson, D. W., and Vu, K. (2017). "The outlook for advanced economies." *Journal of Policy Modelling*, 39(3), 660–672.

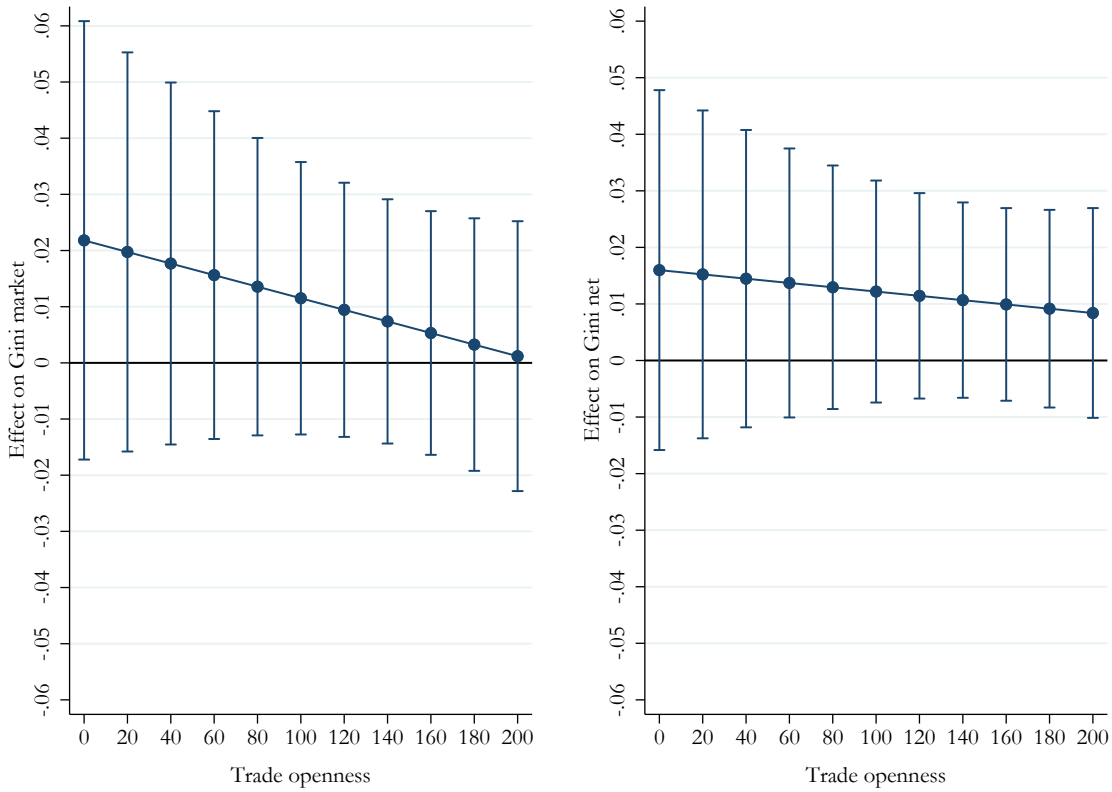
Table A2: First stage regression results (2SLS)

Panel sample	(1) Full	(2) Benchmark	(3) Advanced	(4) Developing
$\Omega^{i}_{\tau-1}$	0.430***	0.548***	0.630***	0.332*
	(4.82)	(5.08)	(5.02)	(1.78)
Partial R^2	0.067	0.131	0.233	0.024
F-Test, weak ID	45.573	62.899	58.875	10.652
F-Test, p-value	0.000	0.000	0.000	0.079
Controls	Yes	Yes	Yes	Yes
Fixed Effects				
Country	Yes	Yes	Yes	Yes
Period	Yes	Yes	Yes	Yes
Countries	139	82	34	105
Observations	794	516	244	550

Notes: T-statistics in parentheses. 2SLS panel fixed effects estimations based on nine periods using 5-year averages between 1970 and 2014. Robust standard errors clustered at the country level. All specifications include country and year fixed effects, and baseline control variables: GDP per capita, population(log), dependecy ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical values: 16.38 (10 %), 8.96 (15 %), 6.66 (20 %). Significance levels: ***p < 0.01; **p < 0.05; *p < 0.1.

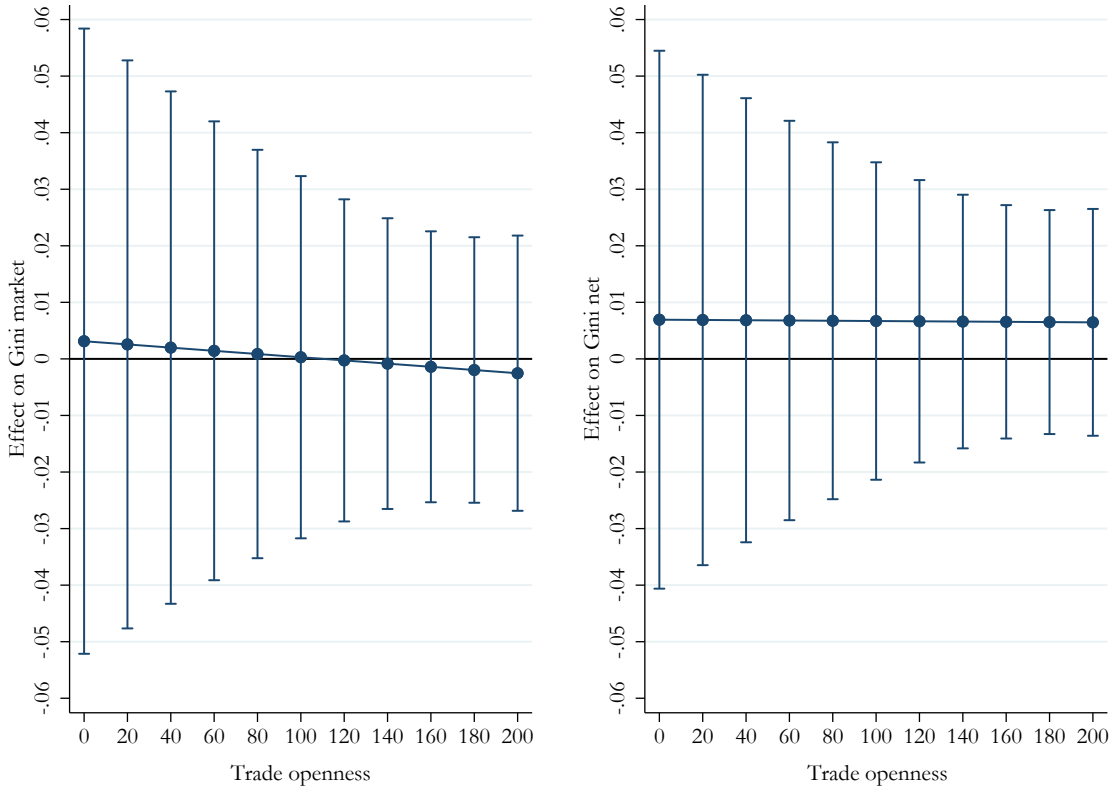
Supporting information: APPENDIX II

Figure A1: Robustness – Non-monotonic relationship, full sample (OLS)



Source: SWIID 5.1, World Bank (2017), own calculations.
Notes: The figure shows marginal effects of trade openness on income inequality conditional on the level of trade openness. Estimates use an OLS panel fixed effects model that includes trade openness in levels and squared terms. The model is estimated with robust standard errors clustered at the country level. The dots show the marginal effects of a one percentage point increase in trade openness on income inequality, at a given level of trade openness (x-axis). The lines indicate the 90 percent confidence intervals.

Figure A2: Robustness – Non-monotonic relationship, benchmark sample (OLS)



Source: SWIID 5.1, World Bank (2017), own calculations.
Notes: The figure shows marginal effects of trade openness on income inequality conditional on the level of trade openness. Estimates use an OLS panel fixed effects model that includes trade openness in levels and squared terms. The sample includes 82 countries and 517 observations based on nine periods using 5-year averages between 1970 and 2014. The model is estimated with robust standard errors clustered at the country level. The dots show the marginal effects of a one percentage point increase in trade openness on income inequality, at a given level of trade openness (x-axis). The lines indicate the 90 percent confidence intervals.

Table A3: Robustness – EMD economies excluding transition countries (2SLS)

	(1) D1	(2) D2	(3) D3	(4) D4	(5) D5	(6) D6	(7) D7	(8) D8	(9) D9	(10) D10	(11) Gini market	(12) Gini net
Trade openness	0.0476	0.0391	0.0366	0.0343	0.0309	0.0253	0.0158	-0.00120	-0.0368	-0.193	-0.366	-0.301
	(1.47)	(1.32)	(1.23)	(1.16)	(1.09)	(1.00)	(0.78)	(-0.08)	(-1.06)	(-1.11)	(-1.02)	(-1.03)
Fixed effects												
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries	96	96	96	96	96	96	96	96	96	96	96	96
Observations	504	504	504	504	504	504	504	504	504	504	504	504
Partial R^2						0.020						
F Test, weak ID						8.135						
F Test, p-value						0.130						

Notes: Emerging and developing economies (EMD) excluding transition countries economies excluding transition countrieTransition economies include China and East-EU member states (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania,Slovakia, Romania). 2SLS panel fixed effects estimations based on nine periods using 5-year averages between 1970 and 2014. T-statistics in parentheses. Robust standard errors clustered at the country level. All specifications include baseline control variables: GDP per capita, population(log), dependecy ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical values: 16.38 (10 %), 8.96 (15 %), 6.66 (20 %). Significance levels: ***p $<$ 0.01; **p $<$ 0.05; *p $<$ 0.1.

Table A4: Robustness – Baseline including ICT capital stock as control

	OLS				2SLS			
	Full sample		Benchmark sample		Full sample		Benchmark sample	
	(1) Gini market	(2) Gini net	(3) Gini market	(4) Gini net	(5) Gini market	(6) Gini net	(7) Gini market	(8) Gini net
Trade openness	-0.000519	0.00289	-0.0145	-0.00820	-0.0197	0.0161	-0.00228	0.0190
	(0.0155)	(0.0115)	(0.0179)	(0.0115)	(0.0578)	(0.0463)	(0.0554)	(0.0450)
ICT capital stock	0.248	0.382*	0.0463	0.149	0.219	0.403*	0.0723	0.207
	(0.277)	(0.204)	(0.215)	(0.122)	(0.282)	(0.211)	(0.250)	(0.167)
Fixed effects								
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries	90	90	64	64	90	90	64	64
Observations	569	569	428	428	569	569	428	428
Partial R^2					0.078		0.109	
F Test, weak ID					39.170		42.419	
F Test, p-value					0.002		0.002	

Notes: This table includes ICT capital stock (proxy for technological change) as control variable. All specifications include baseline control variables: GDP per capita, population(log), dependecy ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. OLS and 2SLS panel fixed effects estimations based on nine periods using 5-year averages between 1970 and 2014. Clustered robust standard errors in parentheses. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical value: 16.38 (10 %). Significance levels: ***p < 0.01; **p < 0.05; *p < 0.1.

Table A5: Robustness – Baseline using 3-year periods

	OLS				2SLS			
	Full sample		Benchmark sample		Full sample		Benchmark sample	
	(1) Gini market	(2) Gini net	(3) Gini market	(4) Gini net	(5) Gini market	(6) Gini net	(7) Gini market	(8) Gini net
Trade openness	0.0124	0.0143	-0.0142	-0.00418	-0.0334	-0.00931	0.0143	0.0214
	(0.0132)	(0.0110)	(0.0145)	(0.0118)	(0.0649)	(0.0535)	(0.0382)	(0.0309)
Fixed effects								
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries	140	140	82	82	140	140	82	82
Observations	1151	1151	748	748	1151	1151	748	748
Partial R^2					0.049		0.111	
F Test, weak ID					50.877		80.871	
F Test, p-value					0.000		0.000	

Notes: OLS and 2SLS panel fixed effects estimations based on 15 periods using 3-year averages between 1970 and 2014. All specifications include baseline control variables: GDP per capita, population(log), dependecy ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. Clustered robust standard errors in parentheses. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical value: 16.38 (10 %). Significance levels: ***p < 0.01; **p < 0.05; *p < 0.1.

Table A6: Robustness – Subsamples using 3-year periods (2SLS)

(13)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	Gini market	Gini net
(a) Full sample												
Trade openness	-0.00389	-0.00587	-0.00608	-0.00567	-0.00490	-0.00383	-0.00240	-0.000358	0.00347	0.0286	-0.0360	-0.0122
	(-0.40)	(-0.67)	(-0.75)	(-0.76)	(-0.73)	(-0.64)	(-0.44)	(-0.06)	(0.35)	(0.65)	(-0.56)	(-0.23)
Countries	137	137	137	137	137	137	137	137	137	137	137	137
Observations	1136	1136	1136	1136	1136	1136	1136	1136	1136	1136	1136	1136
Partial R^2						0.051						
F Test, weak ID						52.197						
F Test pvalue						0.000						
(b) Benchmark sample												
Trade openness	-0.00851	-0.0101	-0.0101	-0.00934	-0.00802	-0.00597	-0.00283	0.00239	0.0129*	0.0395	0.0132	0.0207
	(-1.14)	(-1.48)	(-1.60)	(-1.64)	(-1.57)	(-1.33)	(-0.70)	(0.55)	(1.86)	(1.17)	(0.35)	(0.67)
Countries	81	81	81	81	81	81	81	81	81	81	81	81
Observations	745	745	745	745	745	745	745	745	745	745	745	745
Partial R^2						0.113						
F Test, weak ID						82.178						
F Test pvalue						0.000						
(c) Advanced economies												
Trade openness	-0.0127**	-0.0114**	-0.00991*	-0.00811	-0.00587	-0.00304	0.000698	0.00603**	0.0149***	0.0295	-0.00381	0.00376
	(-2.23)	(-2.04)	(-1.70)	(-1.38)	(-1.04)	(-0.59)	(0.16)	(2.02)	(3.77)	(0.81)	(-0.11)	(0.16)
Countries	34	34	34	34	34	34	34	34	34	34	34	34
Observations	361	361	361	361	361	361	361	361	361	361	361	361
Partial R^2						0.164						
F Test, weak ID						59.871						
F Test pvalue						0.000						
(d) Developing economies												
Trade openness	0.0310	0.0228	0.0179	0.0135	0.00882	0.00310	-0.00465	-0.0162	-0.0360	-0.0405	-0.224	-0.209
	(1.55)	(1.31)	(1.10)	(0.86)	(0.57)	(0.20)	(-0.28)	(-0.80)	(-1.15)	(-0.40)	(-1.02)	(-1.07)
Countries	103	103	103	103	103	103	103	103	103	103	103	103
Observations	775	775	775	775	775	775	775	775	775	775	775	775
Partial R^2						0.016						
F Test, weak ID						10.880						
F Test pvalue						0.165						

Notes: 2SLS panel fixed effects estimations based on 15 periods using 3- year averages between 1970 and 2014. T-statistics in parentheses. Robust standard errors clustered at the country level. All specifications include country and year fixed effects, and baseline control variables: GDP per capita, population(log), dependecy ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical values: 16.38 (10 %), 8.96 (15 %). Significance levels: ***p $<$ 0.01; **p $<$ 0.05; *p $<$ 0.1.

Table A7: Robustness – Baseline including time trend as control

	OLS				2SLS			
	Full sample		Benchmark sample		Full sample		Benchmark sample	
	(1) Gini market	(2) Gini net	(3) Gini market	(4) Gini net	(5) Gini market	(6) Gini net	(7) Gini market	(8) Gini net
Trade openness	0.00699	0.00969	-0.0104	-0.00334	-0.0571	-0.0201	0.00200	0.0208
	(0.0132)	(0.0103)	(0.0151)	(0.0108)	(0.0633)	(0.0508)	(0.0391)	(0.0326)
Trend	0.267	-0.162	0.433	0.0146	0.308	-0.143	0.412	-0.0265
	(0.420)	(0.325)	(0.420)	(0.298)	(0.410)	(0.318)	(0.414)	(0.307)
Fixed effects								
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries	139	139	82	82	139	139	82	82
Observations	794	794	516	516	794	794	516	516
Partial R^2					0.064		0.120	
F Test, weak ID					43.848		58.143	
F Test, p-value					0.000		0.000	

Notes: This table includes the trend within nine periods as control variable. Period fixed effects are excluded. All specifications include country and year fixed effects, and baseline control variables: GDP per capita, population(log), dependency ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. OLS and 2SLS panel fixed effects estimations based on nine trend periods using 5-year averages between 1970 and 2014. Clustered robust standard errors in parentheses. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical value: 16.38 (10 %). Significance levels: ***p $<$ 0.01; **p $<$ 0.05; *p $<$ 0.1.

Table A8: Robustness – Subsamples including time trend as control

(13)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	Gini market	Gini net
(a) Full sample												
Trade openness	-0.00172	-0.00195	0.0000333	0.00240	0.00488	0.00736	0.00968	0.0115**	0.0114	-0.0442	-0.0565	-0.0195
	(-0.20)	(-0.25)	(0.00)	(0.32)	(0.68)	(1.07)	(1.57)	(2.12)	(1.48)	(-0.89)	(-0.90)	(-0.39)
Trend	-0.00523	-0.0127	-0.0265	-0.0401	-0.0530	-0.0652*	-0.0768**	-0.0874***	-0.0911*	0.469*	0.271	-0.172
	(-0.10)	(-0.26)	(-0.57)	(-0.90)	(-1.27)	(-1.71)	(-2.25)	(-2.62)	(-1.69)	(1.73)	(0.66)	(-0.54)
Countries	136	136	136	136	136	136	136	136	136	136	136	136
Observations	783	783	783	783	783	783	783	783	783	783	783	783
Partial R^2						0.064						
F Test, weak ID						43.983						
F Test pvalue						0.000						
(b) Benchmark sample												
Trade openness	-0.00679	-0.00784	-0.00683	-0.00531	-0.00340	-0.00103	0.00206	0.00649*	0.0141***	0.00853	0.000664	0.0197
	(-1.03)	(-1.34)	(-1.25)	(-1.04)	(-0.73)	(-0.25)	(0.56)	(1.83)	(2.60)	(0.26)	(0.02)	(0.62)
Trend	0.00521	-0.00725	-0.0254	-0.0429	-0.0592	-0.0743*	-0.0883**	-0.100***	-0.104**	0.497	0.393	-0.0390
	(0.08)	(-0.13)	(-0.47)	(-0.84)	(-1.24)	(-1.73)	(-2.34)	(-2.84)	(-1.97)	(1.58)	(0.94)	(-0.13)
Countries	81	81	81	81	81	81	81	81	81	81	81	81
Observations	513	513	513	513	513	513	513	513	513	513	513	513
Partial R^2						0.126						
F Test, weak ID						60.845						
F Test pvalue						0.000						
(c) Advanced econ.												
Trade openness	-0.00485	-0.00294	-0.00122	0.000342	0.00189	0.00348	0.00514	0.00685**	0.00822**	-0.0169	-0.0276	-0.0169
	(-1.31)	(-0.83)	(-0.34)	(0.09)	(0.53)	(1.01)	(1.57)	(2.17)	(2.17)	(-0.73)	(-0.96)	(-0.88)
Trend	0.0216	-0.0118	-0.0424	-0.0666	-0.0855	-0.100	-0.111**	-0.119***	-0.116**	0.630	0.988*	0.196
	(0.32)	(-0.18)	(-0.59)	(-0.92)	(-1.22)	(-1.56)	(-2.03)	(-2.72)	(-2.07)	(1.44)	(1.91)	(0.64)
Countries	34	34	34	34	34	34	34	34	34	34	34	34
Observations	244	244	244	244	244	244	244	244	244	244	244	244
Partial R^2						0.227						
F Test, weak ID						58.967						
F Test pvalue						0.000						
(d) Developing econ.												
Trade openness	0.0254	0.0214	0.0236	0.0265	0.0290	0.0301	0.0287	0.0220	0.000279	-0.210	-0.201	-0.171
	(1.36)	(1.09)	(1.05)	(1.04)	(1.05)	(1.05)	(1.04)	(0.97)	(0.02)	(-1.12)	(-0.98)	(-0.98)
Trend	-0.0817	-0.0824	-0.0832	-0.0838	-0.0838	-0.0824	-0.0781	-0.0665	-0.0285	0.690	0.162	0.107
	(-1.03)	(-1.10)	(-1.05)	(-0.99)	(-0.94)	(-0.91)	(-0.91)	(-0.91)	(-0.34)	(1.12)	(0.19)	(0.16)
Countries	105	105	105	105	105	105	105	105	105	105	105	105
Observations	550	550	550	550	550	550	550	550	550	550	550	550
Partial R^2						0.016						
F Test, weak ID						7.279						
F Test pvalue						0.103						

Notes: This table includes the trend within nine periods as control variable. Period fixed effects are excluded. All specifications include country and year fixed effects, and baseline control variables: GDP per capita, population(log), dependency ratio, social globalization index, political globalization index, FDI index, and large scale natural disasters. 2SLS panel fixed effects estimations based on nine trend periods using 5-year averages between 1970 and 2014. Clustered robust standard errors in parentheses. Weak ID test using Cragg-Donald Wald F-statistic. Stock and Yogo (2005) weak ID critical value: 16.38 (10 %). Significance levels: ***p < 0.01; **p < 0.05; *p < 0.1.

Table A9: Robustness – Alternative definitions of natural disasters (2SLS)

	all large scale disasters		all exogeneous disasters		all disasters	
	(1)	(2)	(3)	(4)	(5)	(6)
	Gini market	Gini net	Gini market	Gini net	Gini market	Gini net
Trade openness	-0.00792	0.0180	-0.00109	0.0209	-0.00450	0.0182
	(0.0449)	(0.0360)	(0.0417)	(0.0334)	(0.0440)	(0.0352)
Fixed effects						
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
Countries	82	82	82	82	82	82
Observations	516	516	516	516	516	516
Partial R^2	0.115		0.133		0.122	
F Test, weak ID	54.533		64.161		58.327	
F Test, p-value	0.000		0.000		0.000	

Notes: Benchmark sample. The instrument (predicted openness) is constructed in a gravity model including (i) all large scale natural disasters (columns 1-3), (ii) all exogeneous natural disasters (columns 4-6), and (iii) all natural disasters (columns 7-9). All specifications include baseline controls. 2SLS panel fixed effects estimations based on nine periods using 5-year averages between 1970 and 2014. Robust standard errors are clustered at the country level. t-statistics in parentheses. Significance levels: ***p $<$ 0.01; **p $<$ 0.05; *p $<$ 0.1.