International Journal of Applied Economics, Finance and Accounting
ISSN 2577-767X
Vol. 18, No. 2, pp. 411-423
2024
DOI: 10.33094/ijaefa.v18i2.1479

Impact analysis of bilateral trade openness and income inequality based on the system GMM method: A case study of transnational dynamic panel data

Fan Ying[1*]
Azeem Fazwan Bin Ahmad Farouk[2]
Li Qing Lin[3]

[1,2,3]*Centre for Policy Research, Universiti Sains Malaysia, Penang, 11800, Malaysia.*
[1]*Email: fanying0419@gmail.com*
[2]*Email: azeemf@usm.my*
[3]*Email: qinglin.li@student.usm.my*

Keywords:
Bilateral trade openness
GMM analysis
Human resources
Income inequality
Labor proficiency.

JEL Classification:
A10.

Received: *23 August 2023*
Revised: *2 December 2023*
Accepted: *26 February 2024*
Published: *22 March 2024*
(Corresponding Author)*

Abstract

To analyze the impact of bilateral trade openness on income inequality, the study selected 16 countries with the highest global import and export trade rankings as research subjects, combined with cross-border dynamic panel data from 2005 to 2020, and used the Gaussian Mixture Model (GMM) to analyze the dynamic impact of natural and policy factors on domestic income inequality in the process of deepening bilateral trade openness. Empirical research has found that the policy-oriented expansion of openness in 16 countries has an inhibitory effect on domestic income inequality, while natural openness is influenced, to varying degrees, by different trading partners. High-quality education and sound infrastructure can help regulate income inequality. The results indicate that policy-based openness between 16 countries and those with weaker technological output, i.e., patent quantity, education level, i.e., higher education, and immigration, can suppress domestic income inequality, which is consistent with the expected hypothesis of the impact mechanism. The results indicate that in-depth research on the relationship between trade openness and income inequality can provide a basis for policymakers to adjust trade policies and provide recommendations to reduce income inequality. Meanwhile, the results and methods of this study can provide references for other scholars and promote research progress in related fields.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Data Availability Statement: The corresponding author may provide study data upon reasonable request.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

1. Introduction

Trade openness (TO) between countries contributes to the high-quality development of the domestic economy (Abdmoulah, 2023). TO degree reflects the degree to which a country's market is open to the outside world (Cui, Guo, & Bian, 2023) The continuous development of social productivity has greatly promoted the deepening and expansion of the international division of labor and exchange, thus requiring the free flow of goods and production factors worldwide to allocate limited resources more effectively and reasonably (Usman, Kousar, Makhdum, Muhammad, & Nadeem, 2022). From a macro perspective, TO can promote the development of the national economy, but there may also be income inequality (II) (Kumari et al., 2023). International Monetary Fund(IMF) report shows that under the growth of developing countries and market economies, the Gini coefficient dropped from 0.7 in 1988 to 0.625 in 2013, indicating that the gap in per capita income among countries is still obvious (Kinfack & Bonga-Bonga, 2023). The II of most developed countries is also becoming increasingly significant. In most developed countries, TOp 1% of people earn 10% of the total,

such as the United States. The economic growth of developing countries such as China and India has lifted most of the population out of poverty. However, the income of the Top group far exceeds that of the general population (Vetsikas & Stamboulis, 2023). Since China's reform and opening up, its economy has grown rapidly, people's material living standards have also been improved, and the continuous increase in per capita income has opened up space for wealth differentiation (Mohamed Sghaier, 2023). Since 2000, China's Gini coefficient has remained above the warning line of 0.4 for a long time. There are many influencing factors for high domestic II, which are closely related to the decrease in the proportion of labor income. This is mainly reflected in the continuous decrease in the proportion of labor income to national income (Barakat, Madkour, & Moussa, 2023).

Mtar and Belazreg (2023) in the article "On the nexus of innovation, trade openness, financial development and economic growth in European countries: New perspective from a GMM panel VAR approach", used the panel Vector Autoregression (VAR) method to study the relationship between trade openness, economic growth, and other factors in 11 European countries from 2001 to 2016. It was found that there is a one-way relationship between economic growth and financial development, between trade and economic growth, and between innovation and financial development. Lee, Lee, and Cheng (2022) in the article "The impact of Foreign Direct Investment (FDI) on income inequality: Evidence from the perspective of financial development", the relationship between income inequality, foreign direct investment, and financial development was examined in a sample of 37 countries from 2001 to 2015. Using a panel smooth transition regression model, empirical results showed that foreign direct investment helps reduce income inequality, But when a country reaches a certain level of financial development, this beneficial impact will weaken. Khatun and Saadat (2022) used econometric analysis to determine the optimal level of income inequality in South Asia, using panel data from Bangladesh, India, Nepal, Pakistan, and Sri Lanka over a period of 34 years. The results of this study confirm that the optimal level of income inequality does exist, occurring when the Gini coefficient is 0.4492. Liu, Lai, and Liu (2022) In the article "Trade liberalization, domestic reforms, and income inequality: Evidence from Taiwan", they estimated the impact of trade liberalization on household income inequality and studied whether trade liberalization or domestic reforms are the main factors affecting the exacerbation of inequality in Taiwan, a middle-income open economy. Evidence suggests that domestic reforms are conducive to technological progress in skilled labor and changes in industrial structure, rather than trade liberalization, which is the main driving force of income inequality.

There are many studies on TO and income distribution, but a single-dimensional analysis cannot comprehensively measure the influencing factors of domestic II (Bouaziz, Salhi, & Jarboui, 2020). Therefore, the study proposes an analysis of the impact of bilateral trade openness and income inequality based on the system GMM method, with 16 countries ranked among the top 15 in global import and export trade volume in 2020 as the research objects. Firstly, using cross-border dynamic panel data from 2005 to 2020, stable and non accidental trade data is screened based on the rules of the bilateral trade network; Secondly, based on the perspective of bilateral trade, the source and destination of trade flows are distinguished, and the expansion gravity model is used to subdivide trade openness into natural openness and policy openness. It is found that policy openness has a trade protection tendency, which suppresses natural openness, resulting in a lower actual degree of openness than natural openness; finally, the system GMM method is used to further deepen the dynamic impact of natural and policy factors on domestic income inequality in the process of bilateral trade opening. Analyze the driving factors of domestic income inequality, hoping to enhance the comprehensiveness of trade opening policy decisions.

2. Analysis of the Impact Measurement of BTO and Domestic II

This chapter analyzes the impact measurement of Bilateral Trade Openness (BTO) and domestic II. Firstly, the impact mechanism between BTO and domestic II is analyzed. Through literature regression, research and hypotheses on the mechanism of action are conducted to analyze the role of TO policy in national II and its impact. The second section is the measurement analysis of BTO and domestic II. TO method is divided into two parts using the extended gravity model: policy-oriented openness and natural-oriented openness. Regression is performed by increasing variables such as country area and coastal countries.

2.1. Impact Mechanism of BTO and Domestic II

TO aims to speed up the free flow of goods, services, technology, information, and other elements in the international market. It can promote competition in domestic and international markets, achieve effective resource allocation, and maximize profits (Bayar, Günçavdı, & Levent, 2023). When TO increases the overall economy and income, the issue of unequal distribution can lead to domestic II phenomena, which can impact the economic development and social stability of various countries (Barrales-Ruiz, von Arnim, & Mohammed, 2023). Therefore, the study conducted research and hypotheses on the mechanism of action through literature regression, analyzing the role of TO policy in the process of Country II and how it had an impact. The improvement of the TO level mainly affects II through the relative demand, sources, and benefits of production factors. A single level of factors cannot independently affect domestic II. From a bilateral perspective, attention is paid to the gap in technology, education, and immigration, which is a relative

comparative advantage (Aziz, Memon, & Qader, 2023). Figure 1 shows the impact mechanism of TO on domestic II.

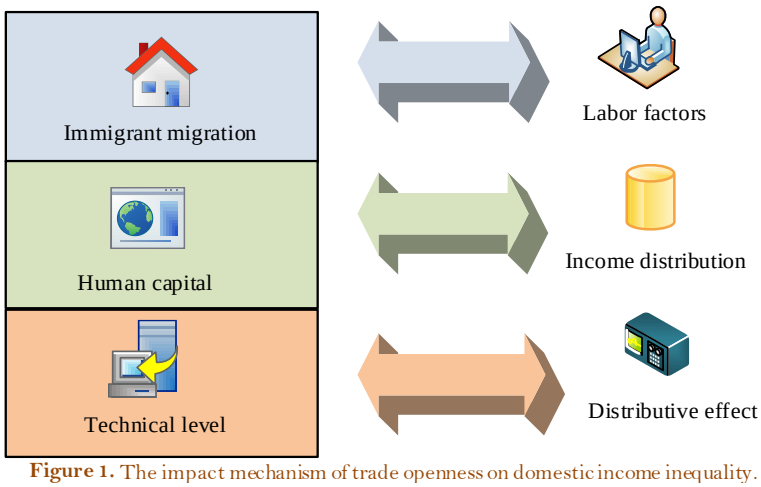

Figure 1. The impact mechanism of trade openness on domestic income inequality.

Technological methods are constantly spreading in globalization, and the technological levels of developing and developed countries are different. Many empirical studies have shown that the technological changes in developed countries are skill-biased. The main factors contributing to the formation of trade distribution effects are technological differences and skill biases of new technologies. The wage gap and skill premium in developed countries are less affected by trade in developing countries. Skill-biased technology is the main cause of skill premium rather than trade (Gao & Qiu, 2023). Policy and national spillover effects influence domestic income inequality in open and closed economic growth. The nature of enterprises and employees differs, and allocating capabilities in different research and manufacturing sectors impact the labor market and operations. Departmental changes can lead to a redistribution of human resources (HR) and technology. The complementarity between capabilities and technology will exacerbate domestic competition. Knowledge spillover has an impact through productivity innovation. The connection between the country itself and its policy and trading partners and funding subsidies will exacerbate domestic II on a global scale (Betancourt Gómez, 2023). Increasing trade development in developing countries includes reducing freight, insurance, tariffs, and travel and communication costs. Domestic trade is affected by TO, which manifests as a balance between the reduction of trade costs and communication travel costs. The interaction output of technical personnel can also disrupt the balance of car manufacturing (Castaldo & De Bonis, 2023). Under the technology diffusion effect, BT can promote upgrading technology and quality through import and export, and domestic labor needs to be redistributed, thereby affecting domestic II (Dvoskin & Landau, 2023).

In summary, the mechanisms of import and export channels are different during TO, but both can cause technology diffusion effects. BT from technologically advantageous countries will increase the demand for skilled labor, exacerbating domestic income inequality. Therefore, hypothesis 1 is proposed: TO in countries with technological disadvantages can promote income equality.

There is a relativity between material resources and HR, mainly manifested in the fact that labor capital contains its own production knowledge, labor management skills, and civilized qualities. It combines human beings and HR and will not be transferred due to product transactions (Casas & Torres, 2023). The most important part of HR investment is education expenditure. The level of education will be used to measure human capital. The education level will affect the labor force's proficiency, thus affecting labor productivity. A high level of education will enable society to obtain more resources, and its labor force will have more professional skills and knowledge, indicating that HR is more advanced (Shaikh & Ragab, 2023). Through the influence mechanism of the technological level, the proficiency of the labor force will affect income distribution. The difference in teaching level has led to an increase in the proportion of income distribution among the workforce receiving higher education. Their labor level is more proficient, exacerbating domestic II (Premrov & Schnetzer, 2023).

In summary, human capital is influenced by the level of education in various countries, and to a certain extent, it will affect the distribution of labor income. During BTO, there may be differences in quality between countries with different levels of education. When conducting trade with countries with relatively advantageous educational levels, the demand for higher education talents will increase accordingly. The lower level of underdeveloped areas will exacerbate domestic income inequality. Therefore, hypothesis 2 is proposed: TO in countries with educational disadvantages can promote domestic income equality. Figure 2 shows the proposed path for hypothesis 2.

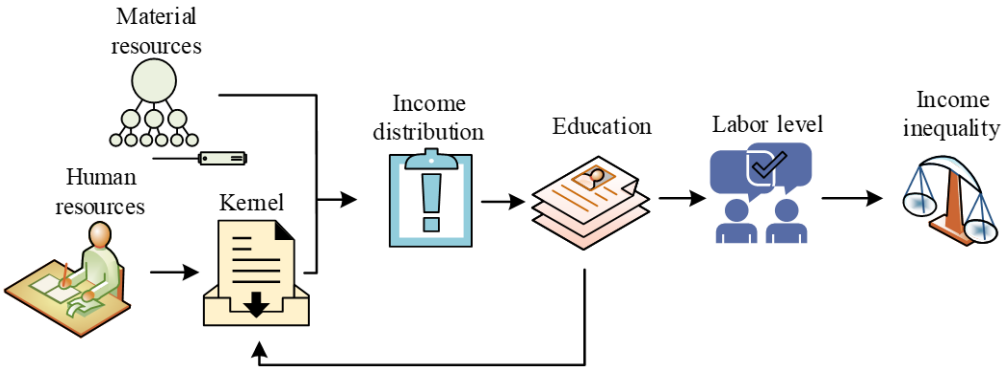

Figure 2. The proposed path for hypothesis 2.

The mixed effects of trade drive domestic II, and BT flows impact its immigration (Ofori, Dossou, Asongu, & Armah, 2023). Multiple factors lead to personnel mobility from a bilateral perspective. Immigration is not a randomly assigned process. Relevant personnel will choose to immigrate based on the economic conditions and opportunities provided by the country (Sommet & Elliot, 2023). Overall, there is a positive correlation between immigration and per capita income levels and favorable economic and environmental indicators (McFarland, Hill, & Montez, 2023). Relevant studies suggest that population migration reduces Region II (Kebede & Tawiah, 2023). Immigrant groups typically have a higher level of education than residents. Their quality of life and survival skills have advantages, which can affect the host country through total factor productivity, and the types of skills available for production will also increase accordingly.

In summary, TO drives the national economy, and technology-intensive talents will selectively relocate. Global labor resources will be redistributed, further promoting the host country's economic development and contributing to income equality in the immigrating countries. Therefore, hypothesis 3 is proposed: TO with immigrants moving to disadvantaged countries will promote domestic income equality.

2.2. Measurement Analysis of BTO and Domestic II

TO degree measures the proportion of total imports and exports to Total Gross Domestic Product (GDP) of the year at a specific time, reflecting the country's dependence on foreign markets, also known as foreign trade dependence (Barma & Modibbo, 2022). The study uses the extended gravity model to divide the TO method into policy-oriented and natural-oriented openness. The degree of natural openness was obtained by simultaneously increasing variables such as national area and coastal countries for regression. The difference between the fitted and true values is used as the policy-based openness and Equation 1 is the regression model used.

$$\begin{aligned}\ln TSH_{ijt} = {} & \beta_0 + \beta_1 \ln(GDP)_{it} + \beta_2 \ln(GDP)_{jt} + \beta_3 \ln(POP)_{it} + \beta_4 \ln(POP)_{jt} \\ & + \beta_5 \ln(Area)_i + \beta_6 \ln(Area)_j + \beta_7 \ln(Dist)_{ij} + \beta_8 Contig_{ij} \\ & + \beta_9 Comlangoff_{ij} + \beta_{10} Landlock_i + \beta_{11} CP_{it} + \beta_{12} CP_{jt} \\ & + \varepsilon_{ijt}\end{aligned} \quad (1)$$

In Equation 1, the importing and exporting countries are represented by i, and their cooperating trading countries are represented by j. The proportion of total imports and exports between i j countries to the GDP i countries in t is represented by TSH. The country's gross domestic product and population are expressed in terms of GDP and POP, respectively. The land area of a country is represented by $Area$. The bilateral geographical distance is represented by $Dist$. Whether these two trading parties are adjacent and have a common language is represented by $Contig$ and $Comlangoff$, respectively. Whether the trading object is coastal is represented by $Landlock$. The interaction terms are represented by CP_{it} and CP_{jt}, respectively. The weights and free terms are represented by β_n and $n \in [0,12]$. Table 1 shows the description and explanation of variables.

Table 1. Variable description and explanation.

Variable type	Variable	Variable symbol	Data sources
Bilateral trade volume	Total import and export volume	Trade	DOTS
	Total imports	Import	
	Total exports	Export	
Bilateral trade openness	Trade share (TSH)	Ln TSH	$\ln TSH = \ln(Trade / GDP_i)$

Variable type	Variable	Variable symbol	Data sources
Economic level	Gross domestic product	$lnGDP_i$、$lnGDP_j$	World Bank
Geographic environment	Bilateral distance	lnDist	GeoDist library
	Coastal state	$LandLock_j$	
Resource conditions	Population size (POP)	$lnPOP_i$、$ln\ POP_j$	
	land area	$lnArea_i$、$lnArea_j$	
Cultural distance	Adjacent state	Contig	
	common language	Comlangoff	
Interaction	Population size and the adjacent state interaction term	CP_i、CP_j	$CP_i = Contig * \ln POP_i$ $CP_j = Contig * \ln POP_i$
Real trade openness	Trade dependence	Open	$Open = Trade / GDP_i$
Natural open	Natural openness	Nopen	Formula fitting obtained
Policy-oriented openness	Trade policy guided openness	Popen	$Popen = Open - Nopen$

Note: * symbol represents data multiplication.

In Table 1, most of the data comes from corresponding guidance and library files, and some data needs to be fitted through regression results. Equation 2 is the natural type openness fitting formula.

$$Nopen_{ijt} = T\hat{S}H_{ijt} = \exp(\hat{\lambda}_T Z_{ijt}) \quad (2)$$

In Equation 2, the fitted natural type openness is represented by $Nopen_{ijt}$. The coefficients and variable combinations in the equation are represented by $\hat{\lambda}_T$ and Z_{ijt}, respectively. The difference between the actual TO degree and the fitted natural type openness is the policy type openness. Equation 3 represents policy-based openness.

$$Popen_{ijt} = Open_{ijt} - Nopen_{ijt} \quad (3)$$

In Equation 3, the policy-based openness is represented by $Popen_{ijt}$. The actual openness is expressed in $Open_{ijt}$. According to the model summary and indicator comparison of the overall natural and policy-oriented openness of 16 countries, the extent of natural openness is smaller than that of policy-oriented openness. The reasons for the fluctuations in policy-based openness vary, which can reflect the differences in the policy roles of different countries. The natural openness of countries like South Korea has remained relatively low, while countries like Belgium have shown a clear upward trend. Overall, natural openness is relatively balanced and at a low level. The degree of policy-oriented openness is relatively high, and the impact on bilateral trade varies in different years. From the perspective of BT, the degree of policy-oriented and natural-oriented openness is imbalanced, and the overall data dimension is stable. BT and trade results are robust, and data quality issues can be ruled out. The auxiliary regression analysis of the imbalanced panel shows that the model is more suitable for this Ah Yong fixed effect. The fixed variable is the generation time dummy variable, and combined with least squares dummy variable regression analysis, the results are relatively more robust. In the extended stress model and sub-sample regression analysis, the economic development level, land area, whether there is a common language, and whether the coastal areas directly impact the overall natural openness of bilateral countries.

Regarding the income distribution of TO, the relative status of specific countries is more important. For the international division of labor system, developing countries have abundant resources of unskilled labor, but their comparison needs further analysis. The reason is that the definition of factor intensity is based on the current situation of local resources. In the comparison between middle-income countries and high-income countries, middle-income countries lack professional skills and have abundant labor resources. However, their professional skills and labor resources are different compared to low-income countries. Expert Meschi believes that the import and export trade between developing countries and high-income countries will exacerbate the income distribution disadvantage of developing countries, and traditional conclusions only apply to middle-income countries. Based on previous literature research, the study will differentiate 16 countries based on their level of development. The classification includes developing and developed countries, and the heterogeneity test distinguishes between the income levels of trading partners and the forms of trade imports and exports. The analysis confirms that trade partners with good development levels and advantages regarding upward space and location are the 16 natural open-oriented targets.

The II measurement includes the Gini coefficient, Theil coefficient, and the construction index of income groups. Table 2 shows the sources of the Gini coefficient of the World Bank's D&S dataset and its income division.

Table 2. The source of the Gini coefficient of the D&S data set and its income division.

Project	Reference unit									
	Family		Family equivalents		Personal		Personal equivalents		Total	
Source	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
Expenditure	/	23	/	/	/	104	/	1	/	128
Income	254	72	/	12	108	46	/	34	362	164

In Table 2, the reference units are both household and individual directions. The measurement standard for household income is total or after-tax, and the source measurement includes income or expenditure. Figure 3 shows the drawbacks of D&S and some commonly used datasets.

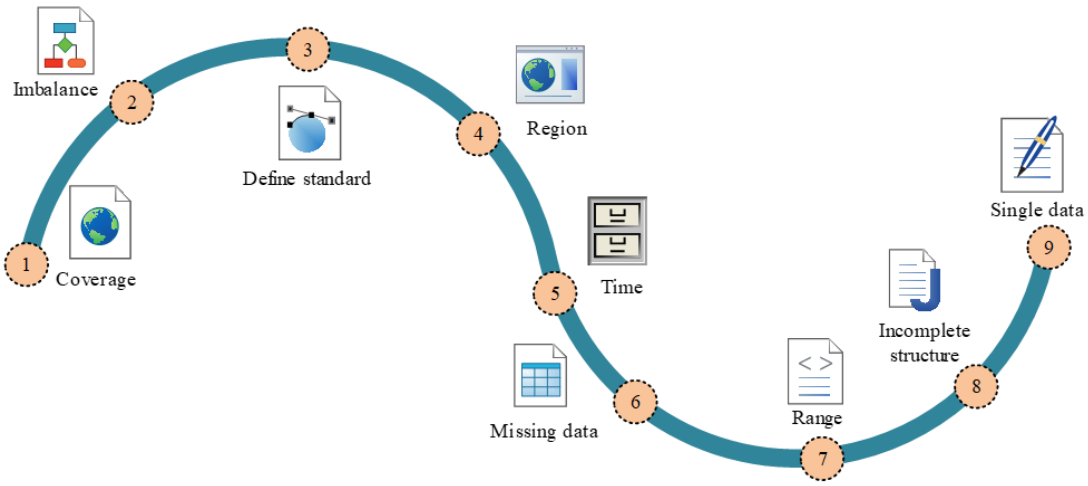

Figure 3. Disadvantages of D&S and some commonly used datasets.

The drawbacks of the D&S dataset are insufficient data coverage, sparse and imbalanced population, and different sources of defining standards. The drawbacks of the orld Income Inequality Databas (WIID) dataset are severe data loss and differences in population span. The disadvantage of the Luxembourg Income Study (LIS) dataset is that it only covers more affluent countries and has a single data structure. Therefore, the study used a niversity of Texas Inequality Project (UTIP) database.

3. Empirical Analysis of BTO and Domestic II

This chapter conducts empirical analysis on BTO and domestic II. The natural and open indicators are calculated using a gravity model, and the dynamic impact of heterogeneity characteristics is analyzed. The systematic GMM methods and gravitational models can reduce potential endogeneity issues to a certain extent. Adopting absolute geographical location can further reduce endogeneity. In this chapter, the first step is model construction and variable description. Next is statistical and regression analysis. Then there is endogeneity, robustness, and heterogeneity testing analysis. Finally, it is the verification of the action mechanism.

3.1. Model Construction and Variable Description

Natural and open indicators are measured using gravity models to analyze the dynamic impact of heterogeneity characteristics. The study adopts the system GMM method for analysis, and Equation 4 is the model set.

$$Inequality_{it} = \alpha + \beta_1 Inequality_{i,t+1} + \beta_2 Open_{ijt} + \sum_k \gamma_k X_{ikt} + T_t + \eta_i + \varepsilon_{ijt} \quad (4)$$

In Equation 4, 16 research target countries are represented by i, and their BT partners are represented by j. The period is represented by t. The domestic II indicators of households are represented by $Inequality$. TO indicator is represented by $Open$. A series of control variables are represented by X_k. The time dummy variable is represented by T. The development level and BT distance of 16 countries are represented by η. The residual is represented by ε. Table 3 shows the variable explanations and their data sources.

Table 3. Explanation of variables and their data sources.

Variable type	Variable	Variable symbol	Data sources
Explained variable	Domestic income inequality	Inequality	EHII index in UTIP
Explanatory variable	Trade openness	Open	DOTS
	Natural open	Nopen	
	Policy-oriented openness	Popen	
Control variable	Per capita GDP	GDPpc	WorldBank
	educational level	Edu1	
	Foreign direct investment	FDI	
	Government size	Govern	Economic freedom of the world
	Labor regulation	Labor	
	Female participation	Women labor	Worldbank
	Women's status	Women score	
	Trade infrastructure	Trade infra	
	Inflation rate	Infla	
	unemployment rate	UnemployR	
	Urbanization degree	Urban	
Action mechanism variable	Research expenditure	Rd (=rd1-rd2)	Worldbank
	Number of patents	Patent (=Patent1-patent2)	
	The primary education enrollment rate	Primary (=Primary1-primary2)	
	Secondary education enrollment rate	Secondary (Secondary1-secondary2)	
	The higher education enrollment rate	Tertiary (Tertiary1-tertiary2)	
	Immigrant migration	Migration (=Migration1-migration2)	
Natural resource endowment	Cultivated land area	Farmland	Worldbank
	Labor force	Labor	
	Per capita arable land area of the labor force	Resource 1,2 (=Farmland1,2/labor1,2)	
	Natural resources	Resources	*Resources=1:resources 1>resources2*
Technological resource endowment	Unit research input patent output	Technology1,2(=Patent1,2/rd1,2)	Worldbank
	Technical resources	Technology	*Technology=1:technology1>technology2*

In Table 3, the suffix 1 of the variable name represents the 16 countries, and the suffix 2 represents the trade target countries of the 16 countries. There are a total of 11 control variables and six mechanism variables, with the main source of variables being World Bank.

3.2. Statistics and Regression

Research is conducted to screen trade values through social network analysis to stabilize trade behavior. The dataset adopts unbalanced panels. Table 4 shows the descriptive statistics of the core explanatory variables.

Table 4. Descriptive statistical results of core explanatory variables.

Core variables	N	Mean	P50	Sd.	Min.	Max.	Range
Inequality	10009	0.026	0.028	0.005	0.009	0.032	0.023
Open	9825	0.006	0.001	0.022	0	0.340	0.341
Nopen	10534	0.012	0	0.263	0	9.126	9.216
Popen	8918	0.004	0	0.018	-0.055	0.296	0.351

In Table 4, there are a few cases where the minimum values of the three dimensions of TO are 0. The household II indicators in 16 countries are within the range of 0.009 to 0.032, with a small data range but relatively large changes. There are issues with the substitution and segmentation of TO indicators, and the

fitted policy-based open indicators are less than zero, indicating a trend toward increasing trade protection. Table 5 shows the descriptive statistics of the control variables.

Table 5. Descriptive statistical results of control variables.

Control variable	N	Mean	P50	Sd.	Min.	Max.	Range
lnGDPpc	11498	17.96	20.99	6.526	0	21.97	21.97
lnFDI	6706	23.78	23.97	1.408	17.88	25.91	8.012
lnInfla	10621	0.756	0.793	0.962	-3.284	3.068	6.351
lnGovern	11498	1.272	1.278	0.273	0.481	1.878	1.398
lnLabor	11498	1.127	1.259	0.503	-0.326	1.955	2.281
lnTradeinfra	9738	4.219	4.326	0.394	2.478	5.018	2.544
lnUnemployR	10714	1.813	1.813	0.467	0.752	3.263	2.511
lnUrban	10961	1.236	1.236	0.979	-0.948	3.893	4.842
lnWomenlabor	11499	4.094	4.094	0.258	3.099	4.332	1.234
lnWomenscore	11499	4.429	1.129	0.136	4.136	4.606	0.471

In Table 5, although some variables have negative and zero minimum values, the overall variation amplitude of the control variables is insignificant, and the distribution is relatively balanced. The system GMM model is used to estimate dynamic Panel data. Table 6 shows the benchmark regression model after sequentially adding variables.

Table 6. Benchmark regression model with sequentially added variables.

Variable	(1) Open	(2) Open	(3) Nopen	(4) Popen	(5) Both	(6) Both+Dist.	(7) All	(8) ALL+Year
L.inequality	0.112 ***	-0.200 ***	0.106 ***	0.113 ***	0.118 ***	-0.036 ***	-2.05 ***	/
Open	-0.147 ***	-0.076	/	/	/	/	/	/
Nopen	/	/	-0.001	/	-0.035 ***	0.152	0.025	0.000
Popen	/	/	/	-0.112 **	-0.040 *	-0.046 **	-0.049 *	-0.000 ***
lnDist	/	0.004 *	/	/	/	0.000	0.002	-0.000 ***
Dlevel1	/	0.113 ***	/	/	/	/	0.098 ***	0.000 ***
Edu1	/	0.000 ***	/	/	/	-0.000 ***	0.000 ***	-0.000 ***
L.edu1	/	0.000 ***	/	/	/	0.000 ***	0.000 ***	-0.000 ***
lnGDPpc2	/	-0.000 ***	/	/	/	-0.000 ***	-0.000 ***	-0.000 ***
lnFDI	/	-0.001 ***	/	/	/	-0.001 ***	-0.001 ***	-0.000 ***
lnInfla	/	-0.002 ***	/	/	/	-0.002 ***	-0.003 ***	0.000 ***
lnGovern	/	-0.007 **	/	/	/	-0.021 ***	-0.012 ***	0.000
lnLabor	/	0.015 ***	/	/	/	0.018 ***	0.012 ***	-0.000
Constant	0.024 ***	-0.001	0.023 ***	0.023 ***	0.023 ***	0.249 ***	0.106 ***	0.028 ***
Observations	7609	3268	8002	6911	6911	3268	3268	3268
Observing individuals	661	467	719	609	609	466	466	466
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No	No	Yes

In Table 6, the data in parentheses are Standard errors. The significance levels of 0.01, 0.05, and 0.10 were marked with ***, **, and *, respectively. In column (1), the actual TO and domestic II with their lag values are added to the regression, and on this basis, control variables are added to form column (2). Due to interference from other factors, the actual TO significantly impacts II and becomes an insignificant inhibitory effect. This shows that the interference of other factors leads to the unstable effect of TO on domestic II, indicating that the subdivision of natural and policy-oriented openness helps analyze the internal impact of domestic II. From the tests of variables in columns (3), (4), and (5), policy-oriented openness has a more

significant inhibitory effect on domestic II. From the analysis of variables in columns (6), (7), and (8), the role of geographical factors is not obvious, developed countries face more serious social problems, and the impact of natural openness on domestic II is not significant. In order to explain the changes and core issues, the study did not include annual dummy variables and fixed effects of control time later.

3.3. Analysis of Endogeneity, Robustness, and Heterogeneity Testing

When constructing a natural open system, the system GMM methods and gravity models can reduce potential endogeneity issues to a certain extent and reduce endogeneity by using absolute geographical location. Table 7 shows the endogeneity test results.

Table 7. Endogeneity test results.

Variable	(1) Base	(2) Colony	(3) Institution	(4) Continent	(5) Open
L.Inequality	-0.206***	-0.201***	-0.161***	-0.157***	-0.225***
Nopen	0.023	-0.143	-0.495	-0.023	/
Popen	-0.049*	-0.049*	-0.084**	-0.073**	/
Open	/	/	/	/	-0.096
lnDist	0.003	/	/	/	/
colony	/	0.018*	0.011	0.005	-0.011
institution	/	/	0.046***	0.045***	0.055***
Asia	/	/	/	-0.018**	-0.023
Europe	/	/	/	-0.048***	-0.068***
Dlevel1	0.098***	0.096***	-0.015	0.031**	0.027
Constant	0.107**	0.182***	0.335***	0.119*	0.059
Observations	3268	3268	3268	3268	3268
Observing individuals	468	468	468	468	468
KP-LM	/	Pass	Pass	Pass	Pass
Waldrk F	/	Pass	Pass	Pass	Pass
Control variable	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No

In Table 7, the significance levels of 0.01, 0.05, and 0.10 are marked with ***, **, and *, respectively. From the endogeneity test results, the impact of natural openness on domestic II is insignificant, while policy-based openness can effectively reduce domestic II. Adding colonial historical relationships, regional dummy variables, and institutional quality to column (1) of Table 7 can form data for columns (2), (3), and (4). The direction of its impact has not been changed, indicating the robustness of the results, which can also be confirmed again in the data in column (5). Table 8 shows the endogeneity test of the variable lag period.

Table 8. Endogeneity test of the variable lag period.

Variable	(1) Base	(2) CoreLag	(3) CoreLag_IV	(4) AllLag_IV	(5) Open_ALL
L.Inequality	-0.157***	-0.183***	-0.158***	-0.065***	-0.071***
Nopen	-0.023	-1.059	-0.043	0.058	/
L.Nopen	/	0.902	/	/	/
Popen	-0.073**	-0.118*	-0.079*	-0.069**	/
L.Popen	/	-0.091	/	/	/
Open	/	/	/	/	-0.123*
L.Popen	/	/	/	/	0.005
Dlevel1	0.031**	0.011	0.031**	0.005	0.006
Colony	0.005	-0.001	0.006	-0.007	-0.007
Institution	0.047***	0.052***	0.047***	0.000	0.000
Asia	-0.018**	-0.019**	-0.018**	-0.008***	-0.009***
Europe	-0.148***	-0.038***	-0.047***	-0.001	-0.001
Constant	0.119*	0.109	0.122*	0.223**	0.215**
Observations	3268	3178	3268	3268	3178
Observing individuals	468	449	468	468	449
KP-LM	Pass	Pass	Pass	Pass	Pass
Waldrk F	Pass	Pass	Pass	Pass	Pass
Control variable	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No

In Table 9, the significance levels of 0.01, 0.05, and 0.10 are marked with ***, **, and *, respectively. According to KleibergenPaap-Lagrange Multiplier (KP-LM) statistics and Waldrk F statistics in the test results, the original hypothesis of insufficient and weak identification of Instrumental variables estimation can be rejected. This indicates that the variable passed the 1% significance test, indicating that the selection of Instrumental variables estimation is reasonable. Table 9 shows the robust regression results of sample method bias.

Table 9. Sample method bias robustness regression results.

Variable	(1) Base	(2) Discontinuity	(3) Truncation	(4) Balance	(5) LSDV	(6) GINI
L.Inequality	-0.158***	-0.212***	-0.206***	-0.212***	-0.321***	/
L.GINI	/	/	/	/	/	-0.065**
Nopen	-0.022	0.008	0.089	-0.077	0.094*	1.388
Popen	-0.073**	-0.228***	-0.273***	-0.081**	-0.017*	1.521
Dlevel1	0.031**	0.003	-0.018	0.008	0.015***	1.765***
Colony	0.005	0.004	-0.022*	0.005	0.001***	-0.529*
Institution	0.046***	0.046***	0.045***	0.045***	0.024***	-0.209**
Asia	-0.017**	-0.013*	-0.008	-0.013*	0.032***	-0.983***
Europe	-0.047***	-0.031***	-0.025***	-0.035***	-0.031***	-1.555***
Observations	3268	3268	2996	2912	3268	4050
Observing individuals	468	468	458	377	468	479
Control variable	Yes	Yes	Yes	Yes	Yes	Yes

In Table 10, the significance levels of 0.01, 0.05, and 0.10 are marked with ***, **, and *, respectively. The core and dependent variables are subject to 1% tail reduction and truncation to reduce the impact of outliers on regression analysis. From the sample test results, only the coefficient size of the natural and policy open indices and control variables fluctuates, and their significance can remain stable. The overall state of the coefficient level is relatively stable, with a small base of the domestic II index and a small fluctuation range, indicating that the results under the system GMM method are still stable. Moreover, the second-order lag instrumental variables estimation is helpful for behavior modeling, further showing that the system GMM is a better model. Table 10 shows the results of income-level heterogeneity testing.

Table 10. Income level heterogeneity test results.

Variable	Low income	Low to medium income	Medium to high income	High income
L.Inequality	/	-0.137**	-0.133***	-0.198***
Nopen	/	-4.137**	-2.114***	-0.057
Popen	/	0.121	0.175***	-0.067**
Dlevel1	/	-0.077***	0.042***	0.007
Colony	/	-0.011*	0.015**	0.001
Institution	/	0.053***	0.017***	0.041***
Asia	/	-0.037***	-0.021***	-0.003
Europe	/	-0.024***	-0.016***	-0.025***
Observations	4	291	747	2226
Observing individuals	1	46	115	307
Control variable	Yes	Yes	Yes	Yes

In Table 10, the significance levels of 0.01, 0.05, and 0.10 are marked with ***, **, and *, respectively. The trade target countries of 16 countries are divided into four types. Regarding policy-oriented openness, trade with high-income countries will promote domestic income balance, while trade with other low-income countries will exacerbate domestic trade. For natural openness, trade with countries of any income level can alleviate domestic II, with significant differences. The study added region and TO degree interaction indicators in the benchmark model. Table 11 shows the results of regional heterogeneity testing for BT partners in 16 countries.

Table 11. Regional location heterogeneity test results.

Variable	Africa	America	Asia	Europe	Oceania	Regional * trade
L.EHII	-0.333***	-0.068	-0.104***	-0.208***	-0.235*	-0.206***
Nopen	-0.247	0.068	-3.376***	0.023	3.608	-27.323***
Nopen_Asia	/	/	/	/	/	26.459***
Nopen_Europe	/	/	/	/	/	26.775***

Variable	Africa	America	Asia	Europe	Oceania	Regional * trade
Popen	0.267	0.015	0.024	-0.045***	-0.348*	-3.226***
Popen_Asia	/	/	/	/	/	3.249***
Popen_Europe	/	/	/	/	/	3.188***
Dlevel1	-0.081**	0.026*	0.041***	-0.029*	/	-0.029***
Colony	-0.022***	0.013***	0.027***	0.001	-0.001	0.016***
Institution	0.007	0.015**	0.031***	0.037***	0.025	0.055***
Asia	-0.062***	-0.015***	-0.023***	0.009	-0.035***	/
Europe	-0.025***	-0.012***	-0.017***	-0.014*	-0.0058	/
Observations	203	404	982	1622	52	/
Observing individuals	32	63	149	216	11	/
Control variable	Yes	Yes	Yes	Yes	Yes	/

In Table 11, the significance levels of 0.01, 0.05, and 0.10 are marked with ***, **, and *, respectively. From the regression analysis results, the policy trade amount of countries in different locations naturally shows polarization, with varying degrees of significance. In policy-oriented openness, trade between European and Oceania countries will reduce domestic II, while the trade role of other regional countries is the opposite. The trade with African and Asian countries in natural openness will reduce domestic II, and the trade-related role of Asian countries is more significant. Overall, the trade role of countries in Asia and Africa will exacerbate domestic II. Table 12 shows the heterogeneity test of resource endowments.

Table 12. Heterogeneity testing of resource endowments.

Variable	Rich natural resources	Scarcity of natural resources	Rich technical resources	Scarcity of technical resources
L.EHII	-0.332***	-0.151***	-0.179***	0.196***
Nopen	0.116*	0.201	0.179***	-0.179***
Dlevel1	-0.054***	0.016	-0.036***	-0.109***
Colony	0.111**	0.029***	-0.025***	-0.022***
Institution	0.019***	0.021***	0.013**	0.037***
Asia	-0.097**	0.008	-0.013**	0.019***
Europe	-0.085*	-0.024***	-0.013*	-0.005
Observations	1066	1148	1939	4701
Observing individuals	152	160	199	474
Control variable	Yes	Yes	Yes	Yes

In Table 12, the significance levels of 0.01, 0.05, and 0.10 are marked with ***, **, and *, respectively. After analyzing the regression results, for policy-oriented openness, trade between countries with abundant natural resources will promote domestic income balance and weaken domestic II. The effect is opposite from the perspective of natural-oriented openness. From the perspective of natural openness, trade between countries with abundant technological resources will exacerbate domestic II. From the perspective of policy-oriented openness, the reserves of technological resources do not affect the inhibitory effect of trade on domestic income inequality. The trade significance between countries with scarce technological resources is stronger.

3.4. Verification of Mechanism of Action

Through sorting and analysis, the study found that the main influencing factors of domestic II are the technical level, human capital, and immigration migration of both sides of the trade. It used those as intermediary variables to construct a model for testing and analysis. Table 13 shows the regression analysis results of the mechanisms of patents, research and development investment, and immigration migration.

In Table 13, the significance levels of 0.01, 0.05, and 0.10 are marked with ***, **, and *, respectively. After analyzing the test results, natural openness can reduce the R&D investment gap between trading countries. The difference in the number of patents will exacerbate domestic II and lead to technology spillovers. The gap in research and development investment has no significant effect. The degree of policy-based openness is directly proportional to the amount of immigration, which contributes to domestic income equality, but the effect is insignificant. Overall, it can suppress domestic II and trade between countries with relatively low levels of education can also play a role in suppressing domestic II. The main influencing factors of domestic II are technology, education, and immigration, mainly reflected in differences in the number of

technology patents and differences in Human Resources (HR) education levels. Compared with the relevant research from 2018 to 2022, this study uses bilateral trade rules to screen stable trade behavior and uses an extended gravity model to fit actual trade openness into natural and policy openness, although avoiding subjective measurement of complex trade policies. The traditional view is that farther bilateral geographical distance means higher bilateral trade costs, and geographical distance is often associated with lower trade shares. But from the perspective of natural openness, the farther the geographical distance, the closer the trade between the two countries.

Table 13. Regression analysis results on the mechanisms of patents, R&D investment, and immigration migration.

Variable	Number of patents	EHII	R&D investment	EHII	Immigrant migration	EHII
L.EHII	/	-0.167***	/	-0.156***	/	-0.166***
Nopen	449243.2	0.073	-60.974**	-0.019	-13680000	0.016
Popen	-36909.3	-0.075**	1.701	-0.073**	3193418.5	-0.071***
Patent	/	0.000***	/	/	/	/
Rd	/	/	/	0.000	/	/
Migration	/	/	/	/	/	-0.000
Dlevel1	25229.3	0.021	1.439	0.032**	-398073.8	0.036***
Colony	127734.8***	-0.001	1.248*	0.005	-509042.5	0.003
Institution	-4160.9	0.046***	1.055***	0.046***	503307.9	0.046***
Asia	90.294	-0.024***	3.527***	-0.018**	338588.3	-0.016***
Europe	201.829	-0.040***	-1.298	-0.048***	850071.4	-0.048***
Observations	4050	3268	4050	3268	4050	3268
Observing individuals	478	468	478	468	478	468
Control variable	Yes	Yes	Yes	Yes	Yes	Yes

4. Conclusion

The research objects are 16 countries ranking top in the global import and export trade. The research uses natural and policy-oriented opening indicators to subdivide BT. Combined with transnational dynamic panel data, the system GMM model is used to analyze the dynamic impact of natural and policy factors on domestic II in deepening BTO. The empirical analysis results indicate that, under the interference of other factors, the effect of TO on domestic II is unstable, indicating that the subdivision of natural and policy-oriented openness helps analyze the internal impact of domestic II. Policy-oriented openness has a more significant inhibitory effect on domestic II, while domestic II is not significantly affected by natural-oriented openness. The results under the system GMM method are still stable, and the second-order lag instrumental variable estimation is helpful for behavior modeling. This further shows that the GMM system is a better model.

Regarding policy-oriented openness, trade with high-income countries will promote domestic income balance, while trade with other low-income countries will exacerbate domestic trade. For natural openness, trade with countries of any income level can alleviate domestic II, with significant differences. The degree of policy-based openness is directly proportional to the amount of immigration, which contributes to domestic income equality, but the effect is insignificant. Overall, it can suppress domestic II and trade between countries with relatively low levels of education can also play a role in suppressing domestic II. The verification results of the mechanism of action indicate that the main influencing factors of domestic II are technology, education, and immigration. The differences in patent quantity are reflected in technology, while the differences in education level are reflected in HR. The results are consistent with the expected assumptions. This study uses bilateral trade rules to screen stable trade behavior, and uses an extended gravity model to fit actual trade openness into natural and policy openness, avoiding subjective measurement of complex trade policies. The limitation of this study lies in the lack of in-depth analysis of the impact of policies on trade openness. Although the difference between actual trade openness and natural openness can explain the openness guided by trade policies, there are many factors that affect trade policies, and the policies have timeliness and lag effectiveness. The specific implementation of trade policies requires time. Future research needs to further explore measurement methods for policy-based openness, continuously pay attention to the effects of various national trade policies on domestic income inequality, further enhance the effectiveness of systematic analysis, and provide data support for the formulation and implementation of national trade policies.

References

Abdmoulah, W. (2023). Export sophistication and economic performance, new evidence using TiVA database. *International Review of Applied Economics*, *37*(1), 113-137. https://doi.org/10.1080/02692171.2022.2026299

Aziz, A., Memon, J. A., & Qader, A. A. (2023). Functional income distribution in Pakistan: Co-integration and vector error correction model analysis. *International Journal of Finance & Economics*, *28*(1), 1081-1091. https://doi.org/10.1002/ijfe.2464

Barakat, M., Madkour, T., & Moussa, A. M. (2023). The role of logistics performance index on trade openness in Europe. *International Journal of Economics and Business Research*, *25*(3), 379-394. https://doi.org/10.1504/ijebr.2023.129967

Barma, M., & Modibbo, U. M. (2022). Multiobjective mathematical optimization model for municipal solid waste management with economic analysis of reuse/recycling recovered waste materials. *Journal of Computational and Cognitive Engineering*, *1*(3), 122-137. https://doi.org/10.47852/bonviewjcce149145

Barrales-Ruiz, J., von Arnim, R., & Mohammed, M. (2023). Income distribution and economic activity: A frequency domain causal exploration. *Metroeconomica*, *74*(2), 306-327. https://doi.org/10.1111/meca.12418

Bayar, A. A., Günçavdı, Ö., & Levent, H. (2023). Evaluating the impacts of the COVID-19 pandemic on unemployment, income distribution and poverty in Turkey. *Economic Systems*, *47*(1), 101046-101067. https://doi.org/10.1016/j.ecosys.2022.101046

Betancourt Gómez, M. E. (2023). Income distribution, banks and managers: A linear joint-production model with financial assets. *Metroeconomica*, *74*(1), 74-93. https://doi.org/10.1111/meca.12404

Bouaziz, D., Salhi, B., & Jarboui, A. (2020). CEO characteristics and earnings management: Empirical evidence from France. *Journal of Financial Reporting and Accounting*, *18*(1), 77-110. https://doi.org/10.1108/jfra-01-2019-0008

Casas, P., & Torres, J. L. (2023). Automation, automatic capital returns, and the functional income distribution. *Economics of Innovation and New Technology*, *32*(1), 113-135. https://doi.org/10.1080/10438599.2021.1891659

Castaldo, A., & De Bonis, V. (2023). Exploring the existence of a short-run kuznets curve: Does the fourth industrial revolution affect income distribution? *The BE Journal of Economic Analysis & Policy*, *23*(2), 515-524. https://doi.org/10.1515/bejeap-2020-0231

Cui, X., Guo, L., & Bian, Y. (2023). Improving business environments: A new approach to promote trade openness? *Applied Economics*, *55*(1), 43-57. https://doi.org/10.1080/00036846.2021.2023090

Dvoskin, A., & Landau, M. T. (2023). Income distribution and economic cycles in an open-economy supermultiplier model. *Structural Change and Economic Dynamics*, *64*(1), 273-291. https://doi.org/10.1016/j.strueco.2022.12.012

Gao, B., & Qiu, B. (2023). Income distribution and unequal gains from trade. *The World Economy*, *46*(1), 236-255. https://doi.org/10.1111/twec.13271

Kebede, J. G., & Tawiah, V. (2023). Financial globalization and income inequality nexus: panel quantile regression approach. *Journal of Economic Studies*, *50*(2), 73-95. https://doi.org/10.1108/jes-04-2021-0179

Khatun, F., & Saadat, S. Y. (2022). The optimum level of income inequality in South Asia: An econometric analysis. *South Asia Economic Journal*, *23*(1), 7-29. https://doi.org/10.1177/13915614211039087

Kinfack, E., & Bonga-Bonga, L. (2023). The growth effect of trade openness on African countries: Evidence from using an instrumental variable panel smooth transition model. *Bulletin of Economic Research*, *75*(2), 366-379. https://doi.org/10.1111/boer.12360

Kumari, R., Shabbir, M. S., Saleem, S., Yahya Khan, G., Abbasi, B. A., & Lopez, L. B. (2023). An empirical analysis among foreign direct investment, trade openness and economic growth: Evidence from the Indian economy. *South Asian Journal of Business Studies*, *12*(1), 127-149. https://doi.org/10.1108/sajbs-06-2020-0199

Lee, C. C., Lee, C. C., & Cheng, C. Y. (2022). The impact of FDI on income inequality: Evidence from the perspective of financial development. *International Journal of Finance & Economics*, *27*(1), 137-157. https://doi.org/10.1002/ijfe.2143

Liu, J., Lai, M. Y., & Liu, Z. S. (2022). Trade liberalization, domestic reforms, and income inequality: Evidence from Taiwan. *Review of Development Economics*, *26*(3), 1286-1309. https://doi.org/10.1111/rode.12875

McFarland, M. J., Hill, T. D., & Montez, J. K. (2023). Income inequality and population health: Examining the role of social policy. *Journal of Health and Social Behavior*, *64*(1), 2-20. https://doi.org/10.1177/00221465221109202

Mohamed Sghaier, I. (2023). Trade openness, financial development and economic growth in North African countries. *International Journal of Finance & Economics*, *28*(2), 1729-1740. https://doi.org/10.1002/ijfe.2503

Mtar, K., & Belazreg, W. (2023). On the nexus of innovation, trade openness, financial development and economic growth in European countries: New perspective from a GMM panel VAR approach. *International Journal of Finance & Economics*, *28*(1), 766-791. https://doi.org/10.1002/ijfe.2449

Ofori, I. K., Dossou, M. A., Asongu, S. A., & Armah, M. K. (2023). Bridging Africa's income inequality gap: How relevant is China's outward FDI to Africa? *Economic Systems*, *47*(1), 101055-101086. https://doi.org/10.1016/j.ecosys.2022.101055

Premrov, T., & Schnetzer, M. (2023). Social mix and the city: Council housing and neighbourhood income inequality in Vienna. *Urban Studies*, *60*(4), 752-769. https://doi.org/10.1177/00420980221119408

Shaikh, A., & Ragab, A. (2023). Some universal patterns in income distribution: An econophysics approach. *Metroeconomica*, *74*(1), 248-264. https://doi.org/10.1111/meca.12412

Sommet, N., & Elliot, A. J. (2023). Opposing effects of income inequality on health: The role of perceived competitiveness and avoidance/approach motivation. *European Journal of Social Psychology*, *53*(1), 61-77. https://doi.org/10.1002/ejsp.2884

Usman, M., Kousar, R., Makhdum, M. S. A., Muhammad, R. Y., & Nadeem, A. M. (2022). Do financial development, economic growth, energy consumption, and trade openness contribute to increase carbon emission in Pakistan? An insight based on ARDL bound testing approach. *Environment Development and Sustainability*, *25*(1), 444-473. https://doi.org/10.1007/s10668-021-02062-z

Vetsikas, A., & Stamboulis, Y. (2023). Does innovation activity affect trade openness? An ARDL bounds testing approach for 10 European countries. *The Journal of International Trade & Economic Development*, *32*(1), 163-188. https://doi.org/10.1080/09638199.2022.2080855