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How does economic complexity influence income inequality? New evidence from international data

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ABSTRACT

This paper examines the relationship between economic complexity and income inequality. Using panel data on eighty-eight countries from 2002 to 2017 and two estimation methods, this paper finds that economic complexity is significantly associated with higher income inequality. Moreover, because building economic sophistication is a long and costly process, we further identify whether the changes in the nature of this relationship is conditional on the evolution of other economic and social factors. The results provide qualified evidence that when the level of education, government spending, and trade openness reach certain thresholds, they facilitate the beneficial aspects of higher economic complexity on reducing with income inequality. Conversely, in an environment with less education, ineffective government spending, and low economic openness, economic complexity fails to reduce income inequality. Our findings are relevant for policymakers in tailoring their policies toward combating inequality in the process of developing a knowledge-based economy.

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1. Introduction

In recent decades, rapid economic growth and rising inequality have become two of the most salient phenomena in the world (Chong, 2004; Nielsen and Alderson, 1997; Norris et al., 2015). Although better economic conditions result in a dramatic reduction in poverty and significant enhancement in social welfare, widening income disparity is emerging as a concern. A growing body of evidence suggests that rising inequality could dampen investment and consumption, and hence growth, by fueling economic, financial, and political instability (Acemoglu et al., 2012; Carvalho and Rezai, 2014; Cingano, 2014; Kumhof et al., 2015; Rajan, 2010). Moreover, inequality could lead to poor public choices while damaging trust and social cohesion, which further hurt growth (Bourguignon and Dessus, 2009; Claessens and Perotti, 2007). As tackling income inequality is still a challenging task for not only developing countries but also developed economies, identifying the determinants of income inequality has always been at the center for both policymakers and academics (Norris et al., 2015). A crucial line of research questions whether economic development can solve the problem of income inequality. Kuznets (1955) is a pioneering author who proposed an inverted-U-shaped relationship between economic development and income inequality. He asserted that income inequality increases until a critical income level is attained, after which inequality begins to decrease. However, the empirical evidence in support of the Kuznets hypothesis is still

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mixed. Whereas some papers provide qualified support (Campano and Salvatore, 1988; Chong, 2004; Meniago and Asongu, 2018; Nielsen and Alderson, 1997; Thomas, 2015; Wu and Yao, 2015), others document an S-shaped curve (Yang and Greaney, 2017) or no systemic relationship between economic growth and the level of income inequality (Deininger and Squire, 1996; Papanek and Kyn, 1986; Perera and Lee, 2013).

The mixed evidence might result from the limitations in measuring economic development and the complex nature of income inequality. First, the use of the gross domestic product (GDP), GDP per capita, and the total contribution of economic sectors to GDP as an aggregate indicator of economic development has been widely criticized (Hartmann et al., 2017). Because it aggregates broad categories, GDP measurement reflects only the "quantitative" aspects of economic development but fails to capture the sophistication of what is produced or produced competitively, a more "qualitative" aspect of economic progress. In fact, economic performance and its value can vary across a diverse range of products (Lee and Vu, 2019). Therefore, GDP measurement as an aggregate monetary measure of economic outcomes only partly reflects a country's economic development (Hartmann et al., 2017; Sbardella et al., 2017; Stiglitz et al., 2010). Second, clarifying the determinants of income inequality is not simple because the evolution of income distribution involves a variety of economic, social, and institutional factors, such as factor endowments, institutions, social capital, historical trajectories, technological change, and returns to capital (Acemoglu and Robinson, 2012; Autor, 2014; Beinhocker, 2006; Brynjolfsson and McAfee, 2012; Collier, 2007; Davis, 2009; Engerman and Sokoloff, 1997; Frey and Osborne, 2013; Hartmann, 2014; Piketty, 2014). To some extent, these factors can be expressed through a country's level of productive capabilities (Cristelli et al., 2013; Engerman and Sokoloff, 1997; Felipe et al., 2012; Hausmann and Rodrik, 2003; Hausmann et al., 2014; Hidalgo, 2015; Hidalgo and Hausmann, 2009; Innis, 1970; Rodrik, 2006). More specifically, Hidalgo and Hausmann (2009) propose the concept of "economic complexity" to measure a country's productive capabilities. It can be expressed through the diversity and ubiquity of what a country can produce. This evokes the idea of examining the relationship between economic complexity and income inequality.

The connection between a country's productive structure and its ability to generate and distribute income was documented in a few papers (Hirschman, 1958; Rosenstein-Rodan, 1943; Singer, 1950). Similarly, the role of economic transformation or structural change in enhancing total factor productivity, fostering economic growth, and redistributing economic outcomes was also highlighted in the literature (Dollar et al., 2016; Kaldor, 1956; Kuznets and Murphy, 1966). This study takes a further step by examining the influence of economic complexity on income inequality. In fact, the literature reveals little understanding of this relationship. To the best of our knowledge, these studies include Le Caous and Huarng (2020), Hartmann et al. (2017), and Lee and Vu (2019). However, their findings are contradictory. On the one hand, Le Caous and Huarng (2020) and Hartmann et al. (2017) find a negative association between economic complexity and income inequality. On the other hand, Lee and Vu (2019) find that economic sophistication has a positive effect on income disparity when they employ a system—general method of moments (GMM) estimator. Moreover, these papers ignore the moderating effect of other determinants on the relationship between economic complexity and income inequality. According to Hidalgo and Hausmann (2009), economic complexity is a long and costly process of acquiring new capabilities. During this process, other economic, social, and institutional factors continually evolve and can affect the nature of the relationship between economic complexity and income inequality. Therefore, it is worthwhile to examine whether this relationship has any turning point or moderating factor.

Based on a panel data set of eighty-eight countries and territories from the World Bank database for 2002 to 2017, this research explores the dynamic relationship between economic sophistication and income inequality. It contributes to the literature in several ways. First, a fixed-effects two-stage least squares (2SLS) model with instrumental variables is used in this study to compare the results with those obtained from a cross-country fixed-effect panel regression of Hartmann et al. (2017), ordinary least squares (OLS) estimation of Lee and Vu (2019), and the hierarchical linear modeling of Le Caous and Huarng (2020). Second, we consider the dynamic relationship by introducing a lagged dependent variable into our regression model and employ system-GMM to address the endogeneity problem. Third, the results demonstrate that the relationship between economic complexity and income inequality can change depending on the context. Specifically, when the education level, government spending, and trade openness reach certain thresholds, they facilitate the benefits of higher economic complexity on dealing with inequality in income distribution. In contrast, the contribution of economic complexity to lowering income disparity becomes blurred in an environment with less education, ineffective government spending, and low economic openness. Overall, by further explaining the moderating effects of human endowment, government policies, and international trade on the influence of economic complexity on inequality, we expand existing knowledge on the contribution of policy-targeted factors to lowering income disparity.

The paper proceeds as follows. Section 2 discusses economic complexity and its relationship to income inequality as well as the moderating effects in this relationship. Next, Section 3 describes econometric models, data, and estimation methods. Section 4 presents and discusses our main and robust results. Section 5 concludes the paper.

2. Literature review and hypothesis development

2.1. The concept of economic complexity

Knowledge is one of the key inputs in production. Because knowledge is stored and disseminated among people, products are regarded as vehicles of knowledge transfer and integration (Hausmann et al., 2014). As a result, the enormous amount of knowledge is obtainable through the market. Knowledge is divided into two types: explicit and tacit. Although the former is disclosed simply through communication, the latter is revealed only through its application (Nonaka, 1994). The problem is that most of the knowledge required for production is tacit. In fact, the slow, costly, and uncertain transfer of tacit knowledge is regarded as a constraint on economic growth (Hausmann et al., 2014). As a result, to accelerate production and enhance efficiency, people and firms need to specialize in specific activities for which they have available tacit knowledge. This idea is further developed in the division of labor theory suggested by Smith (1776). According to this theory, the secret to a nation's wealth is the division of labor, in which people and firms specialize in different activities to improve economic efficiency. When a country has a larger market size, it has more individuals who can specialize. Consequently, a more extensive division of labor is attained (Hidalgo and Hausmann, 2009). However, the contribution of the division of labor to economic growth depends not only on how much knowledge is stored but also on how diverse types of knowledge are integrated through human interaction (Hausmann et al., 2014). Indeed, "the division of labor is what allows us to access the quantity of knowledge that none of us would be able to hold individually" (Hausmann et al., 2014, p.15).

People with diverse knowledge must interact in the formation, management, and operation of production activities (Felipe et al., 2012). This leads to the development of productive capabilities at different levels, such as individuals, organizations, and organizational networks (Hausmann et al., 2011). Although individuals can share their expertise through global markets, a division of labor is difficult to achieve through international trading. The reason is that the individual activities that emerge from the division of labor cannot be imported due to constraints on property rights, regulations, infrastructure, specific labor skills, and so on (Hidalgo and Hausmann, 2009). Instead, a country needs to develop its own diversified productive capabilities to enable its own division of labor (Hidalgo and Hausmann, 2009). After this capability set emerges, a complex society can exist and sustain itself using the diverse knowledge that its members possess to create whatever products they can (Hausmann et al., 2014).

Hidalgo and Hausmann (2009) propose the concept of "economic complexity" to indicate the stock of knowledge accumulated in a population, also known as productivity knowledge, or production complexity. Based on the idea that countries are connected by the products they export, the economic complexity approach aims to measure economic complexity by quantifying the competitiveness of countries and the quality of their exported products. Correspondingly, Hidalgo and Hausmann (2009) constructed an economic complexity index based on the "method of reflections", in which economic complexity is measured through the reflection of economic outcomes (Mariani et al., 2015). Specifically, revealed comparative advantage (RCA), or the extent to which a country effectively exports a given product, is used to reflect the level of economic complexity. Correspondingly, the authors define two concepts associated with economic complexity, "diversity" and "ubiquity". The former represents the number of products a country can export with RCA, and the latter indicates the number of countries that have an advantage in exporting a given product. Hence, an economy is more sophisticated if it can export a wider range of products, which have relatively high ubiquity (i.e., exported by few other countries).

2.2. Economic complexity and income inequality

Because producing a given product requires a set of productivity knowledge, a country's export diversity and product ubiquity also imply the diversity and ubiquity of its productivity knowledge. According to Hidalgo and Hausmann (2009), given more diverse and unique production knowledge, a highly complex country can achieve higher level of specialization that is more likely to involve two primary processes. The first is to find new products given the combinations of available knowledge, and the second is related to the accumulation of new capabilities and their combination with other previously available capabilities to develop yet more products. These may have two different effects on income inequality.

Based on simple qualitative and quantitative approaches, the literature indicates that economic complexity can be a negative predictor of income inequality (Hartmann et al., 2017; Le Caous and Huarng, 2020). A country with a diversification of knowledge can develop highly sophisticated industries, which, in turn, result in a relatively flat occupational structure, dispersed skills and knowledge, and extensive class consciousness (Constantine and Khemraj, 2019; Hartmann et al., 2017). As a result, this helps reduce income inequality by increasing occupational opportunities for high-skilled, low-skilled, and even unskilled workers while empowering them in salary negotiations (Albassam, 2015; Egger and Etzel, 2012; Hartmann, 2014). In contrast, in a low-complexity economy, where the productive structure and employment depend mainly on low skills, the simple production of low-value-added products do not require much in terms of high technology, skills, or product knowledge, therefore, it has limited choices of occupation (Constantine and Khemraj, 2019). Consequently, the economic rewards of these products accrue to small groups of individuals, leading to high income disparity, with high incomes, a small middle class, and low wage shares. In fact, the idea that a sophisticated economy, which is made up of a variety of complex production activities, reduces income disparity is similar to the thinking by Kuznets and Lewis (Kuznets, 1955), which asserts that structural changes explain shifts in income distribution. In addition, a knowledge-based economy with diversified production activities can also ensure the long-term sustainability of firms and the resilience of the country in the context of a volatile global market (Barnes et al., 2015; Joya, 2015). Consequently, the employability and wage rates of workers at all levels are sustained, and this eventually reduces income gaps (Blancheton and Chhorn, 2019; Hartmann et al., 2017). At the same time, higher specialization enabled by economic complexity can yield higher productivity and increasing returns to scale. This enhances the lifetime earnings of workers

(Constantine, 2017). Higher wages enable the poor to move up the social ladder and result in lower income disparity (Hartmann et al., 2017; Hidalgo, 2015).

However, the negative link between economic complexity and income inequality fails to explain widening income inequality in the US, considering that it experienced substantial structural changes in the 1980s (Card and DiNardo, 2002; Levy and Murnane, 1992). Instead, the theory of skills-based technological change could shed light on the rise in wage inequality following technology progress. Skills-biased technical change refers to "a shift in the production technology that favors skilled (e.g., more educated, more able, more experienced) labor over unskilled labor by increasing its relative productivity and, therefore, its relative demand" (Violante, 2008, p.1). According to this theory, when a new technology emerges, the demand for highly skilled workers increases. Consequently, income inequality rises. The application of the skills-based technological change theory in the context of economic complexity implies a positive relationship between economic complexity and income inequality. Specifically, during the initial stage of structural transformation, diversifying economic activities can raise fixed and sunk costs related to new product development and new market expansion (Aw and Lee, 2017; Hoffman et al., 2016; Klinger and Lederman, 2011). Firms that have limited resources and experiences but lack economies of scale and information might suffer the most in this early phase (Qian and Yaşar, 2016). To ensure production efficiency and profitability, they can increase demand for skilled labor and create technological change (Anderson, 2005). In a nutshell, economic diversification drives the skills-biased nature of new economic activities, which leaves low-skilled labor at a disadvantage (Meschi and Vivarelli, 2009). As a result, when a country tries to become more complex, it shifts focus from low-value products that require natural resources and low-skilled knowledge to those requiring higher skills. This leads to a rise in the income gap (Berman et al., 1998; Card and DiNardo, 2002; Violante, 2008). In accordance with the theory of skills-based technological change, Lee and Vu (2019) empirically affirm the direct positive relationship between economic complexity and income inequality.

Nevertheless, there is a lack of literature regarding whether the theory of skills-based technological change can hold in the long run, given the multiple changes in income inequality and its determinants (Card and DiNardo, 2002; Weiss, 2008). In fact, based on a cost–benefit analysis of economic diversification at different stages in this process, Le et al. (2020) propose an inverted-U-shaped relationship between economic diversification and income inequality. The economic diversification might widen income gaps at the initial stage of diversification until a threshold level is reached, and afterward a complex economic structure contributes to a reduction in income inequality.

In this study, we argue that economic complexity might continuously widen income gaps for several reasons. First, in knowledge-based economies, although the high level of specialization enables more occupational opportunity, each production activity still requires qualified workers with specialized knowledge in order to achieve high productivity (Constantine, 2017). The demand for skilled labor continues to grow (Constantine, 2017), along with the process of diversifying economic structures in which new sectors continue to emerge and replace traditional ones (Hartmann, 2014), while the set of required capabilities is subject to frequent change (Hodgson, 2003). As a result, the occupational opportunities are greater but are not equal between skilled and unskilled labor. In fact, skilled workers acquire new knowledge more quickly, given their available capabilities and better adaptation to the changing requirements of the labor market and, therefore, benefit more from economic complexity. In short, higher economic complexity can continually widen income disparity. Based on these arguments, we derive our first hypothesis as follows:

H1: Higher economic complexity is associated with higher income inequality.

Building economic sophistication is a long process (Hidalgo and Hausmann, 2009), during which other determinants of income inequality can evolve. To address the inability of the skills-based technological change theory to explain the positive relationship between economic complexity and inequality in the long run (Card and DiNardo, 2002; Weiss, 2008), we assume that there are a few factors that can moderate or even change the nature of this relationship over time.

Lee and Sissons (2016) propose some ways to reduce income disparity, including: raising wages and increasing employment. The literature reveals that attainment of higher education helps increase an individual's lifetime earnings (Castro Campos et al., 2016; Norris et al., 2015) whereas trade liberalization creates more demand for low-skilled and unskilled labor (Asteriou et al., 2014; Hamori and Hashiguchi, 2012; Reuveny and Li, 2003). Moreover, fiscal policies aimed at social transfers, especially for the poor, are widely recognized as government efforts to directly narrow income gaps (Anderson et al., 2015; Goñi et al., 2011; Lustig, 2016; Martínez-Vázquez et al., 2012). Thus, we expect that education, government spending, and trade openness make a beneficial contribution to the effectiveness of economic complexity in lowering income inequality.

First, economic development has long been acknowledged as a process of structural change in a country's production structure (Lewis, 1955; Rostow, 1959). During the process of structural transformation to new and more complex industries, human capital not only is a crucial determinant of economic growth but also plays an important role in tackling income inequality (Lee and Vu, 2019; Romer, 2012). Education is a crucial determinant of human capital in income equations (Mincer, 1958, 1974). More education is generally associated with "better jobs" and "higher incomes", which help the poor escape poverty and, therefore, reduce income disparity (Castro Campos et al., 2016; Norris et al., 2015). As the economic structure becomes more complex, better education enables an individual to learn and acquire new capabilities faster. Consequently, it helps low- and unskilled workers to adapt better to the changes in labor market requirements. Eventually, they receive more benefits from the diversification of the economic structure by taking better advantage of diverse occupational opportunities due to growing economic complexity. Therefore, the attainment of higher education can strengthen the positive contribution of economic complexity to employment and wage rates, especially for the poor. In addition, it could also mitigate the risks and costs that low- and unskilled workers might suffer due to structural changes and a higher level of specialization during the process of economic diversification.

Second, government spending is widely acknowledged as a policy that helps reduce income inequality in many countries and regions (Anderson et al., 2015; Goñi et al., 2011; Lustig, 2016; Martínez-Vázquez et al., 2012). Public spending on social transfers that inject income or raise spending power for individuals, especially the poor, represents government efforts at redistributing income (Afonso et al., 2008). Whereas higher economic complexity creates more job opportunity and potential better wage rates, government spending facilitates better access to such benefits among workers, especially low- and unskilled ones. For example, spending on public transportation system reduces travel costs and encourages the poor to look for jobs in a wider area. Government expenditures on job training, education, and public health enhance the capacity and health of low- and unskilled workers, which, in turn, increases their likelihood of being employed and having higher earnings (Afonso et al., 2008). Moreover, this government support, especially when involved in training and education, also helps low- and unskilled workers to quickly adapt to new requirements in the labor market in the process of structural transformation. As a result, government expenditure could offset the negative effects of higher economic complexity on the employment and earnings of this vulnerable segment of society.

Third, standard trade theory predicts that trade openness could reduce the wage gap between skilled and unskilled labor in developing countries, by raising the demand for unskilled workers, therefore, inducing reduction in income inequality (Stolper and Samuelson, 1941). This hypothesis was empirically tested and supported in a few previous papers (Asteriou et al., 2014; Hamori and Hashiguchi, 2012; Reuveny and Li, 2003). In this study, we assume that trade liberalization will further strengthen the benefits of economic complexity for job opportunity and wages by facilitating more production and trading activities. Moreover, because trade openness helps maintain demand for low- and unskilled labor (Beaton et al., 2017), it also mitigates the negative effects of structural changes on the employment and earnings of these labor segments due to changing and more demanding skills requirements. Our second hypothesis is stated as follows:

H2: Higher education, government spending, and trade openness lessen the positive impact of economic complexity on income inequality.

To our knowledge, Le Caous and Huarng (2020), Hartmann et al. (2017), and Lee and Vu (2019) are the only papers to date that examine the impact of economic complexity on income inequality. However, none of them tests the effects of policy tools in moderating this relationship. Moreover, these authors provide mixed evidence regarding the relationship between economic complexity and income inequality. This implies the existence of potential moderators in this relationship. Based on the above discussion, we re-examine the relationship between economic complexity and income inequality as well as explore the moderating effects to identify any factor that might change the nature of this relationship.

2.3. Other control variables

In addition to economic complexity and the three determinants of income inequality mentioned earlier, GDP per capita and institutions are included in the regression model as the control variables.

According to Kuznets (1955), the income level and income inequality have an inverted-U-shaped relationship. During the initial stage of economic development, income inequality increases with the level of income until a certain threshold of GDP per capita is reached. Beyond this turning point, higher income would help lower income inequality. Following the theoretical underpinnings of Kuznets (1955), this study also hypothesizes an inverted-U-shaped relationship between the income level and income inequality.

Similarly, substantial empirical evidence shows that the relationship between income inequality and institutions takes an inverted-U shape (Andres and Ramlogan-Dobson, 2011; Chong and Calderón, 2000; Chong and Gradstein, 2007; Dobson and Ramlogan-Dobson, 2012; Li et al., 2000; Perera and Lee, 2013). Initially, improvements in institutional systems mostly involve substantial reductions in the bureaucratic burden and corruption or significant changes in tax collection (Chong and Calderón, 2000). These reforms led earlier mechanisms in the informal economy to collapse, and new formal practices and system need to be learned. Therefore, institutional reform, at the early stage, causes high additional costs for the poor in the informal sector but benefits those in the formal sector. Dobson and Ramlogan-Dobson (2012) report a trade-off between inequality and corruption in which corruption-reducing policies hurt employment and welfare in the informal sector, hence, it might result in higher income inequality. Eventually, when institutional quality reaches a threshold, better institutions facilitate democracy and the effectiveness of public service delivery and contribute to lowering income inequality (Chong and Calderón, 2000). Based on the literature, we expect an inverted-U-shaped relationship between institutions and income inequality.

3. Methodology

3.1. Models and estimation method

To assess the relationship between economic sophistication and income inequality, we develop a model based on the theoretical model of the Kuznets curve. The model takes the following form:

$$IIQ_{i,t} = \beta_0 + \beta_1 ECI_{i,t} + \beta_2 EDU_{i,t} + \beta_3 GOV_{i,t} + \beta_4 TRADE_{i,t} + \beta_5' X_{i,t} + \eta_i + \varepsilon_{i,t} \quad (1)$$

where $IIQ_{i,t}$ is income inequality; $ECI_{i,t}$ is the economic complexity index; $EDU_{i,t}$ is the education level; $GOV_{i,t}$ is government expenditure; $TRA_{i,t}$ is trade openness; $X_{i,t}$ represents the vector of other control variables frequently used in the income inequality literature, including GDP per capita and its square and institutions and its square. β is the vector of estimated coefficients, η is country-specific effects, ε is the error term, i and t are the country and time, respectively. We also include year dummies to capture time-fixed effects. As per our arguments in Section 2.3, we add the square of GDP per capita and the square of institutions to examine the existence of nonlinear relationships between them and income inequality. In line with the proposed hypothesis, we expect the coefficients of economic complexity index, β_1, to be positive.

Although the objective of this paper is to examine the effect of economic sophistication on income inequality, reverse causality that runs from income inequality to economic complexity might occur. In other words, the question that arises is whether economic complexity as a determinant of income inequality can be treated as plausibly exogenous. It could well be that a country's distribution of income significantly contributes to the accumulation of knowledge (Berg and Ostry, 2013; Lee and Vu, 2019; Persson and Tabellini, 1994). This reverse causation is ignored by Hartmann et al. (2017) in studying the links between economic complexity, institutions, and income inequality. We deal with this issue by using a fixed-effects 2SLS model with instrumental variables (IVs). We choose research and development expenditure (as a percentage of GDP) as the exogenous instrument. However, this task is still challenging given the fact that finding exogenous variables is not easy, and the estimation results are sensitive to the choice of IVs (Lee and Vu, 2019).

Moreover, because income inequality has highly persistent effects, it is better to examine the impact of economic complexity on income inequality in a dynamic setting. Thus, we employ a dynamic approach, which is represented by the following model:

$$IIQ_{i,t} = \gamma_0 + \gamma_1 IIQ_{i,t-1} + \gamma_2 ECI_{i,t} + \gamma_3 EDU_{i,t} + \gamma_4 GOV_{i,t} + \gamma_5 TRA_{i,t} + \gamma_6' X_{i,t} + \eta_i + \varepsilon_{i,t} \quad (2)$$

where $IIQ_{i,t-1}$ is the one-period lag in income inequality. γ_1 reflects the persistence of adjustment to an equilibrium, while γ_2 captures the short-run effect of economic complexity on income inequality. This dynamic form allows us to estimate both short- and long-run coefficients of economic complexity on income inequality. Specifically, the long-run effect of economic complexity on income inequality is given by $\gamma_2/(1-\gamma_1)$.

To test whether the effects of economic complexity on income inequality are conditional on human capital, government expenditure, and economic openness, we introduce three interaction terms in model (3). The use of interaction terms to capture the contingency effect on the relationship between variables of interest is common in empirical literature (Ibrahim and Law, 2016). First, we include the interaction term between economic complexity and the level of education to detect the moderating role of education on the relationship between economic complexity and income inequality. The new model takes the following form:

$$IIQ_{i,t} = \theta_0 + \theta_1 IIQ_{i,t-1} + \theta_2 ECI_{i,t} + \theta_3 EDU_{i,t} + \theta_4 GOV_{i,t} + \theta_5 TRA_{i,t} + \theta_6' X_{i,t} + \theta_7 ECI_{i,t} \times EDU_{i,t} + \eta_i + \varepsilon_{i,t} \quad (3)$$

Second, the interaction term between economic complexity and government spending is included in model (4) to determine how the link between economic complexity and income inequality varies with the evolution in government spending. The estimated model is represented by the following equation:

$$IIQ_{i,t} = \alpha_0 + \alpha_1 IIQ_{i,t-1} + \alpha_2 ECI_{i,t} + \alpha_3 EDU_{i,t} + \alpha_4 GOV_{i,t} + \alpha_5 TRA_{i,t} + \alpha_6' X_{i,t} + \alpha_7 ECI_{i,t} \times GOV_{i,t} + \eta_i + \varepsilon_{i,t} \quad (4)$$

Third, we apply the same framework to examine the moderating role of economic openness on the relationship between economic complexity and income inequality. We include the interaction term between economic complexity and trade openness in Eq. (5) as follows:

$$IIQ_{i,t} = \lambda_0 + \lambda_1 IIQ_{i,t-1} + \lambda_2 ECI_{i,t} + \lambda_3 EDU_{i,t} + \lambda_4 GOV_{i,t} + \lambda_5 TRA_{i,t} + \lambda_6' X_{i,t} + \lambda_7 ECI_{i,t} \times TRA_{i,t} + \eta_i + \varepsilon_{i,t} \quad (5)$$

Based on the proposed hypothesis, we expect the coefficients of the three interaction terms to be negative in models (3)–(5).

The dynamic panel equations (2)–(5) have correlation problems between unobserved country specific effects and lagged dependent variables as well as potential endogeneity of the variables. Because of these problems, we cannot use the traditional estimation methods, such as pooled OLS and fixed or random effects. By assuming that the error term is not serially correlated and that the lagged levels of the endogenous variables are uncorrelated with future error terms, Arellano and Bond (1991) recommend the use of lagged regressors as the instruments. However, in finite samples, the estimation of parameters may be biased and less precise. Blundell and Bond (1998) suggest combining the difference estimator with an estimator in levels to increase efficiency. The former is called difference-GMM estimation while the latter is called system-GMM estimation.

Thus, we use system GMM for estimating these dynamic panel data equations.[1] Specifically, the first-difference regression is instrumented with lagged level variables, and the level regression is instrumented with lagged first-difference variables. As a result, the system-GMM estimator is preferred over pooled OLS, fixed-effect, and difference-GMM

[1] For more details on system-GMM estimation, see Arellano and Bover (1995) and Blundell and Bond (1998).

Table 1
Variable descriptive statistics ($N = 891$).

Variable	Mean	Std. Dev.	Min	25th	50th	75th	Max
Gini	3.56	0.22	3.13	3.39	3.56	3.72	4.09
GDPpc	9.17	1.29	6.23	8.16	9.18	10.38	11.42
Educ	3.70	0.77	0.68	3.36	3.97	4.23	4.92
Gov	2.75	0.35	1.24	2.54	2.84	2.99	3.36
Trade	4.38	0.46	3.10	4.09	4.41	4.73	5.76
Ins	3.36	0.86	1.38	2.69	3.25	4.04	4.97
ECI	0.40	0.91	−2.41	−0.18	0.49	1.11	2.24

Note: This table presents descriptive statistics of the main variables. The dependent variable, Gini, is post-tax and post-transfer. With regard to the independent variables, *GDPpc* is the natural logarithm of GDP per capita (in 2010 constant USD); *Educ* is the enrollment in tertiary education (% gross); *Gov* is general government final consumption expenditure (% of GDP); *Trade* is total exports and imports of goods and services (% of GDP); *Ins* is the average of six components of institutional quality (Kaufmann et al., 2011), rescaled from 0 to 3; and *ECI* is the economic complexity index.

estimators because of its consistent and unbiased estimation parameters. It can solve the endogeneity problem in which some explanatory variables might not be exogenous or predetermined.

We use a two-step system-GMM estimation proposed by Arellano and Bond (1991) and obtain robust standard errors using Windmeijer (2005) finite sample correction. The consistency of the GMM estimators depends on the validity of the assumption that the error terms do not exhibit serial correlation and on the validity of the instruments. Thus, we use the AR (2) test that examines the null hypothesis of no second-order correlation as well as the Hansen test, which examines the null hypothesis of overidentifying restrictions.

3.2. Data

With regard to the dependent variable, we use the Gini post-tax and post-transfer to measure income inequality, taken from the Standardized World Income Inequality Database. This database was developed for cross-national research on income inequality by maximizing the comparability of data while maintaining the widest possible coverage across countries and over time.

The economic complexity represents the diversity and ubiquity of products that a country can make. Whereas the former component quantifies the number of products that a country can produce competitively, the latter measures the number of countries that can produce a product competitively. The economic complexity data is collected from the MIT Media Lab's Observatory of Economic Complexity and is constructed based on international trade data, which connects countries to the products they export.

The other control variables, including GDP per capita, enrollment in institutions of higher education (tertiary education), government final consumption expenditure over GDP, and the total export and import of goods and services over GDP come from the World Bank's World Development Indicators. The institutional quality variable is created by taking the average of six components of institutions, from the Worldwide Governance Indicators.

Depending on the availability of data, we prepared an unbalanced panel data set on eighty-eight countries and territories, of which thirty-four are high-income countries and fifty-four are middle-income countries according to the World Bank classification.[2] The estimation sample is from 2002 to 2017 because the Worldwide Governance Indicators database only covers continuous data beginning in 2002. Table 1 presents the statistical description of the main variables. Except for institutional quality data, the variables are transformed into their natural logarithmic form.

4. Results and discussions

Table 2 presents the estimation results of Eqs. (1)–(5). The fixed-effects 2SLS estimation result on the influence of economic complexity on income inequality is reported in column (1). The estimated coefficient of the economic complexity index is positive and statistically significant, which means that a more complicated production structure is positively associated with a higher level of income inequality. This result contradicts the results of Hartmann et al. (2017) and Lee and Vu (2019), in which economic sophistication significantly reduces the income gap.[3] However, in this paper, we apply the fixed-effects 2SLS with an IV with a panel data from 2002 to 2017, which is different from the cross-country fixed-effects panel regression of Hartmann et al. (2017) and the OLS estimation of Lee and Vu (2019).

[2] We also include six low-income countries (the maximum data that we could collect from the World Bank database and MIT Media Lab's Observatory of Economic Complexity). The estimation result (not reported here to save space) is similar to the main finding, which indicates a positive relationship between economic complexity and income inequality.

[3] For comparison with the results of Hartmann et al. (2017) and Lee and Vu (2019), we also average our panel to cross-sectional data and apply an OLS estimation. The obtained result (not reported here to save space) indicates a negative relationship between economic complexity and income inequality, which is similar to that of two others.

We further examine the dynamic relationship between economic complexity and income inequality by introducing one lag of the dependent variable and applying system-GMM estimation. The estimation result is presented in column (2). Again, we find that the estimated coefficient of the economic complexity index is positive and statistically significant, which means that an increase in economic complexity leads to higher income inequality, not less.[4] The estimation of the coefficient of the lagged dependent variable equals 0.9, indicating a highly persistent effect of income inequality. Moreover, it justifies the relevance of using a dynamic model and system-GMM estimation. Given that the short-run effect of economic complexity on income inequality is 0.009[5] and the adjustment speed is nearly 10 percent per annum, the estimated long-run effect equals 0.095. This long-run impact is similar to the coefficient of economic complexity in column (1) of Table 2.

Regarding control variables, we find that the coefficients of GDP per capita and its square are significantly positive and negative, respectively. This result reveals that, as a country develops, income inequality first increases, then peaks, and finally decreases. Similarly, the coefficients of institutions and its square are significantly positive and negative, respectively. For countries with low institutional quality, the initial institutional improvement widens income disparity. At later stages of institutional reform, progress in institutions effectively reduces income inequality. Overall, these two results mean that two inverted U-shaped relationships exist – between the income level and income inequality and between institutions and income inequality – supporting the Kuznets hypothesis (Campano and Salvatore, 1988; Chong, 2004; Chong and Calderón, 2000; Le et al., 2020). For other control variables, we find that human capital, government expenditure, and trade openness have significant negative impacts on income inequality.

The estimation result indicates that the education level is not only an important determinant of income distribution but also an effective tool for tackling income disparity (De Gregorio and Lee, 2002; Lessmann and Seidel, 2017). Fiscal policy, such as progressive taxation or social spending, is considered an effective tool for reducing income disparity (Afonso et al., 2008). This outcome on the relationship between government expenditure and income inequality is consistent with several empirical findings (Claus et al., 2012; Lustig, 2016; Martínez-Vázquez et al., 2012) but contradicts other studies (Dollar and Kraay, 2002; Dollar et al., 2016). Finally, our result confirms the argument that trade liberalization significantly reduces income inequality (Egger and Etzel, 2012; Krieger and Meierrieks, 2016). It is in line with some empirical studies, which show that trade liberalization equalizes the distribution of income (Asteriou et al., 2014; Meschi and Vivarelli, 2009). However, it contradicts other papers, which find that higher trade openness increases income inequality (Bergh and Nilsson, 2010). In general, these findings provide strong support for human capital investment, an active government role, and trade liberalization in tackling income inequality. The bottom portion of Table 2 shows that not all the regressions reject the null hypothesis of no second-order correlation and the null hypothesis of the validity of overidentifying restrictions at conventional levels.

We examine the moderating role of other control variables on the effectiveness of economic complexity in reducing the income gap. Columns (3)–(5) of Table 2 report the negative and statistically significant coefficients of moderating variables, indicating that a higher level of education, government spending, and trade openness are beneficial factors that help higher economic complexity to equalize income distribution. According to Brambor et al. (2006), the coefficient of interaction should not be used for interpretation because it does not fully capture the marginal effects of institutions in the specification. Therefore, we calculate the marginal effect of economic complexity on income inequality at different levels of other explanatory variables. Table 3 reports the marginal effect of a change in the economic complexity index given the different levels of education, government spending, and trade openness (10th, 25th, 50th, 75th, and 90th percentiles). It provides strong evidence that, for a given country, the effect of economic complexity on income inequality is reduced as education, government spending, and trade openness increase. This finding is further supported by the rejection of the null hypothesis that the effects of economic complexity are at the same at the 50th, 75th, and 90th percentiles for three variables.

Fig. 1 strongly supports this argument. When the education level, government spending, and trade openness reach a certain threshold, they facilitate the benefits from higher economic complexity in dealing with income inequality. First, the higher education level helps mitigate the income disparity from the advancement in the economic structure. For example, if low-paid workers are better educated, they will adapt better to higher work requirements (Schultz, 1963; Sylwester, 2002). As a result, the income gap between skilled and low- and unskilled labor is narrowed, instead of being widened. Second, if public spending becomes more efficient, it will allow the low- and unskilled workers to access necessary conditions (e.g., health care, education, housing, social protection, and transportation) for improving their work capacity. Thus, government expenditure is an effective tool for ensuring a fair income redistribution under a highly complex economic structure. Third, economic openness reduces the power of economic elites by reducing the market share and spreading technology across society (Acemoglu et al., 2005). In addition, economic freedom increases opportunity for the poor to make use of international trade, for example, through greater business opportunities and technology transfers (Krieger and Meierrieks, 2016). At a high level of trade openness, the positive effect of economic complexity on income inequality is curtailed. In contrast, in an environment with less education, ineffective and low government spending, and less economic openness, economic complexity fails to decrease income inequality.

[4] We also include the square of economic complexity in Eq. (2) to test whether an U-shaped (inverted-U-shaped) relationship exists between economic complexity and income inequality. The result (not reported here to save space) indicates that the squared term of economic complexity is not statistically significant at any conventional level, which means that such a nonmonotonic relationship does not exist, at least in the period studied (from 2002 to 2017).

[5] The result for the coefficient of economic complexity is quite similar to the finding of Lee and Vu (2019), in which they employ two-step system-GMM with panel data on nearly 100 countries from 1965 to 2014.

Table 2
Estimation results.

	(1)	(2)	(3)	(4)	(5)
Lag. Gini		0.905***	0.846***	0.852***	0.847***
		(0.031)	(0.042)	(0.040)	(0.043)
GDPpc	0.206*	0.087***	0.134***	0.112***	0.150***
	(0.112)	(0.033)	(0.049)	(0.041)	(0.048)
GDPpc_sq	−0.017**	−0.005***	−0.007***	−0.006***	−0.008***
	(0.007)	(0.002)	(0.003)	(0.002)	(0.003)
Ins	0.200***	0.036**	0.059**	0.064***	0.060**
	(0.071)	(0.019)	(0.025)	(0.020)	(0.029)
Ins_sq	−0.031***	−0.005**	−0.007**	−0.008***	−0.007*
	(0.011)	(0.003)	(0.004)	(0.003)	(0.004)
Educ	−0.027**	−0.020***	−0.030***	−0.021***	−0.023***
	(0.010)	(0.006)	(0.010)	(0.006)	(0.008)
Gov	−0.038**	−0.014**	−0.011*	−0.022***	−0.015**
	(0.016)	(0.006)	(0.006)	(0.008)	(0.007)
Trade	0.085***	−0.015**	−0.016*	−0.018**	−0.012*
	(0.011)	(0.006)	(0.009)	(0.008)	(0.007)
ECI	0.094*	0.009*	0.028*	0.043**	0.041**
	(0.052)	(0.005)	(0.017)	(0.018)	(0.020)
Educ × *ECI*			−0.010*		
			(0.006)		
Gov × *ECI*				−0.018**	
				(0.007)	
Trade × *ECI*					−0.011**
					(0.005)
Constant	2.612***	−0.002	0.060	0.140	−0.048
	(0.466)	(0.080)	(0.171)	(0.149)	(0.119)
AR(2) *p*-value		0.183	0.248	0.182	0.238
Hansen *p*-value		0.388	0.676	0.509	0.848
R^2	0.114				
No. observations	759	891	891	891	891
No. countries	78	88	88	88	88
No. instruments		86	87	87	87

Note: This table reports the estimation results of models (1)–(5). The dependent variable is the natural logarithm of the Gini index. *GDPpc* is the natural logarithm of GDP per capita (in 2010 constant USD). *Ins* is the average of six components of institutional quality (Kaufmann et al., 2011), rescaled from 0 to 3. *Educ* is enrollment in tertiary education (% gross). *Gov* is general government final consumption expenditure (% of GDP). *Trade* is total exports and imports of goods and services (% of GDP). *ECI* is the economic complexity index. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3
Marginal effect of economic complexity on income inequality conditional on the level of education, government spending, and trade openness.

	Education	Government spending	Trade openness
10th percentile	0.004	0.002	0.000
	(0.004)	(0.004)	(0.004)
25th percentile	−0.004	-0.002	−0.003
	(0.003)	(0.003)	(0.004)
50th percentile	-0.011*, aa	-0.007*,a	−0.007
	(0.005)	(0.004)	(0.005)
75th percentile	-0.013*,aa	-0.010**,aa	-0.010*
	(0.007)	(0.004)	(0.006)
90th percentile	-0.004*,aa	-0.012***,aa	-0.013*,a
	(0.007)	(0.005)	(0.006)

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. aaa, aa, and a indicate statistical significance of the difference between marginal effect at the 25th, 50th, 75th, and 90th percentiles compared to the 10th percentile at the 1%, 5%, and 10% levels, respectively.

We check whether these results are robust to several modifications. First, the effect of economic complexity on income inequality might differ systemically across income levels. Thus, including all countries with different economic development can lead to biased results if the relationship in one country group dominates the others. Thus, we use spline regression to allow for different slopes in economic complexity, which might be associated with high- and middle-income countries. A dummy variable that equals 1 if a country is in the middle-income country group and 0 otherwise is added to Eq. (5). Then, this variable is interacted with the economic complexity variable. The estimation result is reported in column (1) of Table 4. The coefficient of the interaction variable is negative and statistically significant. However, its

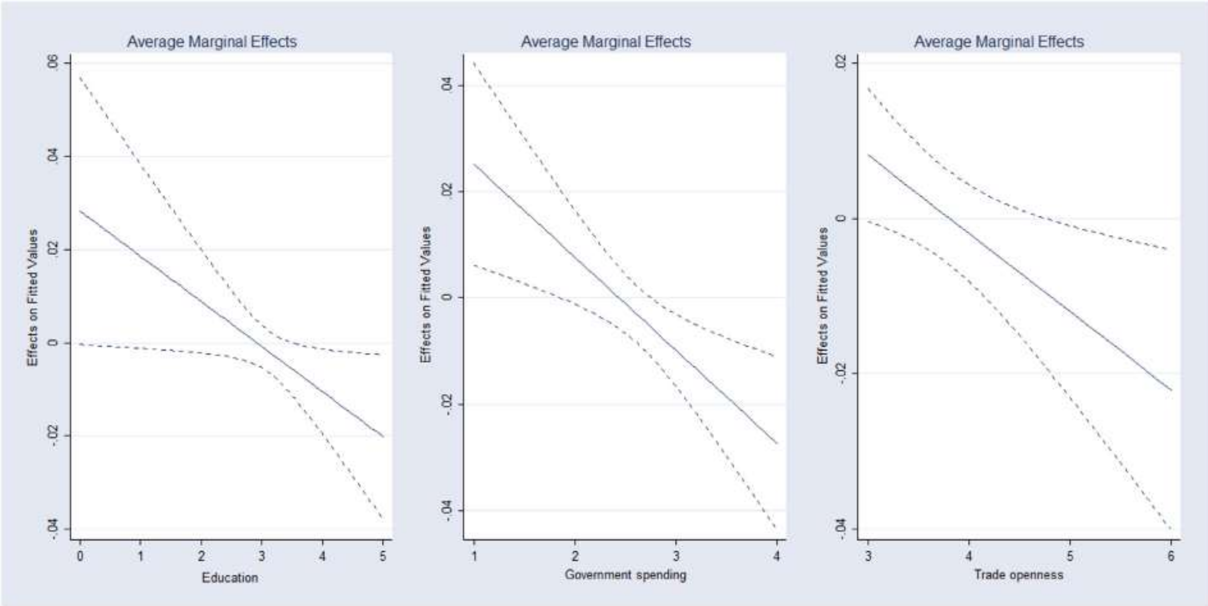

Fig. 1. Marginal effects of economic complexity conditional on the level of education, government spending, and trade openness. *Note*: The solid blue line plots the marginal effect of economic complexity on different levels of education, government spending, and trade openness based on the regression results of Table 2. The dotted lines are 90% confidence intervals.

magnitude is still lower, not statistically higher, than the coefficient of the economic complexity variable. This result means that, although the impact of economic complexity on income inequality is lower in middle-income countries than in high-income countries, it is still not significantly negative. Moreover, high-income countries face larger income gaps in the transformation to a knowledge-intensive economy than middle-income countries.

Second, we check the robustness of results with other proxies for dependent and control variables, including the Gini pretax and pretransfer, ECI+, secondary school enrollment, government expenditure on health, and foreign direct investment. Column (2) of Table 4 shows the positive and statistically significant coefficient of the economic complexity variable, which confirms the failure of economic complexity to reduce pretax and pretransfer income inequality. Moreover, instead of ECI, we use ECI+, a new metric, which takes into account the difficulty of producing products. The estimation result (column (3) of Table 4) still confirms our finding that higher economic complexity leads to higher income inequality. Columns (4)–(6) also reveal that these new control variables only facilitate the benefits of higher economic complexity on reducing income inequality when they reach certain high thresholds.

Third, we test for the potential influence of outliers by removing the top and bottom 1 percent of the distribution of the dependent variable, the Gini index, and the main variable of interest, ECI. Moreover, to examine whether our results are sensitive to the exclusion of countries with a high level of income inequality, we drop four countries (the top 5 percent of the countries in our sample) – Botswana, South Africa, Zambia, and Colombia – and re-estimate all the models. We apply the same idea to countries with a low level of income inequality (the bottom 5 percent of the countries in our sample): Belarus, Denmark, Norway, and Sweden. Dropping these countries does not significantly change our main results. Overall, the outliers do not affect our conclusion about the positive effect of economic complexity and the moderating role of control variables on income inequality (results are not reported here to save space).

5. Conclusions

This paper offers insights into the relationship between economic complexity and income inequality. We employ a fixed-effects 2SLS panel regression with IVs and system-GMM estimation with panel data on eighty-eight countries from 2002 to 2017.

The results show that the relationship between economic complexity and income inequality is not simply negative (Hartmann et al., 2017; Le Caous and Huarng, 2020) or positive (Lee and Vu, 2019) but, rather, far more complicated. Higher economic complexity is significantly associated with higher income inequality. In addition, the income level, institutional quality, education level, government expenditure, and trade liberalization are important determinants of income distribution. These findings are all consistent with the literature (Anderson et al., 2016; Asteriou et al., 2014; Kuznets, 1955; Lee and Vu, 2020; Lustig, 2016; Reuveny and Li, 2003; Romer, 2012; Stolper and Samuelson, 1941). Although economic sophistication is a strong predictor of income disparity, this relationship could be controlled through

Table 4
Robustness test.

	(1)	(2)	(3)	(4)	(5)	(6)
Lag. Gini	0.916***		0.897***	0.885***	0.884***	0.870***
	(0.035)		(0.040)	(0.027)	(0.030)	(0.048)
Lag. Gini_pre		0.939***				
		(0.036)				
GDPpc	0.087**	−0.028*	0.099**	0.044	0.072*	0.125***
	(0.034)	(0.015)	(0.043)	(0.033)	(0.038)	(0.045)
GDPpc_sq	−0.005**	0.001	−0.006**	−0.003	−0.004*	−0.007***
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Ins	0.055**	0.095**	0.028	0.064***	0.046**	0.054*
	(0.023)	(0.040)	(0.031)	(0.021)	(0.022)	(0.028)
Ins_sq	−0.008**	−0.013**	−0.004	−0.008***	−0.006*	−0.007*
	(0.004)	(0.005)	(0.005)	(0.003)	(0.003)	(0.004)
Educ	−0.018***	−0.008*	−0.025***		−0.018***	−0.023**
	(0.006)	(0.004)	(0.008)		(0.007)	(0.009)
Gov	−0.014**	0.005	−0.006	−0.011		−0.013
	(0.006)	(0.005)	(0.009)	(0.010)		(0.009)
Trade	−0.013**	−0.006*	−0.015**	−0.012**	−0.013*	
	(0.006)	(0.003)	(0.006)	(0.005)	(0.008)	
ECI	0.018*	0.010**		0.042*	0.006	−0.006
	(0.010)	(0.004)		(0.022)	(0.006)	(0.004)
Dummy_middle	0.016					
	(0.011)					
Dummy_middle × *ECI*	−0.017*					
	(0.010)					
ECI+			0.016*			
			(0.008)			
Educ_secondary				−0.024**		
				(0.010)		
Educ_secondary × *ECI*				−0.011**		
				(0.005)		
Gov_health					−0.006	
					(0.005)	
Gov_health × *ECI*					−0.010*	
					(0.006)	
Fdi						0.002
						(0.001)
Fdi × *ECI*						−0.001*
						(0.000)
Constant	−0.037	0.247**	0.061	0.315	0.142	−0.081
	(0.143)	(0.120)	(0.140)	(0.200)	(0.148)	(0.131)
AR(2) *p*-value	0.131	0.112	0.103	0.075	0.333	0.086
Hansen *p*-value	0.320	0.691	0.512	0.492	0.575	0.771
No. observations	891	871	800	949	855	810
No. countries	88	86	86	85	87	87
No. instruments	87	84	75	87	82	87

Note: This table reports the results of robustness testing. The dependent variable is the natural logarithm of the Gini index. *GDPpc* is the natural logarithm of GDP per capita (constant 2010 USD). *Ins* is the average of six components of institutional quality (Kaufmann et al., 2011), rescaled from 0 to 3. *Educ* is the tertiary school enrollment (% gross). *Educ_secondary* is the secondary school enrollment (% gross). *Gov* is the general government final consumption expenditure (% of GDP). *Gov_h* is the general government final consumption expenditure on health. *Trade* is the total exports and imports of goods and services (% of GDP). *Fdi* is foreign direct investment, net inflows (% of GDP). *ECI* is the economic complexity index. *Dummy_middle* is a dummy variable that equals 1 if a country is in the middle-income country group and 0 otherwise. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

several policy tools. Specifically, when the education level, government spending, and trade openness reach certain thresholds, they facilitate the beneficial effects of higher economic complexity on dealing with income inequality. In other words, countries endowed with better human capital, efficient public spending, and economic freedom can reduce income inequality. However, in an environment with less education, ineffective and low government spending, and less economic openness, economic complexity significantly worsens income distribution. These findings indicate that the negative side of economic complexity for income distribution, as suggested in the skills-based technological change theory (Berman et al., 1998; Card and DiNardo, 2002; Violante, 2008), could be mitigated and even eliminated by favorable socioeconomic and institutional conditions. Within the context of one country, our findings indicate that changes in human capital and government spending over time could alter the way in which structural change influences income inequality. This implication is similar to the ideas by Kuznets (1955). Specifically, the Kuznets–Lewis wave (Kuznets, 1955) also features the adverse effects of structural changes on income distribution at its initial stages, before income inequality is neutralized by public finance investments, such as public education, health care, and a social safety net.

Our findings show the reasons underlying the mixed empirical evidence regarding the impact of economic complexity on income inequality in the literature while complementing the insufficiency of skills-based technological change theory (Card and DiNardo, 2002; Weiss, 2008). In addition, this study expands the existing knowledge about not only the impacts of economic complexity on income distribution but also the contribution of the education level, government spending, and trade openness to lowering income disparity.

In a nutshell, this study implies that economic development is not the complete answer for lowering income inequality. In fact, the reduction of income disparity requires a combination of several development policies. The enhancement of productive capabilities, which results in higher economic sophistication, should be implemented together with improvements in institutions, government spending, human capital, and trade liberalization. Specifically, developing countries with a less educated population, ineffective and low government spending, and less economic openness will suffer widening income disparity if they try to increase their economic sophistication. To attain the benefits of economic complexity in lowering income inequality, they need to engage in more comprehensive efforts to increase educational attainment, public spending efficiency, and economic freedom.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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