Economic complexity, shadow economy, and income inequality: fresh evidence from panel data

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Abstract

This research attempts to examine the effects of economic complexity and shadow economy on income inequality for a panel dataset of 99 countries. The two-step system GMM estimation is employed to capture the non-linear relationships among interested variables. The findings indicate that income disparity is significantly and non-linearly linked with economic complexity and grey economy. First, there exists a U-shaped relationship between economic complexity and income disparity. The turning point for which the effect of economic complexity on income inequality changes from negative to positive is -0.732. Second, the impact of shadow economy on income inequality displays an inverted U-shaped pattern. The estimated threshold above which the marginal effect of shadow economy on income inequality changes from positive to negative equals 15.6%. Given the complication of these relationships, the governments are advised to take into consideration the situation of these two socio-economic issues when developing income distribution-related policies.

Jel Classification code: O10, O17, O15, O50.

1. Introduction

How income is distributed among members of society has remained a debate topic in the world. As a building block for peace, equalization in sharing economic rewards helps build trust and social cohesion (IEP 2020). It enables governments and other institutions to call for cooperation among the public in solving socio-economic issues. In contrast, widening income gap causes political and economic uncertainty (Acemoglu et al. 2012, Cingano 2014, Kumhof et al. 2015) and hence, dampens investment and endangers prosperity (Bourguignon and Dessus 2009, Claessens and Perotti 2007). A growing body of research has examined the roots of income inequality. Kuznets (1955) proposes an inverted-U shape curve to demonstrate the relationship between economic prosperity and income disparity during the urbanization and industrialization process. The Kuznets hypothesis is empirically supported across countries (Chong 2004, Meniago and Asongu 2018). Likewise, there is substantial empirical evidence that shows the inverted U-shaped relationship between institutions and income inequality (Andres and Ramlogan-Dobson 2011, Li et al. 2000, Perera and Lee 2013). The common argument of those studies is that when the national income and institutional quality reach certain high thresholds, the lower-income segment of the society could benefit from the improved economic conditions, better democracy, and effective public service provision to move up higher social ladders. This results in lower income disparity. The literature reveals the contribution of other factors, such as education or human capital (Castro Campos et al. 2016, Norris et al. 2015, Romer 2012) and government spending (Anderson et al. 2016, Goñi et al. 2011, Martínez-Vázquez et al. 2012) to tackling income inequality. In this regard, more developed countries which are characterized by high income, good institutions, high educational attainment, and generous funds for social programs should have a lower and decreasing income gap. Nevertheless, it is witnessed that after a declining trend, since 1990, income inequality has continuously risen in most advanced economies and even reached historical highs in some cases such as United States, Chile, and Mexico (Derviş and Qureshi 2016, Siami-Namini and Hudson 2019). Despite efforts to implement redistribution policies, their growth in income inequality could only be contained for periods, but not last for long. According to standard trade theory, rapid globalization, especially trade openness may be a reason for rising inequality in developed countries (Stolper and Samuelson 1941). Specifically, those countries, as capital-abundant economies, will exchange capital-intensive goods for labor-intensive commodities. Trade liberalization, therefore, works in favor of export-oriented businesses and benefits high-skilled workers, leaving low-skilled and unskilled labor of import-competing sectors at a disadvantage. This will further widen the income gap. However, the validity of this hypothesis is inconclusive (Asteriou et al. 2014, Le 2019, Lin 2016, Meschi and Vivarelli 2009, Wood 1997). The research strand regarding determinants of income inequality, especially in advanced economies, therefore, still calls for more contribution.

As wage is a primary source of income, individuals' labor market situation is the root of income inequality (OECD 2018). In more detail, income disparity is driven by two dimensions, including quantity and quality of jobs (OECD 2015, 2018). The former refers to the share of inactive or unemployed workers who are positioned at the bottom end of the income spectrum. The latter is associated with earnings quality (the extent to which effective earnings could ensure their well-being) and labor market security (the risk and expected duration of unemployment). In this regard, changes in the economic and occupational structure that affects the labor market by creating and destroying jobs may have some linkages with the distribution of income.

Knowledge is a crucial input of production and hence, embedded in a country’s productive structures. Economic complexity, as measured by the diversity and ubiquity of a country’s exports, reflects the stock of knowledge accumulated in the society (Hartmann 2014). Progressing to a more complex economy is, therefore, associated with the economic transformation toward the production of new sophisticated products. On one hand, during the economic complexity evolution, new occupational and learning opportunities are created for a wide range of labor regardless of their skills due to the introduction of new industries and sectors (Feldmann 2013, Hartmann et al. 2017). Moreover, workers could enjoy better wages due to higher return to scale enabled by a higher specialization level (Constantine 2017, Lee and Vu 2020). As a result, the enhancement of both job quantity and quality helps equalize income distribution. On the other hand, according to the skill-biased technical change theory (Acemoglu and Autor 2011) and routine-biased technological change hypothesis (Autor et al. 2003, David 2015, Beaudry et al. 2016), while the demand for high-skilled labor increase, the use of machines and robots leads to the depletion of obsolete jobs for medium- and low-skilled workers, especially those involved with routine activities (Dao et al. 2017). This could intensify income inequality.

Shadow economy, which encompasses either illegal activities or undeclared production of legal commodities (Alm and Embaye 2013), may also affect income inequality through its influence on job quantity and quality. As an inevitable part of the economy, the primary incentive of participating in the

underground economy is avoiding tax burdens and regulations. To hide from the local authorities, informal firms deliberately keep small-scale operations (Eilat and Zinnes 2002). The existence of the underground sector is, therefore, referred to as salvage to the low-skilled and unskilled labor (Bajada and Schneider 2009, Hatipoglu and Ozbek 2011, Sethuraman 1976). However, due to the flexibility of employment policies and the lack of access to necessary public goods and services, the rise in labor supply for underground economic activities may widen the wage gap, either within the shadow labor market or between the informal and formal sectors (Binelli and Attanasio 2010, Binelli 2016). The linkage between either the sophistication of an economy or the size of underground sectors and the labor market implies the possible association between either economic complexity or shadow economy and the distribution of income in a society.

The existence of both positive and negative forces in the economic complexity-income disparity nexus hints at the existence of the non-linear relationship between the two factors. Both Le et al. (2020) and Bandeira Morais et al. (2021) find empirical evidence about an inverted U-shaped effect of economic sophistication on income gap. Nevertheless, Le et al. (2020) employ export diversification to proxy a nation's productive structure. This indicator is deemed to be less comprehensive than the economic complexity index, as proposed by Hidalgo and Hausmann (2009). Meanwhile, Bandeira Morais et al. (2021) only show the empirical evidence for Brazil states only. Similarly, the two-sided effects of shadow economy on income disparity also imply the non-linear relationship between the two factors. Nevertheless, to our best knowledge, Yap et al. (2019) is the only research that examines the dynamic nonlinear relationship in the informality-inequality nexus based on both parametric and nonparametric/semiparametric regression. However, this research has some limitations regarding its database. Specifically, Yap et al. (2019) use unbalanced panel data of 154 countries within a relatively narrow time span, only from 2000 to 2007.

The present study fills these literature gaps by examining how economic complexity and shadow economy could influence income distribution. Following theories and preliminary observations, the non-linear nature of those relationships is proposed. The empirical analysis is conducted for a panel data of 99 countries from 2002 to 2016. To address the problem of endogeneity and autocorrelation, the system Generalized Method of Moments (hereafter system-GMM) is applied. The system-GMM method allows the estimation of the dynamic endogenous relationship between two interested explanatory variables and income inequality.

First, this study affirms a U-shaped impact of economic sophistication on income inequality. Initially, higher complexity leads to a fairer distribution of income. Once economic complexity reaches a certain threshold, higher economic complexity exacerbates income gap. On the contrary, the second main outcome confirms that effect of shadow economy on income disparity follows a U-inverted shape. We find a turning point over which the effect of shadow economy on income inequality changes from positive to negative. These results withstand a variety of sensitivity checks, including alternative measures of income inequality and shadow economy, model modification, time span, and estimation methods. Turning to possible policy implications, this on-hand paper provides several alternatives for the governments in the process of tackling income disparity.

The paper is structured as follows. In section 2, we review the existing literature and derive hypotheses. Section 3 discusses the economic models, data, and estimation method. Section 4 reports and discusses estimation results. Further theoretical implications and policy recommendations are presented in Section 5.

2. Literature Review

2.1. Economic complexity and income inequality

As a robust predictor of economic growth, economic complexity implies the improvements of various crucial socio-economic constructs, including institutions and human capital (Hartmann et al., 2017). Due to the complex interrelationship among socio-economic factors, progressing to a sophisticated economy could either narrow or widen income disparity.

On one hand, the literature document two primary ways that economic complexity could lessen income inequality, including narrowing the income gap between workers and capital owners and equalizing occupational opportunities among workers. First, an individual's income may come from two main sources, including capital and labor. Therefore, income inequality is affected by the distribution of economic rewards to the agents of these factors. This, in turn, depends on the distribution of labor and capital in the society and how the output is shared between these two factor endowments. As capital is distributed more unequally compared to that of labor, the rise of labor share, as proxied by the proportion of wages and salaries in total GDP, may lead to lower income disparity (Daudey and Garcia-Peñalosa 2007). The development of a highly complex economy requires the inputs of tacit knowledge that is embedded in labor (Young and Zuleta 2016). Since acquiring this productive knowledge for making diverse and unique products is a costly and risky process, not only the demand for labor but also the workers' bargaining position will increase during the economic complexity evolution. Moreover, participating in a complex productive economy with high productivity will increase return to scale (Constantine 2017, Lee and Vu 2020). This would further raise the labor share in total output (Young and Tackett 2018, Knepper 2020) and hence, shrink income inequality between capital holders and workers (Arif 2021). Second, since productive knowledge is embedded in the diversity and ubiquity of a country's export, economic complexity implies the diversity and ubiquity of production capabilities that a society attains. In this regard, a country with low economic complexity is characterized by peripheral production where there is a limited connection among products. Therefore, not only are the number of business sectors limited but also low opportunities for other economic activities are left (Elgin and Oztunali 2014). As a result, there are limited occupational choices while the national wealth is obtained by small groups in the society (Constantine and Khemraj 2019). When the economy is more sophisticated, the combination of more diverse and unique productive knowledge allows the introduction of new products. The denser product space induces more production activities across sectors. Consequently, the highly complex economy would demand more labor with dispersed skills and various levels of

knowledge (Constantine and Khemraj 2019, Hartmann et al. 2017). During the initial phase of economic complexity revolution, the low-skilled segment could obtain more benefits from a flatter occupational structure with more job and learning opportunities compared to the high-skilled counterparts (Albassam 2015, Egger and Etzel 2012, Hartmann 2014, 2017). This, in turn, facilitates the achievement of a more equal society. Moreover, a highly complex economy could facilitate a higher level of specialization to achieve better production efficiency. This favorable economic condition could be sustained in the long term since an economy with diverse production activities is more resilient from economic shocks (Barnes et al. 2015, Joya 2015). Overall, the poor could get better lifetime earnings that could be used to immediately either improve their living standards or invest in health and education. This helps resolve poverty, enlarges the middle-income class, and reduces income inequality in the long run (Constantine 2017, Hartmann et al. 2017, Hidalgo 2015). Hartmann et al. (2017) provide empirical evidence about the contribution of economic complexity in equalizing income based on a data set of 150 countries from 1963 to 2008 and Le Caous and Huarng (2020) over 87 developing countries during 1990-2017.

On the other hand, a rising income gap either between workers and capital owners or among workers of different skill levels could be also witnessed in a country with high economic complexity due to several reasons. First, when economic sophistication reaches a sufficiently high level, technological advancement may facilitate the substitution of capital for labor. In this regard, the overall occupational opportunities and the bargaining power of workers may reduce. This is followed by lower labor share, and hence, higher income inequality between workers and capital owners (Arif 2011). Second, at a higher level of economic complexity, the increasing use of machines and robots may lead to the depletion of obsolete jobs among low- and medium-skilled workers, especially those associated with routine activities (Raquel and Biagi 2018). Nevertheless, demand for high-skilled labor who could be in charge of “cognitive” tasks and ensure success rate of the new product development is always in an upward trend (Autor and Salomons 2018, Violante 2008, Meschi and Vivarelli 2009). At the same time, there is also a shift from middle-income manufacturing to low-income service jobs where the possibility of machine substitution is low (Autor and Dorn 2013). The progress of economic complexity with its “deindustrialization” effect, therefore, increases income inequality. Additionally, given diverse and unique productive knowledge, a highly complex economy more likely specializes in sophisticated products. Meanwhile, the supply from natural resource-dependent sectors (hence, labor-intensive) and those that require low-skilled knowledge is replaced by imports (Anderson 2005, Meschi and Vivarelli 2009). As a result, the low-skilled labor is further left at a disadvantage where many of them neither retain current jobs nor acquire sufficient knowledge and skills to adapt to more demanding requirements from the labor market. This further enhances income inequality (Berman et al. 1998, Card and DiNardo 2002, Violante 2008). The positive relationship between economic complexity and income inequality could be witnessed through the consequences of economic transformation during the 1980s in the United State (Card and DiNardo 2002, Levy and Murnane 1992) or empirical cross-country evidence provided by Lee and Vu (2020), Chu and Hoang (2020), and Lee and Wang (2021).

Due to the existence of both positive and negative forces in the economic complexity-income inequality nexus, the non-linear relationship between the two factors is examined in some studies. Given that economic complexity could influence the level of income, the theoretical underpinnings for this non-linearity could be drawn from Kuznets (1955) who proposes an inverted U-shape (also known as the Kutznet curve) demonstrating the changes of income inequality by income. At the early phase of economic development, the economic rewards are likely to hold by sub-groups of the society, causing a wide income gap. The economic development in the latter phase allows the participation of more people from various social groups. This results in an improvement in the income distribution. Le et al. (2020) and Bandeira Morais et al. (2021) show empirical evidence to affirm that there exists a similar non-linear effect in the economic complexity-inequality nexus. Initially, the increase in the sophistication of an economy would raise more benefits for capital owners and skillful workers and hence, widening income disparity. However, as the productive structure becomes more diverse, at a certain threshold, the improvement of institutions, bargaining powers of workers, and occupational opportunities enabled by a highly complex economy would turn the effect of economic complexity on income inequality to negative. This constitutes an inverted U-shape relationship between the two factors. The existing literature has some limitations. First, upon the theoretical perspective, the empirical evidence of previous studies does not show the “deindustrialization” effect where the advanced technology in a highly complex economy causes the destruction of manufacturing employment among low- and medium workers, and hence, raise income inequality again. Second, regarding the measurement method, Le et al. (2020) employ export diversification to proxy a nation’s productive structure. This indicator is deemed to be less comprehensive than economic complexity index, as proposed by Hidalgo and Hausmann (2009). Third, about data, Bandeira Morais et al. (2021) only show the empirical evidence for Brazil states only. This study, therefore, revisits the nonlinear analysis of the economic complexity-inequality linkage while compensating for the limitations of previous works.

H1: Economic complexity has a non-linear relationship with income inequality

2.2. Shadow economy and income inequality

As an inevitable part of the official economy, the shadow economy also plays an important role in the distribution of economic rewards (Alm and Embaye 2013, Bajada and Schneider 2005). On the one hand, the shadow economy mostly has a relatively small-scale operation, which is characterized by a higher labor-intensive yet lower capital-intensive production model, as compared to the formal sector. Therefore, the shadow economy mostly attracts the employment of low-skilled and unskilled labor and hence, becomes a survival source of income for the poor, as mentioned in the residue theory (Bajada and Schneider 2009, Hatipoglu and Ozbek 2011, Sethuraman 1976). In this regard, participating in underground market-based activities could be considered as an important option for the poor to be salvaged from poverty (Kim 2005). Along with the process of urbanization, the shadow economy attracts the poor from rural areas to conduct informal jobs in urban areas for higher wages (Bhattacharya 2011). The demand for low-skilled workers for underground activities is relatively stable as informal firms deliberately keep their business operations at a small scale to avoid detection from the government (Eilat and Zinnes 2002). Moreover, the unofficial sectors also function as

salvage for low-skilled employees once they lose official work (Eilat and Zinnes 2002, Dell'Anno and Solomon 2008). The shadow economy, therefore, not only creates jobs and income but also ensures overall employment and reduces the likelihood of income loss among the poor (Bhattacharya 2011, Okumu 2014). This helps reduce income inequality in the long run.

Moreover, given that informal business (mostly include the poor and small firms) generates better income for those at the bottom end of the income spectrum, the development and power of these firms may indirectly narrow the income gap. From the legalism and voluntarism perspectives, the growth of the shadow economy intensifies the unfair competition between formal and informal businesses (Chen 2012). Since the informal sectors are excluded from the government's regulations (such as the imposition of tax and fee), they may have certain advantages to capture higher economic rewards that would be distributed among those of the marginal society. In addition, due to lower entry costs and higher flexibility, the shadow economy attracts new start-ups, which mostly lack access to formal finance to test and grow their business (Williams 2006). The emergence of new ventures, in turn, helps create more job opportunities for low-skilled and unskilled labor. Especially, in a country with high corruption and misplaced institutions, the shadow economy could substitute the "invisible hand" to function as an outlet for the vulnerable segment of the business community in fostering entrepreneurship, creating new markets, intensifying competition, and accessing economic resources that they may not attain in normal conditions. Correspondingly, the poor and small firms could be empowered to receive better shares of economic returns (Asea 1996, Schneider and Enste 2000, Shleifer and Vishny 1998). This, in turn, create positive changes in income distribution.

As the shadow economy grows and accounts for a higher share in the economy, its positive effects in raising income for the poor and facilitating the growth of new ventures and small firms will be stronger. We, therefore, name this channel as "scale effect" that is affirmed in some previous works such as Valentini (2009), Bhattacharya (2011), Okumu (2014), and Huynh and Nguyen (2020).

On the other hand, the shadow economy may widen income gap because of several reasons. First, the exclusion of market-based transactions from official accounts creates obstacles for the government in collecting taxes. The loss of tax revenue hinders the sufficient provision of public goods and services under redistributive policies (Gërxhani 2004, Rosser et al. 2000, 2003, Schneider and Enste 2000). The poor and the low-productivity people would suffer the most from this loss, especially during economic shocks when their survival depends largely on subsidies. In this regard, the growth of the shadow economy may worsen income inequality (Ahmed et al. 2007, Rosser et al. 2000).

Second, competition is the major force of efficiency in resource allocation under a market economy (Scherer 1979). The growth of a shadow economy that breaks the "rules of the game" could reduce competition (Eilat and Zinnes 2002). Specifically, a large share of the shadow economy not only signals the poor institutional quality with the high tax burden, corruption, and bureaucratic issues but also implies the threat from "unfair" competition against informal firms. This would discourage the market entry of new investors, especially foreign ones which mostly want to operate in the formal sectors for better visibility and protection under laws (Cuong 2020, Huynh et al. 2019, Lambsdorff 2003). Another line of research contends that the existence of a larger shadow economy indicates "unofficial" opportunities for either bribery or tax evasion (Chiarini et al. 2013, Egger and Winner 2005) and therefore, may attract more greenfield investments (Ali and Bohara 2017, Cuong 2020). However, the existence of too many underground activities would, in turn, make it costly for the government to implement necessary regulations and policies aiming at maintaining healthy competition and preventing monopolistic practices (Eilat and Zinnes 2002). Consequently, the government would rather ignore it or reap benefits through corruption. This further destroys healthy market competition and leads to higher prices that would further benefit the equity owners and hence, widen income gap.

Third, the rise in labor supply for unofficial economic activities may widen income gap (Binelli and Attanasio 2010, Binelli 2016). This could be explained by the flexibility of wage policies in the shadow economy. While wages are well regulated in the official economy, the shadow participants are not protected by laws or legal commitments for their earnings (Krstić and Sanfey 2007, 2011, Xue et al. 2014). As the shadow economy grows, especially in low-wage sectors, the income inequality within the shadow economy itself and between the formal and informal sectors may increase (Dell'Anno and Solomon 2014, Xue et al. 2014).

Fourth, hiding in the shadow economy undermines the growth of informal firms and hence, further increase the income gap between the shadow and non-shadow sectors. Since the small-scale production makes it easier for firms to hide from the government, the shadow economy is mostly dominated by small-sized firms, which hardly have intensives to expand. Moreover, even when they aspirate for better growth, their lack of access to formal finance and necessary public goods and services limits their innovation and expansion (Straub 2005). As a result, the informal firms are characterized by low productivity and low returns, hence, could not ensure the improvement of income among their employees, including mostly the poor and low-skilled labor.

Fifth, the literature also documents the participation of large-sized firms in the shadow economy (Boycko et al. 1995, Kaminski 1996). However, different from smaller firms that operate unofficially for survival, these large firms aim at tax evasion by declaring less than actual production outputs or avoiding regulations that are deemed to be unfavorable to their profitability. This further benefits the high-income individuals who own or work for large-sized companies, and hence, worsen income inequality (Pashardes and Polycarpou 2008).

The positive impacts of the shadow economy and income inequality are empirically affirmed in some research such as Chong and Grandstein (2007), Pashardes and Polycarpou (2008), Krstić and Sanfey (2007, 2011), Xue et al. (2014), and Berdiev et al. (2018). The arguments of these studies are commonly rooted in the deregulation of the shadow economy. Given that ensuring social equality is primarily embedded in the functions of most governments' regulations and policies, the shadow economy that deliberately conceals underground activities from public authorities could widen the income gap. We, therefore, name this channel as the "deregulation effect". The scale effect and the deregulation effect of the shadow economy would

occur at the same time. Their strength depends on the size of the informal sectors in an economy. Since these effects could influence income inequality in opposite directions, there may be a change in the relative strength of one against the other by the degree of informality. This would form a non-linear relationship between shadow economy and income inequality. Yap et al. (2019) find an inverted N-shaped relationship between the shadow economy and income inequality using panel data of 154 developed and developing countries between 2000 and 2007. Within the threshold from 18 to 65, a larger size of the shadow economy could help reduce income inequality. Meanwhile, a positive impact of the underground economy on income disparity is found outside this range.

H2: Shadow economy has a non-linear relationship with income inequality

3. Model, Data, And Estimation Method

3.1. Model specification

We develop a dynamic functional form to examine the effect of economic sophistication and shadow economy on income distribution, which is:

$$Gini_{t-1} = f\left(Gini_{t-1}, ECI, Shadow, OPEN, EDU\right)$$

1

We follow previous empirical experience (Baccini and Urpelainen 2014; Lehoucq and Pérez-Liñán 2014) to use the one lag period of the explanatory variable relative to our independent variable. This practice is referred to partly reduce the reverse causality and emphasize the impact of independent variable on the dependent variable (Steinberg and Malhotra 2014). To further address the endogeneity issue, the GMM estimation method has been applied (Roodman 2009). We also regress model (1) using the current year of explanatory variables for robustness check.

The theoretical and empirical literature highlight the non-linear relationships between economic sophistication, informal economy, and income disparity. To investigate these relationships, we allow the existence of both quadratic forms of economic complexity and shadow economy in estimation equation. The Eq. (1) is transformed to the following form:

$$Gini_{i,t} = \beta_0 + \beta_1 Gini_{i,t-1} + \beta_2 ECI_{i,t-1} + \beta_3 ECI^2_{i,t-1} + \beta_4 Shadow_{i,t-1} + \beta_5 Shadow^2_{i,t-1} + \beta_6 OPEN_{i,t-1} + \beta_2 EDU_{i,t-1} + \eta_i + \epsilon_{i,t}$$

2

where $\text{Gini}_{i,t}$ is income inequality, $ECI_{i,t-1}$ is economic complexity, $Shadow_{i,t-1}$ measure shadow economy, $OPEN_{i,t-1}$ represents trade openness, and $EDU_{i,t-1}$ is secondary school enrollment ratio. η stand for country specific effects, ϵ is the disturbance term, i and t are country and time indices, respectively. We also include year dummies to capture time related-effects.

If the relationship between economic sophistication and income imparity follows a U-shape form, the coefficients of economic complexity (β_2) and its square (β_3) are negatively and positively significant, respectively. If the link between informal economy and income imparity has an inverted U-Shape distribution, the coefficients of shadow and its quadratic form are positively and negatively significant, respectively.

3.2. Data

The data are collected from variety of source. First, the dependent variable, income inequality, is collected from Standardized World Income Inequality Database (SWIID). While the World Bank estimates Gini index by aggregating survey response from government statistical agencies, the SWIID's Gini index of income inequality is calculated in equalized household earnings adopting Luxembourg Income Study data. Thus, SWIID uses a uniform set of assumptions and definitions of income inequality, which give a more comparable database across countries (SWIID 2021). The SWIID is also superior in terms of sample coverage (which contains 198 countries from 1960), allowing for the broarder cross-national analysis. We select two indices to proxy for income distribution, which are Gini pre-tax and pre-transfer (GINI-pre) and Gini post-tax and post-transfer (GINI_post). While the former index captures the gross income inequality, the later index considers the income differences after controlling for tax and other transfers.

We adopt Economic Complexity Index developed by Hausmann et al. (2019) as a measurement of economic sophistication. This index is based on the original ideal of product space. According to the authors, the development of a country can be viewed as a process of self-discovering its mastered export product (Hausmann, Hwang, and Rodrik 2011). Thus, by calculating export structure (in terms of ubiquity and diversity), ECI captures the development of a country. Hausmann et al. (2019) also indicate that the economic complexity is a good proxy for economic development, as it reflects the knowledge accumulated in society. For that reason, we apply economic sophistication as a consistent predictor of country's development stage, instead of other conventional indices like GDP per capita. Data on ECI is achieved from MIT's Observatory of Economic Complexity. The economic complexity index falls in the range between − 3 and 3. To allow the existence of a square term of economic complexity, we follow the work of (Chu 2021) and transform it from (-3 3) to (0 6).

We follow Schneider (2005) to define shadow economy as "market-based legal production of goods and services that are deliberately concealed from public authorities". This definition excludes criminal activities (such as smuggling, money laundering, drug trafficking) and all other unpaid household works. Schneider (2005) assumes the grey economy as "an un-observed", which is a latent variable that can be calculated using statistic technique,

like Multiple indicator multiple caused model (hereafter MIMIC). There are other techniques for measuring the informal economy, for example, micro survey approaches and currency demand approaches. While the survey method has been criticized to be uncertain reliability as it greatly depends on respondent's answer (Schneider 2005), the currency demand is argued to not fully and accurately address the shadow economy (Feige 2015; Thomas 1999). For that reason, this paper conducts the shadow economy indicator based on MIMIC model as a primary variable for shadow economy. Since its introduction, Schneider (2005)'s measurement of grey economy has been applied in many studies (Bajada and Schneider 2005; Dreher and Schneider 2010)

For robustness, we collect the data provided by Elgin (2021) as substituted indicators for informal economy. The informality, as described by these authors, accounts for production of goods and services that are legal but outside government supervision. Similar to Schneider (2005), the computation of the informal output is based on two estimation methods, the dynamic general equilibrium model (hereafter DEG) and multiple indicator multiple caused model (MIMIC). They are computed from data collected from the Penn World Table 9.1's national income. Both indices are measured as a percentage of GDP. While measurement based on DEG method is standout for its comprehensive covering and strong literature support, the estimation method does require some strong assumptions (Özgür et al., 2021).

With regard to other control variables, trade openness, is calculated as the ratio of export and import to GDP while education is measured as percentage of gross secondary school enrollment. We collect both data from the World Bank's World Development Indicators database.

Our database contains 99 countries for the period from 2002 to 2016 (see Appendix 1). Of which, 38 countries are high-income countries and 61 countries are middle-income countries based on the World Bank classification. We limit our sample to middle and high-income countries because of several reasons. First, there are only 18 low-income countries. Second, the outliers mostly come from 18 low-income countries. Third, these countries have limited data availability. The variable descriptive is presented in Table 1. All variable is transformed to natural logarithm form.

Table 1
Descriptive statistic

Variable	Mean	Std. Dev.	Min	25th	50th	75th	Max
GINI_post	3.600	0.220	3.140	3.447	3.603	3.761	4.200
GINI_pre	3.825	0.150	3.086	3.754	3.846	3.908	4.282
ECI	1.168	0.309	0.029	0.966	1.221	1.414	1.649
SHA (Sheider, 2005)	3.175	0.490	1.818	2.889	3.246	3.515	4.234
SHA (Elgin et al., 2021, DGE)	3.254	0.437	2.083	2.903	3.332	3.562	4.168
SHA (Elgin et al., 2021, MIMIC)	3.319	0.441	2.088	2.977	3.411	3.606	4.228
OPE	4.307	0.471	-1.608	4.018	4.292	4.643	5.421
EDU	4.443	0.343	3.020	4.381	4.552	4.635	5.099

3.3. Estimation method

A common problem in the regression of macroeconomic variables is the appearance of endogeneity in the model. Endogeneity occurs when variables affect each other. Consequently, regression results obtained from traditional estimation methods lead to spurious results (Bascle, 2008). To solve the issues of endogeneity, estimation methods have been developed with the use of instrumental variables. GMM is one of the most commonly used estimators to overcome the difficulty of choosing instrumental variables and solving endogenous problems (Baum, Schaffer, and Stillman 2003).

This study employs the two-step system-GMM estimator because of its efficiency over difference GMM or one-step system-GMM (Bond and Hoeffler 2001). In addition, the errors in the two-step regression model are not reliable if they are not normalized. Therefore, the Windmeijer (2005) sample correction is employed to estimate the robust standard errors. We also select the collapse option to reduce the number of instruments as suggested by Roodman (2009). Time dummy variables are added in the model to eliminate the correlation over time between countries.

The robustness of the GMM estimation relies on the uncorrelated error assumption andthe validity of the instrumental variables. The AR (2) test evaluates the second-order serial correlation in the mode, while the Hansen (1998) J-test helps to assess the problem of excessive use of instrumental variables.

To confirm the nonlinear impact of economic complexity and shadow economy on income distribution, a test developed by Lind & Mehlum (2010) is applied. The rejection of hypothesis H_0 provides evidence for the appearance of a U-shape (or inverted U-shape) correlation between economic complexity or shadow) and income inequality.

4. Results And Discussion

The estimation results of model (2) are shown in Table 4. The columns (1) to (3) illustrate the effects of economic complexity, shadow economy, trade openness, and education level on Gini post tax and transfer index. In Column (1), shadow economy follows Schneider (2005)'s measure, while columns

(2) and (3) use Elgin et al. (2021)'s estimation of informal economy based on DGE and MIMIC method, respectively. At the first glance, economic sophistication, informal economy, and education are the decisive factors affecting income inequality level within a society.

The estimated coefficient of the lagged dependent variable is positively significant. It indicates that the income gap is a long-term variable with large inertia as also pointed out by Fajnzylber et al. (2002). This result supports the use of dynamic model with GMM estimation. The validity of GMM estimation is evaluated through the AR(2) test and Hansen's (1982) J test. The AR(2) test's result rejects the existence of the second-order serial correlation in disturbance terms in all models. Meanwhile, the p-value of Hansen (1982) J test are above 10% significance level, indicating the joint validity of instruments used (Roodman 2009).

Table 2
Estimation results

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini_post tax & transfer			Gini_pre tax & transfer		
	Schneider (2005)	Elgin et al. (2021) DGE	Elgin et al. (2021) MIMIC	Schneider (2005)	Elgin et al. (2021) DGE	Elgin et al. (2021) MIMIC
Lag. GINI	0.992***	0.981***	0.987***	1.012***	0.991***	1.005***
	(0.010)	(0.020)	(0.010)	(0.016)	(0.015)	(0.013)
ECI	-0.043*	-0.060*	-0.054*	-0.043	-0.065**	-0.060**
	(0.024)	(0.031)	(0.031)	(0.026)	(0.025)	(0.028)
ECI_squared	0.026**	0.029*	0.027**	0.027**	0.034***	0.038***
	(0.012)	(0.017)	(0.014)	(0.012)	(0.011)	(0.013)
SHA	0.084***	0.179**	0.159**	0.078***	0.139**	0.114**
	(0.026)	(0.083)	(0.063)	(0.025)	(0.054)	(0.054)
SHA_squared	-0.015***	-0.029**	-0.026***	-0.014***	-0.023***	-0.019**
	(0.004)	(0.013)	(0.010)	(0.004)	(0.008)	(0.008)
OPE	-0.001	-0.003	-0.002	0.003	-0.000	-0.006
	(0.006)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
EDU	-0.014***	-0.008	-0.007	-0.014***	-0.008	-0.015**
	(0.005)	(0.005)	(0.005)	(0.004)	(0.006)	(0.006)
Constant	0.003	-0.125	-0.124	-0.085	-0.108	-0.079
	(0.068)	(0.180)	(0.103)	(0.094)	(0.135)	(0.109)
AR(2) p-value	0.107	0.102	0.733	0.190	0.824	0.204
Hansen p-value	0.731	0.896	0.882	0.606	0.688	0.445
No. Observations	1108	1108	1108	1108	1108	1108
No. Countries	99	99	99	99	99	99

Note: ***, **, * represent the statically significance at 1%, 5%, 10% level, respectively.

First, Table 2 illustrates that the economic complexity has a non-linear effect on income gap. The coefficients related to economic complexity and its square are negative and positive statistically significant. It confirms our hypothesis 2 that the effect of economic sophisticated on income inequality shift from enhancing to exacerbating when economic complexity level exceeds a certain threshold. The nonlinearity could be explained by the changes in demand for labor during the economic complexity evolution. At the early phase of the structural change, the product activities start to become more diverse and require the input of human capital with dispersed skills and knowledge (Hartmann et al. 2017). Consequently, workers regardless of their skill levels could benefit from better job opportunities and higher bargaining powers and in a flatter occupational structure (Albassam 2015; Egger and Etzel 2012). While the rise in the labor share helps reduce the income disparity between workers and capital owners (Daudey and Garcia-Peñalosa 2007; Arif 2021), the higher participation of the low-productivity workforce narrows the wage gap between high- and low-skilled labor. This leads to the improvement of the income distribution. As economic complexity reaches a certain threshold, the shift to more sophisticated production activities results in the substitution of capital-intensive inputs (for example, machines) for labor (Arif 2021). Regarding the inputs of human capital, skillful

workers are more favored (Violante 2008; Meschi and Vivarelli 2009). Furthermore, the disappearance of traditional labor-intensive sectors due to high imports (Anderson 2005; Meschi and Vivarelli 2009) further leaves the low-skilled and unskilled workers in a detrimental situation. As a result, the linkage between economic sophistication and income imparity turns from negative to positive. The nonlinearity in the economic complexity-inequality nexus provides an answer for the inconsistent empirical evidence in the literature. However, our finding contradicts the inverted U-shaped link between economic sophistication and income imparity as found in Brazil states (Bandeira Morais et al. 2021) or between export diversification and income imparity as claimed by Le et al. (2020) at the global scale. Despite economic complexity and GDP have a strong positive association, our finding does not fit the idea of the Kuznets' curve regarding the inverted U-shaped relationship between economic development and income inequality. The reason may be that our dataset covers most high- and middle-income countries since 2002. From that time, their economic complexity may reach a sufficiently high level where the positive contribution of economic complexity on income equalization appears significant right at the early phase. Meanwhile, the positive impact of the "technological unemployment" on income disparity under the deindustrialization process (Adam et al. 2020) could be witnessed in the latter stage.

Second, both shadow economy and its quadric form statistically affect income gap, but in opposite directions. While the former is positive, the latter is negative. It confirms our hypothesis of the inverted U-shaped relationship between shadow economy and income disparity. In other words, there exists a threshold on the shadow economy level, that below this threshold, the deregulation effect dominates the scale effect. In contrast, when shadow economy increases, the deregulation effect is overwhelmed by the scale effect. Specifically, the existence of a small-scale shadow economy is not enough to neither create significant changes in the overall income of the poor nor ensure the sufficient competitiveness of the informal sectors. Consequently, the positive side of the grey economy is not evident. On the other hand, the grey economy is considered as the substitute for good institutions and vice versa. A lower share of the underground activities implies better institutional quality (Schneider and Enste 2000; Saibal and Shrabani 2012). Since good institutions themselves help foster entrepreneurship and firm growth, the shadow economy may not necessarily function as an outlet for business dynamism, competition, and market productivity. Instead, the shadow economy may more likely serve illegal purposes and monopoly practices in favor of the large-sized companies and the rich. This would increase the income gap. Moreover, while formal firms receive supports from the government, the informal sectors find fewer unofficial opportunities to access formal finance and favorable treatments in a country of good institutional quality. Therefore, there may exist a bigger gap in business performance between formal and informal firms. This, in turn, worsens wage inequality between the two sectors. In this situation, the deregulation effect of the shadow economy may prevail to further widen the income gap.

In contrast, when the magnitude of the shadow economy reaches a sufficiently high level, the scale effect of underground activities could be strong enough to leverage the employment and income of the poor while raising the power of the informal sectors in the market. This, in turn, creates a significant reduction in the income gap. Moreover, a higher proportion of shadow economy implies poorer institutions and high tax burdens. The growth of the informal economic activity helps mitigate the tax burdens on the poor and small firms while substitutes the weak institutions to facilitate entrepreneurial dynamism and market efficiency (Asea, 1996; Schneider and Enste 1998; Shleifer and Vishny 1998). The positive impact of shadow economy, hence, may prevail and help equalize the income distribution.

This finding is consistent with Yab et al. (2017). Using a sample of 154 countries from 2000 to 2007, they find an inverted N-shaped linkage between the size of the grey economy and income disparity upon both nonparametric and semi-parametric analyses. Since we employ data set for only high-income and middle-income, the inverted U-shaped impact of the shadow economy as found in this study fits a part of the N-shaped relationship in the study by (Yab et al. 2017) (where the shadow economy accounts for less than 65%).

Table 3
The Lind-Mehlum (2010)'s test for an inverted U-shaped relationship

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini_post tax & transfer			Gini_pre tax & transfer		
	Schneider (2005)	Elgin et al. (2021) DGE	Elgin et al. (2021) MIMIC	Schneider (2005)	Elgin et al. (2021) DGE	Elgin et al. (2021) MIMIC
Economic complexity						
Extreme point	-0.732**	-0.179*	-0.293**	-0.797**	-0.450***	-0.803***
t-value	2.11	1.28	1.90	2.00	2.88	2.63
Shadow economy						
Extreme point	15.591***	20.884**	20.227**	16.200***	20.146**	19.925**
t-value	2.79	1.99	2.20	2.76	2.22	1.83
Note: ***, **, * depict the statically significance at 1%, 5%, 10%, respectively						

The Lind & Mehlum (2010)'s test confirms the presence of both U-shaped and inverted U-shaped relationship on our estimated models. All tested results are statistically significant at conventional confidence levels, rejecting the null hypothesis of no U-shape (inverted U-shape) correlation relationship. Table 3 indicates that when the level of economic complexity increases over − 0,732, its effect on income inequality changes from negative to positive. Whereas, a quadratic estimation of shadow economy yields an extreme point at 15,59 (the case of Schneider (2005)'s measure) and illustrates a U-shape impact of informal economic activity on income gap.

Figure 1 further demonstrates the conditional effect of shadow economy and economic sophistication on income distribution. Panel A illustrates that the impact of informal economic activity on income disparity varies from positive to negative with the increasing proportion of shadow economy. Specifically, within the low shadow economy interval (less than 15.591%), the development of informal economic activity acerbate the income inequality, while within the high shadow economy interval (higher than 15.591%), the development of informal economic activity lowers the income gap. In addition, we draw the effect of shadow economy on Gini pre-tax and transfer (Panel A - right hand side) instead of Gini post tax and transfer. It can be seen that the impact mechanism remains unchanged as with the previous index.

Panel B displays the marginal effect of economic sophistication on income gap with the evolution of economy sophisticated. It is shown that with an increase in knowledge accumulated within society, inequality redistribution effect of economic complexity decreases. When the economy develops to a certain stage (economic complexity index crosses − 0.732), the effect of economic complexity on income inequality changes from negative to positive. The same pattern can be observed in the case of economic complexity and Gini pre-tax and transfer relationship.

We find that high education level encourages fair income redistribution. This finding is consistent with the theoretical basis and supported by other empirical studies (Abdullah, Doucouliagos, and Manning 2015; De Gregorio and Lee 2002). The early human capital theory contends that higher educational attainment could signal better capabilities that help a person get a better job with higher income (Mincer 1974). Schooling, therefore, is a crucial channel to escape poverty and hence, reduce the income gap. In addition, since there is an income disparity between the rate of return on higher education and that on compulsory education, convergence in education levels or more equal educational distribution would reduce income dispersion (O'Neill 1995; De Gregorio and Lee 2002; Winegarden 1979).

We find limited evidence, which supports the positive impact of economic openness on income distribution. According to the Heckscher–Ohlin theory, trade openness may affect income distributions in a country in opposite directions depending on factor endowments. Specifically, a country would export products that require domestically abundant factors (hence, lower opportunity costs) and import those produced with scarce factors (Stolper and Samuelson 1941). Labor-abundant countries likely import skills-intensive products and export labor-intensive goods. Consequently, in labor-abundant countries, trade liberalization would benefit the low-skilled and unskilled employees in developing countries while skilled employees are left at disadvantage. This, in turn, will help narrow the income gap. In contrast, the capital-abundant countries intensively use skilled labor and capital for export-oriented sectors while low-skilled and unskilled labor work for import-competing ones. Therefore, skilled labor in these countries would reap the most benefits from trade openness while local firms of labor-intensive sectors may lose their market. This leads to higher unemployment and lower income among low-skilled and unskilled labor in these countries. The income gap, therefore, becomes wider.

To check the robustness, we further examining the model (2) using (Powell 2016)'s robust instrumental variable quantile regression. This method is based on an instrumental variable framework and using "non-additive fixed effect", which allows the maintenance of the non-separable error terms (Powell 2016). Thus, it helps to control the endogeneity and heterogeneity problem. The institutional quality calculated based on World Bank's World Governance Indicator database is employed as instrument. While institutional quality directly affects economic complexity (Hartmann et al. 2017) and shadow economy (Dreher, Kotsogiannis, and McCorriston 2009; Torgler and Schneider 2009), it indirectly affects income distribution (Hartmann et al. 2017). It is confirmed that the impact of economic complexity on income inequality follows the U-shape relationship and it does not change along the quantiles of the income distribution. Similarly, the impact of shadow economy on income gap is consistent at all income inequality levels and follows an inverted U-shaped form. Other modifications are tested for robustness check, including (1) replacing the economic complexity index with a more traditional index of economic development, GDP per capita; (2) removing trade openness as it is partly reflected in ECI; (3) examining with different time periods, from 2002 to 2015 and from 2002 to 2014; (4) using the current value of explanatory variables instead of lagged value. These above changes do not significantly alter our conclusions on the effects of economic complexity and shadow economy on income inequality. To save space, the results of these tests will be provided upon request.

5. Conclusion

Our study aims to investigate the impact of economic complexity and shadow economy on income disparity. Using the two-step system GMM estimation on a sample of 99 countries from 2002 to 2016, we find that both economic sophistication and informal economy have non-linear effects on income inequality. First, the linkage between economic sophistication and income gap follows the U-shaped relationship. Second, the impact of shadow economy on income disparity follows an inverted U-shaped pattern. In countries with the low level of shadow economy, the increase of informal economic activities widens the income gap. Whereas, in countries characterized by a high proportion of informal economy, the deregulation effect of informal economy is overwhelmed and the rise of informal economy leads to lower income inequality. These results are robust to a variety of tests, including variables measurements, time spans, model specifications, and estimation method. Overall, this study indicates that income disparity is significantly and non-linearly linked with economic complexity and grey economy.

The following policy implications should be pursued to tackle income disparity. Given the complicatedness of these relationships, the governments should take into consideration the situation of these two indicators when developing policies. First, the impact of economic sophistication on income disparity changes during its evolution. For example, advanced countries face the dilemma when higher sophisticated knowledge unavoidably widens the income gap. To achieve prosperity, they must tailor their economic policies and combine them with other socio-economic factors such as education, health, demography, to name a few. These policies may act as a buffer to lessen the negative effects of economic structureal reforms on income gap. On the other hand, developing countries may benefit from the development of economic complexity. To magnify such beneficial effects, the enhancement of productive capabilities for both individuals and firms should be in priority of the governments. Second, policies that affect income inequality through shadow sectors have different and contrasting implications for two types of countries. For countries with the low level of grey economy, the government should implement policies that reduce, or at least maintain, the current size of informal sector. In contrast, the implication becomes more complex in the case of a country with large informal sectors. The findings indicate that in such a situation, sinking informal sector might lead to higher income disparity, which inevitably depresses the poor. The policymakers should always pay attention to this predicament during the process of governing informal economy. Again, the designation and enforcement of social policies are extremely necessary to deal rigorously with the situation. Third, the government should be warned that the economic complexity development could affect the relationship between informal economy and income inequality, and vice versa, the policies on informal economy may spill over to economic complexity. We leave this moderating effect for future research.

Declarations

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Consent for publication: Not applicable

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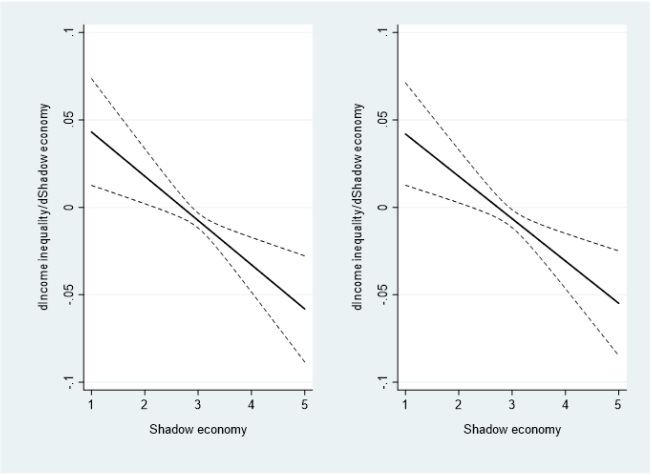
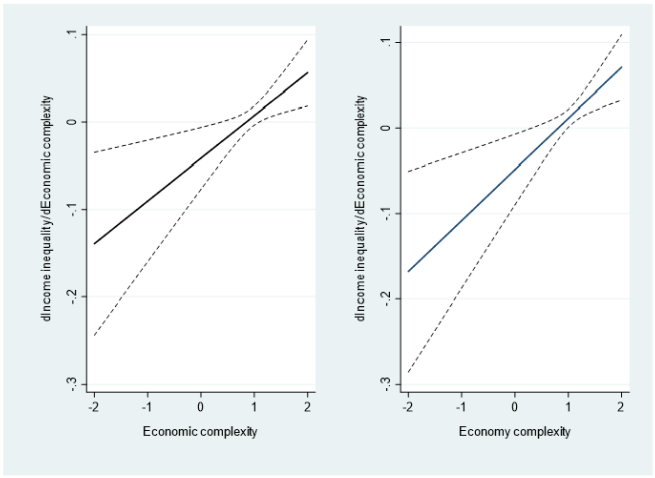
Appendix

Appendix 1 is not available with this version

Figures



A



B

Figure 1

Average marginal effect of shadow economy (Schneider 2005) and economic complexity on income inequality

Panel A. Shadow economy on income inequality (post-tax & transfer and pre-tax & transfer)

Panel B. Economic complexity on income inequality (post-tax & transfer and pre-tax & transfer)

Note: The solid black line represents the marginal impact of economic complexity, shadow economy on income inequality estimated from Table 2. The dotted lines are 90% confidence interval.