



Research article

The destructive effect of corruption on economic growth in Indonesia: A threshold model



Anisah Alfada*

Graduate School of Asia Pacific Studies, Waseda University, Tokyo, 169-8050, Japan

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ABSTRACT

A growing number of corruption cases in Indonesia have raised awareness of corruption's destructive effect on economic development, although no existing studies have considered the threshold value at which corruption hampers economic growth. This study assesses the effect of corruption on economic growth by taking a nonlinear approach to determine the corruption threshold. By analyzing the effect of corruption on economic growth across provinces in Indonesia over the 2004–2015 period, this study examines whether corruption works to the benefit of the provinces with low-corruption levels by supporting their economic growth when the number of corruption cases is below the corruption threshold. In contrast, corruption worsens economic growth in provinces with high levels of corruption when corruption exceeds the threshold. Different from other corruption studies in Indonesia, this study utilizes the number of corruption cases investigated by *Komisi Pemberantasan Korupsi* (KPK; Indonesia Corruption Eradication Commission) as the corruption measure. The corruption threshold effect is assessed using a sample-splitting and threshold model developed by Hansen (2000), and the endogeneity issue is properly addressed using the instrumental variable two-stage least squares (2SLS) estimator. The estimation results reveal that the impact of corruption indicates a growth-deteriorating effect for provinces with corruption levels below the threshold of 1.765 points, and the destructive effect of corruption appears stronger for provinces with corruption levels above the threshold. Another finding is that most provinces struggle with corruption problems, even while they have succeeded in maintaining their corruption levels below the threshold over time. Some provinces, such as Riau and West Java, experience severe corruption problems and have been in a high-corruption group over the last three years. However, some provinces, such as Lampung and North Sulawesi, manage to lower their corruption levels and shift to a low-corruption group.

1. Introduction

Many studies have examined the effects of corruption on economic growth with inconclusive results. Some studies, such as Mauro (1995) and Blackburn et al. (2006), examine the direct effect of corruption on economic growth and present evidence on its adverse effects. These studies confirm the hypothesis that corruption has a growth-deteriorating effect. However, other studies, such as Méon and Weill (2010) and Kato and Sato (2015), provide evidence supporting the “greasing the wheels” hypothesis and argue that corruption enhances economic growth.

Complementing these findings, Dzhumashev (2009) found that the direct effects of corruption also have a statistically significant negative impact when including the interaction term between corruption and government expenditure in the estimation. d’Agostino et al. (2016)

found that the indirect effects of corruption through consumption and military expenditures have strong negative impacts. These varied results suggest that there are differences in the productivity of each type of expenditure because the government devotes different resources to each. This may cause the corruption impact to vary based on the different components of expenditure. Unlike existing studies, which utilize the total government expenditures or military spending, this analysis examines the impact of corruption through two components of government expenditures: consumption and investment expenditures on economic growth. Consumption and investment expenditures are estimated to capture the full contribution effect of the government to the economy. Consumption expenditures are allocated to current expenditures on goods and services and salaries, and investment expenditures are directed to potentially productive areas and affect long-term economic growth (Devarajan et al., 1996).

* Corresponding author.

E-mail addresses: anisahalfada@fuji.waseda.jp, anisahalfada@gmail.com.<https://doi.org/10.1016/j.heliyon.2019.e02649>

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A few studies argue that countries have different production functions and levels of institutional efficiency, which explains why corruption effects differ across countries. Some studies, considering a nonlinear relationship, have found a corruption threshold around which corruption's effect on economic growth changes from positive to negative (Haque and Kneller, 2009; Bose et al., 2008). If the corruption level is above the threshold, the adverse effect retards economic growth. In contrast, when the corruption level is below the threshold, it may support the "greasing the wheels" hypothesis. Using a threshold model, this study measures the corruption threshold and examines the effect of corruption on economic growth to fill in the gap in existing studies. Identifying the corruption threshold contributes to the study of corruption by presenting an indicator to guide governments as they decide what policies to implement.

Some studies emphasize cross-country studies using the corruption perception indices that are extensively available from Transparency International, International Country Risk Guide and the World Bank. Several studies have criticized the indices for being based on perception despite the existence of real measures (Svensson, 2005; Andvig, 2005). A few studies have emphasized a country-specific case using a different corruption measure, such as corruption conviction, and most of these focus on the United States (Goel and Rich, 1998; Glaeser and Saks, 2006; Goel and Nelson, 2011). They argue that the choice of corruption measure does matter in corruption control policy recommendations. Kato and Sato (2015) examined India's provinces using corruption-related cases as corruption measures. They found that the marginal effects of corruption on the manufacturing level in India are positive for both the gross value added per worker and the capital-to-labor ratio in regulated sectors. In contrast to other existing studies, this study proposes using the number of corruption cases investigated by Indonesia's corruption eradication commission (KPK – *Komisi Pemberantasan Korupsi*) in Indonesia's provinces as the corruption measure. This analysis contributes to filling the gap in corruption studies in Indonesia.

Interestingly, since the establishment of KPK, the number of corruption cases has become more likely to grow over time, and KPK has succeeded in bringing many corruption cases in local government to court. The corruption cases involve local government leaders in the last three years (2015–2018) engaging in different types of corruption, such as bribery, budget misuse, and abuse of license agreements. Moreover, the relationship between economic growth and corruption in Indonesia's provinces displays a unique pattern. Some provinces, such as East Kalimantan and Riau, have strong economies despite high levels of corruption, whereas other regions experience middle to low-income levels under low incidence of corruption cases. This uniqueness provides an ideal case for the study of corruption's effect at the regional level. In this study, panel data of 19 provinces for the period 2004–2015 are utilized to estimate the corruption threshold according to the threshold model proposed by Hansen (2000). The endogeneity issue is properly addressed using instrumental variable estimation.

Another purpose of this study is to use the corruption threshold to determine the position of a province's corruption level relative to the threshold, which indicates the province's corruption performance. It is essential for a province that experiences a high-corruption level to be able to lower it. However, most provinces struggle with corruption problems, even while their corruption level drops below the threshold over time. Unlike existing studies that group the data sample based on income level, this study does not differentiate provinces into groups by income. This approach confirms that the corruption level does not directly correspond with the income level.

This study addresses two research questions. First, what is the effect of corruption on economic growth, accounting for different corruption thresholds? Second, has a given province's corruption level improved or deteriorated over time? In investigating these questions, this study yields two findings. First, corruption may negatively affect economic growth for provinces with relatively low-corruption levels, and the effect is stronger for provinces with high-corruption levels. Second, most provinces in Indonesia have historically struggled with corruption issues, but some

have managed to lower their corruption levels and succeeded in reducing corruption problems.

The paper consists of the following four sections. The next section is the literature review, which describes a variety of relevant studies. Section 3 describes the data and methodology employed in the estimation. Section 4 elaborates the empirical results and discussion, and section 5 offers some remarks for future research.

2. Theory

The relationship between corruption and economic growth has been debated. Many studies have found evidence that corruption has harmful effects on economic growth. Mauro (1995) proposes a study of corruption's effects on public and private investments. Corruption shows a negative correlation with economic growth after controlling for institutional efficiency. Tanzi and Davoodi (1998), Aghion et al. (2004) and Blackburn et al. (2006) found that corruption is detrimental to investment and growth and increases economic uncertainty (Bardhan, 1997). Guriev (2004) and Kaufmann and Wei (1999) reveal that corruption creates uncertainty for the investor and increases investment risk in countries with high-corruption levels. In contrast, some studies have shown a supporting effect of corruption on economic development.

Méon and Weill (2010) find that corruption is less detrimental to a less effective country and may be positively associated with efficiency in countries where institutions are incredibly ineffective. Huang (2016) examines the causal relationship between corruption and economic development in 13 Asia-Pacific countries and finds that South Korea and China are experiencing economic advancement despite high-corruption levels. Colombatto (2003) reports that in developing countries, corruption eliminates the unfavorable conditions that hinder development, as it may act as "speed money" under conditions of political instability and institutional inefficiency. Considering corruption determinants of firm behavior, Kato and Sato (2015) find evidence of a "greasing the wheels" effect of corruption at the firm level in India. These current findings on the direct effect of corruption on economic growth are thus inconclusive and depend on the methodology, data sample and period.

However, many existing studies use a linear specification and achieve inconclusive results. The linear specification suggests that countries have different production functions and institutional efficiency conditions that may cause different corruption effects. Considering this fact, some studies have found evidence of a nonlinear relationship in the corruption and growth nexus. Durlauf and Johnson (1995) explore a nonlinear specification of corruption and growth through cross-country analysis and find multiple corruption regimes. Aidt et al. (2008) argue that the corruption effect is influenced by governance quality. Corruption is harmful if the government implements good governance; in contrast, its effect is positive under inefficient governance. Bose, Capasso, and Murshid (2008) find a corruption threshold that determines two distinct regimes by corruption level. In the first regime, the corruption level is high, and corruption has a growth-deteriorating effect. In the second regime, the corruption level is low, and corruption is growth-enhancing. This finding is also supported by Aidt (2009) and Dzhusmashev (2014a). On the other hand, in a recent study, Ali (2015) argues that there are three corruption stages, which can be classified as pre-modern, modern and post-modern corruption. The causes and effects of corruption vary across stages, as do the actions aimed at reducing corruption. He suggests that the evolutionary process from the pre-modern to modern to post-modern stages, allowing for an improvement in institutional quality and economic development, will result in an optimal level of corruption reduction.

The inconclusive findings on the direct effects of corruption on economic growth have also motivated some empirical works that investigate the indirect effect of corruption through government expenditure. Dzhusmashev (2009) states that many empirical studies do not find robust negative results concerning the direct effect of corruption, while the indirect effect is found to be statistically significant. He finds that the direct

effect of corruption can be a threat to economic growth and becomes statistically significantly after including the interaction between corruption and government expenditure in the estimations. Ugur (2014) finds that in low-income countries with inefficient bureaucratic conditions, the indirect effects of corruption through public finance and human capital are likely to harm economic development. Moreover, corruption may distort revenue collection and affect the composition of government expenditure. Some scholars find that corruption is likely to favor large projects such as engineering and infrastructure projects rather than administrative sectors such as salaries (Shleifer and Vishny, 1993; Mauro, 1997). Keefer and Knack (2000) suggest that corruption contributes to inefficient public expenditure and leads to rent-seeking by altering the budget structure. Similar contributions support this view (Fisman and Gatti, 2002; Dzhumashev, 2014b). d'Agostino et al. (2016) confirm a harmful corruption effect associated with military and consumption expenditures; in contrast, they find that corruption in investment expenditures is likely to enhance economic growth. Supporting the crucial impact of corruption on military spending, a recent study by Ali and Solarin (2019) demonstrates that countries with higher levels of corruption tend to exhibit higher levels of military expenditures.

The choice of corruption measure does matter when analyzing corruption in a specific country. A few studies have suggested other corruption measures, such as corruption convictions and corruption-related cases. Goel and Nelson (2011) studied two different corruption measures in the United States, individual state convictions and corruption perception surveys. They found that greater judicial employment reduces corruption using both measures and that corruption convictions increase with the population of the state. Several previous studies utilize corruption convictions at different levels, such as state corruption convictions (Goel and Rich, 1998), average annual federal public corruption convictions (Goel and Nelson, 2011), and federal corruption convictions (Glaeser and Saks, 2006), and most of these studies focus on corruption in the United States.

Two different corruption measures are employed by Olken (2007, 2009) to analyze corruption on several road projects in Indonesia's villages. The first measure is the amount of missing expenditures from material purchased for the projects, and the other is a survey of corruption perception among the villagers around road projects to analyze the gap between opinions and actual experience considering the respondent's subjectivity, personal characteristics, and background. Kato and Sato (2015) use a different corruption measure, corruption-related criminal cases, which is defined as the official number of cases related to violations of anti-corruption laws. They reveal that corruption promotes the gross value added per worker and the capital-to-labor ratio in the regulated manufacturing sectors in India. This study utilized a measure similar to that used by Kato and Sato (2015), the number of corruption cases, which is the only available measure at Indonesia's provincial level.

A few studies have empirically identified the effect of corruption in Indonesia's provinces on economic growth. Henderson and Kuncoro (2004) find that the growing corruption problem at the provincial level is due to a lack of regulation in local governments. Olken (2007) analyses a corruption perception survey administered to residents living near road projects. He examines the missing expenditures on road projects in Indonesia and finds that approximately eight percent of missing expenditures are due to corruption in the purchase of construction materials (Olken, 2009). Vial and Hanoteau (2010) elaborate the effects of plant-level corruption on output and productivity growth. They find that the corruption effects confirm the "grease the wheels" hypothesis. Suryadarma (2012) examines education spending on human resource development. He finds that education spending has a negligible impact on school enrollment in highly corrupt regions, and he concludes that an increase in education spending would not drive an improvement in human capital development in a highly corrupt region. Regarding the limited data available to observe corruption in Indonesia, none of the existing studies examine the growing number of corruption cases in Indonesia's provinces. This study contributes to enriching the empirical

research on corruption and economic growth in Indonesia by using the number of corruption cases investigated by KPK.

The number of corruption cases, on the one hand, considers not only the level of corruption but also the strength of law enforcement. It also represents the power of the leader's motivation to eradicate corruption. On the other hand, it displays the vulnerability of the government system in controlling corruption. Employing corruption as a measure requires a cautious interpretation, especially in corruption control policy recommendations. Observing an increase in the number of corruption cases does not mean that the corruption problem has worsened. An alternate interpretation is that the KPK has performed better and more effectively. The increasing number of corruption cases relates to increasing state losses and, further, to a decrease in the optimal output that should go to the people. Because the data on the amount of state losses are not available for confidentiality reasons, we employed the number of corruption cases to evaluate corruption's effect on economic growth. This study is unique among existing studies because it assesses corruption problems in Indonesia's provinces using corruption cases.

Therefore, to advance our knowledge of the effect of corruption on economic growth at the provincial level, we must pay attention to their nonlinear relationship. This study measures the corruption threshold and shows whether corruption negatively effects or supports economic growth. Under different corruption thresholds, we examine the effect of corruption on economic growth. The instrumental variable estimation is conducted to address the endogeneity issue.

3. Material and methods

3.1. Baseline model and data

The baseline model focuses on the connection of corruption, private investment, government consumption and investment expenditures, and economic growth, as follows:

$$y_{it} = \alpha_1 + \beta_1(\text{corruption}_{it}) + \beta_2(\text{investment}_{it}) + \beta_3(\text{govcons}_{it}) + \beta_4(\text{govinvestment}_{it}) + \beta_5(\text{control variable}_{it}) + e_{it}, \quad (1)$$

where y_{it} is the growth rate of the regional gross domestic product (GDP) per capita, obtained from Statistics Indonesia, which proxies economic growth; the subscripts i and t are province and period indices, respectively; and e_{it} is the error term. Corruption is measured according to the number of corruption cases investigated by KPK over the 2004–2015 period normalized by province population in millions. Corruption data are obtained from the KPK annual report since its first publication in 2004, and we also obtain more detailed corruption data from the Public Relations Bureau of KPK. The proxy for private investment (*investment*) is the gross fixed capital formation of private investment as a share of regional GDP obtained from Statistics Indonesia. This study covers¹ out of 34 provinces in Indonesia from 2004 to 2015 based on the availability of corruption data from KPK.

Government expenditure data are compiled from the Ministry of Finance of Indonesia and divided into two components, government investment expenditure (*govinvestment*) and consumption expenditure (*govcons*), which are measured as shares of regional GDP. Government consumption expenditure includes all current government expenditures for purchases of goods and services, compensation of employees (salary), official trips and maintenance of office buildings or equipment. Investment expenditure is payments for the acquisition of fixed capital assets, stock, land or intangible assets such as the building of schools, hospitals or roads. Total government consumption and investment expenditures

¹ Aceh, Bali, Bengkulu, Central Java, Central Sulawesi, Jakarta, East Java, East Kalimantan, East Nusa Tenggara, Lampung, North Sulawesi, North Sumatera, Papua, Riau, South Kalimantan, South Sulawesi, South Sumatera, West Java, and West Nusa Tenggara.

are equal to 100 percent of the budget.

The other control variables that are assumed to directly affect economic growth are taken from Statistics Indonesia. Initial regional GDP per capita in 2004 (*initial gdp per capita*), the beginning of the dataset in nominal IDR, is used to control for the convergence effect of income levels. The regional GDP growth rate is expected to be negatively associated with initial income at the beginning of the dataset. Trade represents economic openness and is the sum of exports and imports as a share of regional GDP. The mean years of schooling (*schooling*), indicating investment in human capital, is the average number of years of education received by people aged 25 and older in their lifetime. One-year lags of private investment (*investment t-1*) and government investment expenditure (*govinvestment t-1*) are used to capture the multi-year effect of physical infrastructure development.

To capture the effect of corruption through government expenditures, this study includes the interaction terms between corruption and government investment expenditures (*cor*govinvestment*) and between corruption and consumption expenditures (*cor*govcons*). Another interaction term is *cor*investment*, which is used to assess the effect of corruption in private investment. [Dzhumashev \(2009\)](#) argues that the effect of corruption on economic growth is found to be stronger when interacted with public spending and investment. He found that the interaction term between corruption and private investment indicates a negative yet statistically significant relationship with economic growth, and the interaction term between corruption and public spending reveals a positive and statistically significant association with economic growth.

Given a potential endogeneity problem that arises in the causality direction between corruption and economic growth, we addressed this issue using instrumental variable two-stage least squares (2SLS) estimation. The causality direction may go from economic growth to corruption and vice versa. [Paldam \(2002\)](#) argues that a growing economy is more likely to coincide with greater efforts to combat corruption; hence, economic growth may reduce corruption. The requirement for running the 2SLS estimation involves finding a relevant instrumental variable, which is a major challenge in most studies. The instrumental variable must have a correlation with corruption (endogenous variable) and have no correlation with the exogenous explanatory variables.

In this study, we used the corruption conviction rate (denoted by *conviction*) as the instrumental variable for corruption to address the causality problem by following [Kato and Sato \(2015\)](#). The conviction rate is constructed as the ratio of the number of corruption convictions to the number of corruption cases under investigation by KPK in a particular year. The conviction rate must meet the exclusion restriction that it should have a correlation with economic growth (the dependent variable) only through its effect on corruption (the endogenous variable). The conviction rate is expected to be negatively correlated with the number of corruption cases. We expect that a high conviction rate will cause public officials to refrain from engaging in corrupt practices due to the higher probability of being arrested and convicted. Reliable and competent police, attorneys and judges should maintain a trustworthy judicial system to manage an efficient and fast legal process.

Conviction is the appropriate instrumental variable and fits the exclusion restriction as the instrumental variable rather than the other potential variables, which have been employed in extant studies, such as the index of ethnolinguistic fractionalization ([Mauro, 1995](#); [Aidt, 2009](#); [Pallegrini and Gerlagh, 2004](#), among others) or the age of democracy ([Aidt et al., 2008](#); [Gupta et al., 2002](#)). The ethnolinguistic fractionalization index and age of democracy are problematic ([Aidt et al., 2008](#)). Some researchers suggest that a region with many different ethnic groups may encourage corruption because public officials prefer their own groups, which could promote bribe taking. However, some studies have found that the ethnolinguistic fractionalization index has a correlation with economic growth ([Easterly and Levine, 1997](#)). In the same way, a high age of democracy is believed to more effectively control the presence of corruption because of the long-established rule of law. On the other hand, the study by [Papaioannou and Siourounis \(2008\)](#) reveals that democratization has a positive relationship with economic growth. We consider employing a one-year lag period for the conviction rate and checking whether the variable fits the exclusion restrictions as an instrumental variable in our estimations. We suggest that the effect of a one-year lag period for the conviction rate may impact the conviction rate in the following years. In the estimations of the 2SLS and measurement error estimators (robustness check section), the one-year lagged conviction rate is used as the instrumental variable, and for the interaction term analyses, the one-year lagged conviction rate is accordingly interacted with private investment, government consumption and investment expenditures.

It is worth noting that conviction as the instrument may suffer from an accounting relationship issue, which may reduce its validity as a good instrument and fail to satisfy the exclusion restriction. By data construction, the conviction is the number of convictions in corruption-related cases to the number of corruption cases under investigation in that year; in other words, the number of corruption cases is the denominator. Conviction may have a relationship with the dependent variable through the effect of corruption cases as the denominator. We acknowledge the limitation of the conviction rate as the instrument as there are no appropriate instruments in Indonesia at the province level. We rely upon instrument tests using Hansen tests to check if the instruments are exogenous and relevant. According to [Van den Berg \(2007\)](#), exclusion restrictions identify restrictions and cannot be verified using statistical methods. The empirical results critically depend on the validity of the exclusion restriction and this restriction needs to be justified on a priori grounds. The results are used to evaluate which instrumental variables are likely or unlikely to make sense. This is suitable since no empirical evidence is available on the validity of the exclusion restrictions.

In the threshold model estimation, the model requires a balanced dataset; consequently, only 19 out of the 34 provinces with a sufficient number of corruption cases are included in the estimations. Descriptive statistics of the variables are displayed in [Table 1](#). [Table 2](#) shows a simple correlation matrix among the main variables. Some variables, *investment* and *investment t-1*, *govinvestment* and *govinvestment t-1*, indicate a severe

Table 1
Descriptive statistics and variable descriptions.

Variable	Obs	Mean	Standard Deviation	Min	Max	Data Description and Unit Measurement
regional gdp per capita growth	228	11.26	6.42	-12.29	36.95	Regional GDP per capita growth rate (%)
initial gdp per capita	228	2557	2074	698	8451	Regional GDP per capita in the beginning of dataset (2004) in nominal IDR
corruption	228	0.51	0.94	0	6.36	The number of corruption cases investigated by KPK normalized by province population in millions
investment	228	20.61	8.22	6.96	44.59	Gross fixed capital formation of private investment as a share of regional GDP (%)
govcons	228	2.10	1.50	0.17	7.84	Government consumption expenditure as a share of regional GDP (%)
govinvestment	228	0.59	0.64	0.03	5.16	Government investment expenditure as a share of regional GDP (%)
trade	228	71.92	34.16	23.00	193.19	The sum of export and import as a share of regional GDP (%)
schooling	228	8	1.03	6	11	Mean years of schooling is the average number of years of education received by people aged 25 and older in their lifetime (years)

Table 2
Simple correlation matrix.

	regional GDP per capita growth	initial gdp per capita	corruption	investment	govcons	govinvestment	trade	schooling
regional GDP per capita growth	1.000							
initial gdp per capita	-0.097	1.000						
corruption	-0.014	0.276	1.000					
investment	-0.074	0.172	0.167	1.000				
govcons	-0.328	-0.058	0.087	0.126	1.000			
govinvestment	-0.314	0.102	0.073	0.008	0.678	1.000		
trade	0.018	0.565	0.028	0.013	-0.091	-0.017	1.000	
schooling	-0.059	0.589	0.098	0.221	-0.156	0.005	0.128	1.000

multicollinearity problem, with correlation coefficients above 0.8 (not reported in Table 2 to preserve space). To address the multicollinearity problem, those pairs of variables are not regressed together in the same estimations.

3.2. Threshold model

The theoretical analysis encourages the presence of a nonlinear relationship in corruption and growth nexus. Seminal studies, such as Durlauf and Johnson (1995); Bose et al. (2008); Aidt et al. (2008), have found the existence of potential growth regimes. Aidt et al. (2008) employs the threshold estimation developed by Caner and Hansen (2004) and reveals that faster growth reduces corruption in countries with high-quality institutions, while in countries with inefficient institutions, growth has no impact on corruption. The method allows for the data to determine the potential growth regime to which a country belongs and for all parameters in the model to differ across regimes.

In contrast with Aidt et al. (2008), this study conducted a sample-splitting and threshold estimation as developed by Hansen (2000), which does not directly address the endogeneity issue using the instrumental variable as the threshold estimation of Caner and Hansen (2004). Compared with the method utilized by Aidt et al. (2008), this method is characterized by two different aspects. The main difference is that the threshold estimation of Caner and Hansen (2004) is only available for cross-sectional analysis (see Aidt et al., 2008, p.207) and not for panel data, while this study makes use of panel data. Unfortunately, an estimator for structural systems with a threshold effect and the instrumental variable has not yet been developed for panel data. Another aspect is that the threshold estimation of Caner and Hansen (2004) addresses potential endogeneity in the right-hand-side variable. However, this estimation does not account for the endogeneity of the threshold variable. Aidt et al. (2008) constructs corruption (endogenous) in the right-hand-side variable, and quality of institution as the threshold variable is assumed to be an exogenous variable. Nonetheless, this study positions corruption as the explanatory variable in the right-hand-side and the threshold variable. If we treat corruption as an endogenous variable, as both the right-hand-side and threshold variable, the model of Caner and Hansen (2004) cannot address this situation. These are the reasons why the threshold estimation of Caner and Hansen (2004) is not appropriate in our model. Our best alternative is to use instrumental variable 2SLS estimation in a separate part and analyze the corruption and economic growth relationship without a threshold effect to obtain unbiased estimates. Furthermore, the threshold estimation of Hansen (2000) also controls for the threshold effect, allows for the data to determine potential growth regimes, and allows for all parameters in the model to differ across regimes, similar to Caner and Hansen's (2004) model's features.

The choice of the threshold model highlights two points. First, the model provides insight into the importance of measuring the threshold and analyzing the effect of corruption in different corruption regimes. It shows that the corruption effect varies among provinces because provinces have different production functions and levels of institutional quality. Second, within a specific corruption regime, corruption and

economic growth are jointly determined, which implies that the corruption-growth relationship is regime-specific (Aidt et al., 2008).

Laying out a general issue regarding the empirical specification is useful. The corruption threshold is defined as a certain number that determines whether corruption's effect on economic growth is growth-enhancing or growth-deteriorating. The threshold value distinguishes corruption, as the threshold variable, into two regimes, which we refer to as the first regime and second regime. The first regime consists of provinces with corruption levels below the corruption threshold, and the second regime consists of provinces with corruption levels above the threshold.

Before regressing the model specification to obtain the parameter estimates, we must test the statistical significance of a threshold effect with the hypotheses written as follows:

$$H_0 : \beta_1 = \beta_2$$

$$H_1 : \beta_1 \neq \beta_2$$

The linear regression ($\beta_1 = \beta_2$) failed to reject the null hypothesis of no threshold; hence, no threshold exists in the estimation. When the null hypothesis is rejected, then the alternative hypothesis ($\beta_1 \neq \beta_2$) is present, and we may conclude the presence of a threshold (γ) in the estimation. The rejection of the null hypothesis is indicated by the significance level of the bootstrap p-value, and the threshold value occurs if the p-value is below the 5 percent significance level.

The next step is to determine the threshold value (γ). To obtain the confidence interval for (γ), the model constructs the confidence regions based on the likelihood ratio statistic ($LR_n(\gamma)$). Under the heteroscedasticity-robust assumption, the likelihood ratio statistic is written as follows:

$$LR_n(\gamma) = \frac{S_n(\gamma) - S_n(\hat{\gamma})}{S_n(\hat{\gamma})}$$

where $LR_n(\gamma)$ is the likelihood ratio and $S_n(\gamma)$ and $S_n(\hat{\gamma})$ are the residual sum of squares under the null $H_0 : \beta_1 = \beta_2$ and the alternative $H_1 : \beta_1 \neq \beta_2$, respectively. Using the confidence level of 95 percent, the model sets the critical value that is available in Hansen (2000, p.582). The threshold value is then obtained by plotting the likelihood ratio against the threshold value estimate (γ) and the critical value. A graphical method may help to show that the threshold value is obtained when the likelihood ratio line crosses the critical value in a certain number.

Moreover, the presence of the first threshold provides evidence for the second threshold. However, the value of the second threshold is uncertain. This model provides a sample-splitting technique-based output method. We first split the sample in two subsamples based on the first threshold value after which we can perform the same procedure to test the statistical significance of a second threshold effect on each subsample. The first, second and multiple thresholds are tested sequentially. In addition, the threshold model utilizes the bootstrapping procedure and encourages the construction of confidence level regions using 1,000 repetitions for each regression. The bootstrap p-value and 95 percent confidence interval are reported at the bottom of each model specification in the estimation results.

Finally, when the threshold testing and threshold value estimate (p-value and likelihood ratio) result in evidence of the first threshold, we can begin to regress the estimations to find the parameter estimates. The first threshold is used to split the sample into two regimes. The first regime consists of provinces with a corruption level below the threshold value, and the corruption effect is considered to have evidence of the “greasing the wheels” hypothesis on economic growth. By contrast, the second regime consists of provinces that have corruption levels above the threshold and therefore experience growth deterioration.

The baseline estimations to regress the estimated parameters in the model are demonstrated as follows:

$$y_{it} = \beta_1 X_{it} + e_{it} \text{ if } corruption_{it} \leq \gamma \tag{2}$$

$$y_{it} = \beta_2 X_{it} + e_{it} \text{ if } corruption_{it} > \gamma, \tag{3}$$

where y_{it} is the growth rate of regional GDP per capita, the subscript i denotes the province, the subscript t denotes the period, and e_{it} is the error term. Corruption is the threshold variable, and γ is the threshold value. X_{it} consists of the focus explanatory variables: corruption, private investment, government consumption and investment expenditures, and a vector of the control variables. Since this study focuses not only on the corruption threshold but also on the effect of corruption on growth, corruption is considered in both the explanatory and the threshold variables. This follows the baseline estimation of Hansen (2000, p.577). The model allows the parameter estimates to vary depending on the threshold value (γ). Bose et al. (2008) used a similar approach and reported no statistical problem arising from a similar equation. Eqs. (1) and (2) can be written in a single threshold regression as follows:

$$y_{it} = \beta_1 X_{it} I(corruption_{it} \leq \gamma) + \beta_2 X_{it} I(corruption_{it} > \gamma) + e_{it}, \tag{4}$$

where y_{it} , $corruption$, γ , e_{it} and X_{it} are as above, and $I(.)$ is an indicator function of the threshold variable.

The model considers the presence of multiple thresholds by deriving a sample-splitting technique to test for the second and multiple thresholds in Eqs. (5) and (6). The equation to test and estimate the parameters in the second threshold is as follows:

$$y_{it} = \beta_1 X_{it} I(corruption_{it} \leq \gamma_1) + \beta_2 X_{it} I(\gamma_1 < corruption_{it} \leq \gamma_2) + \beta_3 X_{it} I(corruption_{it} > \gamma_2) + e_{it}, \tag{5}$$

Then, the equation allows for a multiple-threshold (j thresholds) regression, as follows:

$$y_{it} = \beta_1 X_{it} I(corruption_{it} \leq \gamma_1) + \sum_{j=2}^{J-1} \beta_j X_{it} I(\gamma_{j-1} < corruption_{it} \leq \gamma_j) + \beta_J X_{it} I(corruption_{it} > \gamma_J) + e_{it}, \tag{6}$$

where y_{it} , $corruption$, γ , e_{it} and X_{it} are as above, and $I(.)$ is an indicator function of the threshold variable.

4. Results and discussion

4.1. Threshold model estimation results

The estimation analysis begins with a unit root test of all main variables included in the estimation. The Levin, Lin, and Chu (LLC) unit root test is designed to test the null hypothesis of a common unit root in the panel versus the alternative of stationarity when the cross-sectional units are independent of each other (Westerlund, 2009). All variables show p-values close to zero, which indicates that the null hypothesis of panel data containing unit roots is rejected. These results suggest that none of the main variables suffers from the nonstationary problem. The results are displayed in Table 3.

First, it is important to understand how we test the evidence of the

corruption threshold. We run Eq. (4) to test for the presence of the first threshold. Table 4 reports a summary of the threshold test results for eight model specifications in columns (1)–(8). The model specifications in column (1) as the benchmark model controls for corruption, private investment, government consumption and investment expenditures. In column (2), initial GDP per capita, trade and schooling are added to the previous specification. In column (3), we exercise the effect of one-year lagged private investment and one-year lagged government investment expenditure in column (4) to analyze the multi-year effect of investment on economic growth. Both one-year lagged private and government investments are determined together in column (5). The interaction term between corruption and private investments is introduced in column (6). The interaction terms for corruption in government consumption and investment expenditures are included in columns (7) and (8), respectively.

Table 4 shows that the first threshold is obtained at a corruption level of 1.765 in columns (1)–(8). The bootstrap p-values confirm that the null hypothesis of “no threshold” is rejected at the 5 percent level in columns (1)–(8). Moreover, the bootstrap p-values of the first threshold in columns (1)–(8) exhibit slightly different ranges regarding the variables estimated in each specification. A graphical method to plot the likelihood ratio (LR_0) against the threshold value (γ) is shown in Graph 1. The likelihood ratio (the red line) is constructed at 16.852, and the threshold value exists when the threshold estimate value (the blue line) crosses the red line.

After testing the presence of the first threshold value, the next step is to construct the first threshold value and regress the parameter estimates in Eq. (4). Graph 2 may help to clarify the construction of the first corruption threshold value. The red line is the 95 percent critical value of 7.35 (see Hansen, 2000, p.582), and the blue line is the likelihood ratio of the threshold (γ). The corruption threshold value is at 1.765 points, i.e., where the blue line crosses the red line. Based on the corruption threshold value, the estimation results are constructed for both the first and second regimes. The first regime displays the estimated parameters for provinces with corruption levels below 1.765, and the second regime shows the estimated parameters for provinces with corruption levels above 1.765. All the estimation results are presented in Tables 5 and 6.

Furthermore, the presence of the first threshold suggests that there is reasonable evidence for the second threshold; however, the value of the threshold is highly uncertain. The second threshold is constructed using a sample-splitting-based output method. The confidence interval region can be an indicator of the threshold. For example, in Table 4 column 1, the confidence interval is between 1.742 and 1.765, which is rather close; thus, we cannot conclusively decide the existence of the second threshold. Another example is the confidence interval in column 7, between 1.742 and 2.556. We suggest the possibility of the second threshold. We fix the corruption threshold at 1.765 and split the sample into two subsamples based on the corruption threshold value (1.765). The first subsample consists of provinces with a corruption level below the threshold, and the second subsample consists of provinces with a corruption level above the threshold. The first subsample contains 34

Table 3
LLC unit root test.

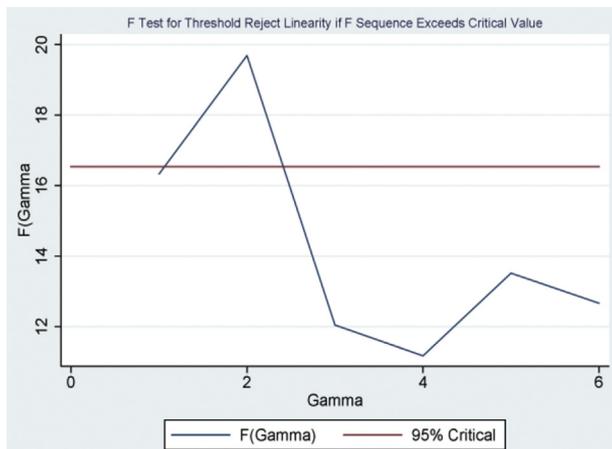
Variables	Sample T-statistics
regional gdp per capita growth	-4.97***(0.00)
corruption	-3.52***(0.00)
investment	2.47** (0.04)
govcons	-5.68***(0.00)
govinvestment	-1.58**(0.036)
trade	2.88***(0.00)
schooling	7.09***(0.00)

Notes: The probability values are in the parentheses. *, **, *** imply 10%, 5%, and 1% level of significance, respectively.

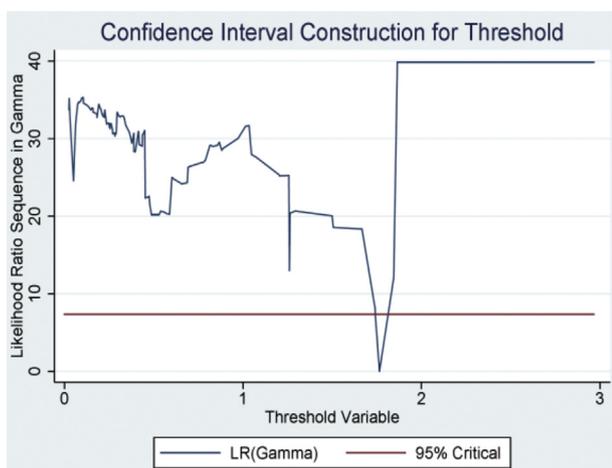
Table 4
Corruption threshold summary.

Threshold	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
First Threshold	1.765	1.765	1.765	1.765	1.765	1.765	1.765	1.765
Bootstrap p-value	0.012	0.012	0.071	0.029	0.03	0.02	0.01	0.032
95% Confidence Interval	1.742; 1.765	1.742; 1.864	1.742; 1.864	1.764; 1.864	1.764; 1.864	1.742; 1.765	1.742; 2.556	1.742; 2.556

Source: Author's calculation



Graph 1. The first threshold test. Source: Stata program.



Graph 2. The first threshold value. Source: Stata program.

observations, and the second subsample comprises 194 observations. We can then perform the same test procedure as the first threshold testing on each subsample. When the second and multiple thresholds were tested with Eqs. (5) and (6), the bootstrap p-values show more than a 5 percent significance level, indicating that no further thresholds exist (we do not report the p-value of the second threshold to preserve space).

Moreover, Graph 3 plots the likelihood ratio (LR_0) against the second threshold value (γ). The likelihood ratio (the red line) is constructed at 17.82, but the second threshold estimate value (the blue line) fails to cross the red line. We can conclude that the second threshold effect does not exist. Another indicator is that the bootstrap p-value shows a higher value; consequently, the null hypothesis of no threshold fails to reject the second threshold. All graphs are produced using the Stata program and provided from the threshold model of Hansen (2000). The threshold value, 95 percent confidence interval, bootstrap p-value, number of observations and R-squared are reported at the bottom of each column in Tables 5 and 6.

The estimation results with a threshold effect are reported in Tables 5 and 6. Table 5 consists of five model specifications to analyze the effect of corruption on growth in columns (1)–(5), and Table 6 involves three model specifications to examine the interaction terms between corruption and private investment and components of government expenditures in columns (6)–(8).

The threshold model allows the estimated coefficients and significance levels to vary in the first and second regimes. In Table 5, we observe that provinces in the regime with a high-corruption level (the second regime) experience an adverse effect of corruption, yet it is statistically significant at the 5 and 10 percent significance levels. For provinces in the first regime, the corruption effect is detrimental to economic growth in most specifications, but the significance level tends to be lower in the first regime than in the second regime. Particularly in column (3), the result shows no effect when including the lag private investment. This finding confirms the neo-classical theory that corruption is a significant hindrance to economic growth. The economic impact of corruption in the second regime shows a higher coefficient than the first regime. In the second regime, an increase of a 1-point corruption level would reduce regional GDP per capita growth rate from 0.37 up to 1.25 percent. While in the first regime, for provinces that have a corruption level with less than 1.765 points, an increase of a 1-point corruption level reduces the regional GDP per capita growth rate from 0.178 to 0.182. These empirical findings suggest that although the corruption effect reveals growth deterioration in both the first and second regimes, the adverse impact of corruption is higher for the high-corruption level than the low-corruption-level provinces.

Private investment is more likely to support economic growth in the second regime for provinces with high-corruption levels in columns (2) and (4), yet it seems to negatively affect growth and the first regime is statistically insignificant in columns (1) and (4). This finding agrees with many studies such as those by Mauro (1995); Tanzi and Davoodi (1998); Aghion et al. (2004) and Blackburn et al. (2006), which show that private investment supports economic growth. The estimation results find robust evidence of the supporting effect of private investment in the second regime for provinces with high-corruption levels. Despite high-corruption levels, provinces in the second regime experience high income per capita.

Government consumption expenditures appear to hinder economic growth both in the first and second regimes in columns (1)–(5). According to Mauro (1998), corruption in administrative matters, such as the payment of salaries and provision of services, is less interesting for corrupt bureaucrats and easier for auditors to monitor. Another type of expenditure, investment expenditure reveals an adverse effect on economic growth across regimes yet statistically significant in columns (1)–(3). This finding is contrary to the expectation that government investment supports economic development in developing countries. The adverse effect of investment expenditure should be interpreted carefully, particularly for policy recommendations, because it implies that the budget allocation for investment expenditures is already excessive based on the output observed in the economy (Ram, 1986; Chen and Lee, 2005).

In Table 6, we focus on the effect of corruption through private investment and components of government expenditures using the interaction terms between corruption and three focus variables: private investment, government consumption and investment expenditures. Brambor et al. (2006) and Berry et al. (2012) suggest the application of a

Table 5
Threshold model - the estimation results.

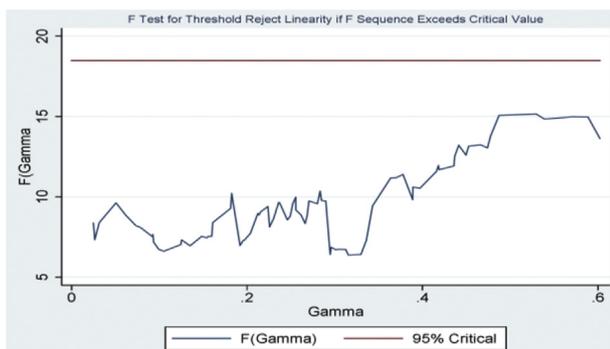
Dependent variable: regional GDP per capita growth	(1)		(2)		(3)		(4)		(5)			
	1 st regime		2 nd regime		1 st regime		2 nd regime		1 st regime		2 nd regime	
	cor<=1.765	cor>1.765	cor<=1.765	cor>1.765	cor<=1.765	cor>1.765	cor<=1.765	cor>1.765	cor<=1.765	cor>1.765	cor<=1.765	cor>1.765
corruption	-0.182 *	-1.258 *	-0.182 *	-0.693 ***	-0.181	-0.686 ***	-0.178 **	-0.373 ***	-0.182 *	-0.390 ***		
	(0.094)	(0.685)	(0.106)	(0.271)	(0.159)	(0.239)	(0.076)	(0.088)	(0.106)	(0.028)		
investment	-0.009	0.513	0.007	0.176 ***			-0.001	0.156 ***				
	(0.050)	(0.399)	(0.051)	(0.025)			(0.050)	(0.018)				
govcons	-1.173 ***	-0.316 *	-1.062 ***	-0.363 *	-1.074 ***	-0.355 *	-1.407 ***	-0.370 ***	-1.389 ***	-0.361 ***		
	(0.277)	(0.186)	(0.310)	(0.207)	(0.297)	(0.194)	(0.230)	(0.113)	(0.225)	(0.109)		
govinvestment	-1.650 ***	-2.326 **	-1.727 ***	-2.718 **	-1.649 ***	-1.192 ***						
	(0.649)	(1.081)	(0.679)	(1.162)	(0.659)	(0.452)						
initial gdp per capita			-0.0006 *	-0.0030 ***	-0.0007 **	-0.0033 ***	-0.0007 **	0.0025 ***	-0.0008 **	0.0026 ***		
			(0.0003)	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.001)		
trade			0.007	0.138 ***	0.009	0.152 ***	0.007	0.115 **	0.009	0.120 ***		
			(0.014)	(0.056)	(0.014)	(0.050)	(0.014)	(0.047)	(0.014)	(0.046)		
schooling			-0.073	-0.313	0.085	-0.369	0.040	0.065	0.057	0.041		
			(0.102)	(0.339)	(0.098)	(0.342)	(0.098)	(0.362)	(0.095)	(0.361)		
investment (t-1)					0.089	0.233			0.096	0.161		
					(0.066)	(0.206)			(0.065)	(0.163)		
govinvestment (t-1)							-0.794 *	-2.883 ***	-0.790 *	-2.382 ***		
							(0.451)	(0.532)	(0.439)	(0.550)		
threshold	1.765		1.765		1.765		1.765		1.765			
95% CI	[1.742, 1.765]		[1.742, 1.864]		[1.742, 1.864]		[1.764, 1.864]		[1.764, 1.864]			
Bootstrap p-value	0.012		0.012		0.029		0.030		0.020			
Obs	194	34	194	34	194	34	194	34	194	34		
R ²	0.220	0.716	0.222	0.302	0.232	0.321	0.210	0.662	0.221	0.666		

Notes: The dependent variable is regional GDP per capita growth rate. The asterisks represent the p-value significance levels (*p<0.1; **p<0.05; ***P<0.01). Standard errors are in parentheses. At the bottom of each regime, threshold level, 95% confidence interval, the bootstrap p-value, number of observations, and joint R2 are reported. Estimation was performed using a code written by Hansen (2000) for Stata. The script is available on request.

Table 6
Threshold model with interaction variables.

Dependent variable: regional GDP per capita growth	(6)		(7)		(8)				
	1 st regime	2 nd regime	1 st regime	2 nd regime	1 st regime	2 nd regime			
	cor≤1.765	cor>1.765	cor≤1.765	cor>1.765	cor≤1.765	cor>1.765			
corruption	-0.182 (0.109)	* -0.531 (0.307)	**	-0.173 (0.111)	-0.636 (0.309)	**	-0.177 (0.157)	-0.621 (0.331)	*
investment	0.019 (0.053)	1.038 (0.492)	**	0.003 (0.050)	0.176 (0.025)	***	0.008 (0.050)	0.173 (0.026)	***
govcons	-1.086 (0.319)	*** -1.435 (2.847)		*** -0.943 (0.381)	*	-0.367 (0.233)	*	-1.084 (0.309)	***
govinvestment	-1.667 (0.685)	*** -1.045 (0.142)	***	*** -1.720 (0.696)	*** -1.683 (0.170)	***	-1.499 (0.825)	* -1.332 (0.796)	*
initial gdp per capita	-0.0006 (0.0003)	* 0.0036 (0.0022)	*	* -0.0006 (0.0003)	*	0.0032 (0.0040)	*	0.0030 (0.0021)	
trade	0.008 (0.013)	0.166 (0.057)	***	0.005 (0.014)	0.138 (0.058)	***	0.006 (0.014)	0.137 (0.060)	***
schooling	0.073 (0.101)	0.099 (0.490)		0.058 (0.103)	-0.315 (0.367)		0.070 (0.101)	-0.306 (0.375)	
cor*investment	0.742 (0.873)	-2.977 (1.992)							
cor*govcons				-1.065 (0.976)	0.018 (0.555)				
cor*govinvestment							-0.542 (0.105)	*** -0.105 (0.058)	*
threshold	1.765			1.765			1.765		
95% CI	[1.742,1.765]			[1.742,2.556]			[1.742,2.556]		
Bootstrap p-value	0.010			0.032			0.017		
Obs	194	34		194	34		194	34	
R ²	0.225	0.400		0.227	0.302		0.223	0.302	

Notes: The dependent variable is regional GDP per capita growth rate. The asterisks represent the p-value significance levels (*p<0.1; **p<0.05; ***P<0.01). Standard errors are in parentheses. At the bottom of each regime, threshold level, 95% confidence interval, the bootstrap p-value, number of observations, and joint R2 are reported. Estimation was performed using a code written by Hansen (2000) for Stata. The script is available on request.



Graph 3. The second threshold test. Source: Stata program.

marginal plot to evaluate the marginal effect of each variable in the interaction term. The threshold model of Hansen (2000) is straightforward in analyzing the threshold effect in the estimation. The threshold model does not incorporate the calculation of marginal effects in the postestimation tests. We recommend for the program developer to develop postestimation tests that include marginal effects and marginal plots in the future; therefore, we can increase meaningful information from interactive models. Brambor et al. (2006) suggest to modify the interpretation of the coefficient estimates of the constitutive variable in the interaction models because the coefficient of the constitutive variable is the weighted average of the conditional marginal effect in the interaction model. In addition, Brambor et al. explain that when two constitutive variables interact (for example, X and Z), there are two ways to interpret the marginal effects in an interaction model. First, one variable, Z, as a conditioning variable, modifies the impact of the other variable, X, on the dependent variable, Y. Similarly, X as the conditioning variable, modifies the effect of Z on Y. In this study, we realize that the marginal effect of corruption is related to the distribution of the conditioning variables (private investment, government consumption and investment

expenditures) in the model. Since the threshold model cannot calculate the marginal effects, the interpretations of the interaction terms are straightforward when using the coefficient estimates of the interacting variables.

The estimation results in column (6) show that the impact of corruption on economic growth that depends on private investment is found to be statistically insignificant. Similarly, the effect of corruption on the economic growth that depends on consumption expenditure reveals a statistically insignificant impact in column (7). In contrast, the effect of corruption on the economic growth that is conditional on investment expenditure reveals a detrimental effect on growth that is statistically significant across regimes in column (8). In the first regime, for the provinces that have a corruption level less than 1.765 points, an increase of 1 percent corruption reduces the regional GDP per capita growth rate by 0.54 percent and is associated with an increase of government investment expenditures, which is higher than the effect of corruption in the second regime by 0.105 percent. The results contradict the findings of Dzhumashev (2009), who found that the effect of corruption on economic growth is stronger when interacting with public spending and investment. Despite the limitation in calculating the marginal effects of corruption in the interaction term models, the estimation results support the existing studies that have found that evidence of the significant effect of corruption depends on government investment expenditure.

4.2. The corruption thresholds and groups of provinces

This research determines that the corruption threshold provides a measure for evaluating a province's corruption performance. According to the corruption threshold found in the empirical results, we question whether a province's corruption status has improved or deteriorated over time. The provinces are grouped based on the corruption threshold revealed in the estimation and not based on income level or geographical location, as done by Bose et al. (2008), because our purpose is to assess which provinces manage to lower the level of corruption and which continue to face high corruption over time.

The corruption threshold value (1.765) is utilized to analyze the province's corruption performance. In Table 7, the provinces are divided into two groups: one group of provinces that has a corruption level with less than 1.765 points and a second group with a corruption level with more than 1.765 points. According to Table 7, most of Indonesia's provinces are grouped in the low-corruption group. On the other hand, Riau experiences a high-corruption level from 2008 to 2015 followed by East Kalimantan for five years (2006–2009 and 2015). The next most corrupt provinces are Papua and Central Sulawesi, which experience a four-year period of high-corruption levels. The highest number of corruption cases in the last three years took place in West Java for the period of 2013–2015. In a different situation, Lampung manages to lower its corruption level after hitting a high-corruption level in 2011. North Sulawesi succeeded in reducing its corruption level and shifted to the low-corruption group in 2015.

The corruption threshold may provide a tool for the government to take more serious action in combating corruption, particularly for high-corruption-level provinces in the second group. We elaborate on two provinces (West Java and Riau) in the second group for corruption case studies. Corruption cases in West Java vary from small scale, such as bribing tax officers, to large scale, such as bribing members of parliament to obtain significant budget allocations or projects. Many corruption cases in West Java involve large projects, such as bribery involving housing projects and licensing, because two cities in West Java (Depok and Bekasi) act as the satellite cities of Jakarta, the capital city, and most of the residential area is developed by private housing developers in those cities. Another province, Riau, has been in the high-corruption group since 2008. In this case, three Riau governors from different periods within 2004–2014 were caught by the KPK in different large-scale cases (fire truck procurement, forest to land conversion licenses, and the national sports week (PON) Riau in 2012).

The other provinces may have a variety of corruption cases depending on each province condition. Understanding a uniqueness cause and effect in each province may provide a close-fitting solution. The corruption threshold allows policy-makers to evaluate the provinces' performance and their corruption problem. Central Java, East Kalimantan, Papua, Riau, West Java and South Sumatera are struggling with eradicating corruption. Local governments should take more serious action to eradicate corruption and lower their corruption levels below the threshold. Lampung and North Sulawesi have managed to reduce their corruption levels and shift to the low-corruption group, and the other provinces have succeeded in keeping their corruption levels in the low-corruption group.

Table 7
Corruption threshold and groups of provinces.

Province	The First Group corruption ≤ 1.765	The Second Group corruption > 1.765
	Period	Period
Aceh	2004–2014	2015
Bali	2004–2014	2015
Bengkulu	2004–2012; 2014	2013, 2015
Central Java	2004–2015	
Central Sulawesi	2005–2011; 2014	2004; 2012–2013; 2015
DKI Jakarta	2004–2015	
East Java	2004–2015	
East Kalimantan	2004–2005; 2010–2014	2006–2009; 2015
East Nusa Tenggara	2004–2015	
Lampung	2004–2010; 2011–2015	2011
North Sulawesi	2004–2012; 2015	2013–2014
North Sumatera	2004–2015	
Papua	2004–2008; 2011–2013	2009–2010; 2014–2015
Riau	2004–2007	2008–2015
South Kalimantan	2004–2015	
South Sulawesi	2004–2015	
South Sumatera	2004–2014	2009–2010; 2015
West Java	2004–2012	2013–2015
West Nusa Tenggara	2004–2015	

Source: Author's calculation

4.3. Instrumental variable estimation

The endogeneity issue is a real concern in the corruption and growth relationship, and the problem has not been appropriately addressed using the threshold model of Hansen (2000). To cope with this issue, we proceed to estimate the 2SLS estimator. In this estimation, the growth equation is as follows:

$$y_{it} = \alpha + \beta_1 corruption_{it} + \beta_2 investment_{it} + \beta_3 govcons_{it} + \beta_4 govinvestment_{it} + \beta_5 X_{it} + \theta_t + \theta_i + \varepsilon_{it}, \tag{7}$$

where y_{it} denotes regional GDP per capita growth rate; $corruption_{it}$, $investment_{it}$, $govcons_{it}$, and $govinvestment_{it}$ are the focus explanatory variables; X_{it} is a vector of the control variables; θ_t is the year-fixed effect; θ_i is the province-fixed effect; and ε_{it} is the error term. Corruption is treated as an endogenous variable, and an instrumental variable is needed to correct the estimation bias resulting from the correlation between corruption and the error term (ε_{it}). The instrument for corruption is the one-year lagged corruption conviction rate (*lagconviction*) in province i in year t , which is normalized by the province population in millions. The instruments for the interaction term variables of $cor*investment$, $cor*govcons$, and $cor*govinvestment$ are denoted as $lagconviction*investment$, $lagconviction*govcons$, and $lagconviction*govinvestment$, respectively.

Table 8 shows the 2SLS estimation results. Robustness checks were appropriately performed to test the instruments and model specifications in columns (1)–(8). F-statistics reject the null hypothesis that all coefficients are zero. The p-values are close to zero indicating a rejection of the null hypothesis. The R-squared values show reasonable coefficients. The Kleibergen-Paap rk LM-statistic's p-values for the under-identification test reject the null hypothesis that corruption is under-identified by the instrument and imply that the equation is full rank and fully identified. The Kleibergen-Paap rk Wald F-statistics for weak identification tests have values higher than the Stock-Yogo critical values (16.38), indicating that the instruments are not weak. The F-statistics, R-squared values, under-identification test results, weak identification test results and Stock-Yogo critical values are available at the bottom of each estimation.

We utilize similar model specifications as the threshold model in columns (1)–(8). In addition, year-fixed effect and province-fixed effect are estimated in all specifications. From the estimation results, corruption can hamper economic growth, the coefficient estimates are statistically significant at the 1- and 5-percent significance levels only for some specifications, and the effect of corruption changes to statistically insignificant in columns (3), (5) and (6). This finding of the adverse effect of corruption confirms the studies by Mauro (1995) and Aidt et al. (2008). An increase of a 1-point corruption level reduces the regional GDP per capita growth rate by 0.56 percent in column (1), and the effects become greater with the inclusion of the other control variables, which range from 0.97 to 1.82 percent in columns (2)–(7). Private investment reveals a positive effect on economic growth but is statistically insignificant in most specifications. This finding is consistent with the threshold mode results. The consumption expenditure effects hinder economic growth, and the estimated coefficient is statistically significant in all specifications. Likewise, government investment expenditure has a growth-deteriorating effect and is statistically significant at the 1-percent level in all specifications.

The main concern of the interaction term models in columns (6)–(8) is the calculation of the marginal effects of corruption. In column (6), the marginal effect of corruption on the economic growth that depends on private investment shows an adverse impact on growth and is statistically insignificant. Likewise, the impact of corruption on the economic growth that is conditioned on government consumption expenditure reveals a growth-deteriorating effect but is statistically insignificant in column (7).

Table 8
Two-stage least squares (2SLS) estimation without threshold effect.

Dependent Variable: regional GDP per capita growth	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
corruption	-0.564*** (0.131)	-1.054*** (0.114)	-1.817 (1.248)	-0.921*** (0.115)	-1.714 (1.270)	-1.166 (2.412)	-0.97** (0.443)	-0.116** (0.050)
investment	0.491*** (0.091)	0.127 (0.097)		0.137 (0.097)		0.129 (0.104)	0.162* (0.098)	0.145 (0.096)
govcons	-0.41*** (0.056)	-0.509*** (0.045)	-0.562** (0.270)	-0.928** (0.403)	-0.978** (0.418)	-0.504* (0.261)	-0.765* (0.394)	-0.652* (0.381)
govinvestment	-2.289*** (0.790)	-2.006*** (0.693)	-1.990*** (0.701)			-2.008*** (0.694)	-2.041*** (0.716)	-2.405*** (0.783)
initial gdp per capita		-0.013*** (0.0014)	-0.021*** (0.0050)	-0.010*** (0.0013)	-0.019*** (0.0014)	-0.013*** (0.0014)	-0.011*** (0.0014)	-0.011*** (0.0014)
trade		0.009 (0.025)	0.018 (0.022)	0.009 (0.025)	0.018 (0.022)	0.008 (0.024)	0.016 (0.024)	0.012 (0.025)
schooling		0.499 (0.349)	0.673* (0.363)	0.447 (0.327)	0.625* (0.343)	0.497 (0.347)	0.479 (0.350)	0.470 (0.351)
investment (t-1)			0.383** (0.173)		0.397** (0.173)			
govinvestment (t-1)				-0.576*** (0.189)	-0.588 (0.713)			
cor*investment						-0.071 (0.102)		
cor*govcons							-0.389 (0.270)	
cor*govinvestment								-1.221** (0.491)
Marginal Effect of corruption						-1.021 (1.020)	-0.913 (0.800)	-0.610* (2.069)
Marginal Effect of investment						0.125 (1.280)		
Marginal Effect of govcons							-0.555 (1.200)	
Marginal Effect of govinvestment							-1.749***	(2.310)
R-squared	0.818	0.846	0.849	0.842	0.846	0.846	0.848	0.848
F-statistics (p-value)	77.50(0.00)	120.2(0.00)	108.3(0.00)	124.1(0.00)	111.0(0.00)	117.2(0.00)	115.1(0.00)	122.9(0.00)
Province-fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Heteroskedasticity-robust	yes	yes	yes	yes	yes	yes	yes	yes
Under-identification test:								
rk LM statistics (p-value)	27.522(0.00)	27.700(0.00)	27.947(0.00)	37.681(0.00)	37.928(0.00)	19.492(0.00)	27.565(0.00)	36.480(0.00)
Weak identification test:								
Cragg-Donald Wald F- statistics	50.63	48.70	45.58	48.25	45.37	71.92	49.80	36.88
Kleibergen-Paap rk Wald F-statistics	21.15	21.66	49.426	21.45	19.292	22.99	22.35	39.09
Stock-Yogo weak ID test critical value: 10% maximal								
IV size= 16.38								
Observations	209	209	209	209	209	209	209	209

Notes: The dependent variable is regional GDP per capita growth rate. The asterisks stand for the p-value significance levels (*p<0.1; **p<0.05; ***P<0.01). Standard errors are in parentheses, unless otherwise indicated. Numbers in parentheses for marginal effects are z statistics. At the bottom of each column, F-statistics (p-value), province and year fixed effects, heteroskedasticity robust, under-identification test (p-value), weak identification test, Stock-Yogo weak ID test critical value, number of observations, and joint R2 are reported.

Different from the findings in columns (6) and (7), the effect of corruption on the economic growth that depends on government investment expenditure exhibits a negative effect and is statistically significant at the 10-percent level in column (8). That is, an increase of 1 point of corruption will reduce the GDP per capita growth rate by 0.6 percent as the government investment expenditure share of GDP increases by 1 percent. These results align with the finding by [Dzhumashev \(2009\)](#). The impact of the interaction term between corruption and public spending supports economic growth, and the effect is found to be stronger in this conditional form.

In addition, [Brambor et al. \(2006\)](#) emphasize an argument that logically, all interactions are symmetric. In the interaction model when two constitutive variables (X and Z) are interacted, one variable, Z, is typically positioned as the conditioning variable that modifies the impact of the other variable, X, on the dependent variable, Y. Symmetrically, X must then modify the effect of Z on Y. Based on this positioning interaction, we calculate the marginal effects of investment, government consumption and investment expenditures in columns (6)–(8),

respectively. The marginal effect of investment on the economic growth that depends on corruption reveals a positive effect but is statistically insignificant in column (6). The marginal effect of the government consumption expenditure conditioned on corruption in column (7) appears to hinder economic growth but is statistically insignificant. In contrast, the marginal effect of the government investment expenditure modified by the effect of corruption demonstrates a growth-deteriorating effect and is statistically significant at the 1-percent level in column (8). Accordingly, an increase of 1 percent of the government expenditure share of GDP will reduce the GDP per capita growth rate by 1.7 percent as corruption increases by 1 point.

4.4. Robustness check – corruption cases under-reporting issue

Official corruption data usually employ the registered corruption incidence from the KPK, police or attorneys. However, many corruption cases are not captured in the data-set because corruption is an unreported and hidden activity. The lack of administration in data collection may be

prone to the under-reporting issue. The unreported corruption cases cause corruption to be measured with error, and the measurement error may cause attenuation bias in estimations. Although corruption theories propose a detrimental effect of corruption on economic growth, the effect is difficult to verify in light of the under-reporting issue. Corruption may have biased coefficients and led to high standard errors. Correcting the estimation results for the attenuation bias can improve the estimates of the 2SLS estimator in the previous section and solve for the under-reporting corruption cases issue.

This section is aimed to examine whether the coefficient estimates of corruption using the 2SLS estimator in the previous section are lower or at the upper bound in the existence of the attenuation bias. To obtain this information, we use the same dataset as in the 2SLS estimations and estimate the instrumental variable with the measurement error (refer to ME) following the theory in Carrol et al. (1995) and the command for Stata developed by Hardin and Schmiediche (2012). The ME estimation method can deal with the measurement error and include instrumental variables. The functionality of the ME method is added to address the ME and analyze statistical models where one or more covariates are measured with error. We proceed to estimate the ME using the growth equation as follows:

$$y_{it} = \alpha + \beta_1 corruption_{it} + \beta_2 investment_{it} + \beta_3 govcons_{it} + \beta_4 govinvestment_{it} + \beta_5 X_{it} + \epsilon_{it}, \tag{8}$$

where y_{it} , $corruption_{it}$, $investment_{it}$, $govcons_{it}$, $govinvestment_{it}$, X_{it} , the subscripts i and t , and ϵ_{it} are the same as for Eq. (7). Corruption is treated as an endogenous variable, and the instrument for corruption is the one-year lagged conviction rate (*lagconviction*). We cannot observe the year and province-fixed effects because of the model limitations. Replicating the same model specifications as the 2SLS model, the ME estimation results are displayed in Table 10.

After obtaining the ME estimation results shown in Table 10, the next step of the estimation strategy is to evaluate the reliability of the 2SLS against the ME coefficient estimates by constructing the reliability ratio of the 2SLS to the ME. The reliability ratio is defined as the 2SLS coefficient estimates divided by the ME coefficient estimates. The ratios are categorized into three types; lower than one, approximately one and larger than one. If the ratio shows a number lower than one (i.e., 0.86), we can say that the 2SLS coefficient estimates with the attenuation bias explain 86 percent of the ME coefficient without the bias. If the ratio is 1 or approximately 1, it means that the 2SLS coefficient is reliable and has no issues related to the attenuation bias. The 2SLS coefficient with the attenuation bias can be overestimated compared with the ME coefficient if the ratio is larger than 1.

A discussion of the reliability ratio is provided in Table 9, and we provide the ME estimation result in Table 10 for detailed information. From Table 9, the corruption coefficient in the 2SLS reveals a lower number than the ME in five specifications in columns (2), (4), (6)–(8), while the other models show a number higher than 1. The reliability ratios range from 0.55 to 1.32 depending on the model specifications. That is, the 2SLS estimation results can explain 55 percent in the lower bound and 32 percent in the upper bound compared with the ME results. The corruption effect in the 2SLS model may be underestimated in five specifications and overestimated in three other specifications because of the measurement error. The reliability ratios, on average, indicate that the 2SLS estimation results are reliable in explaining the effect of corruption in the models.

The remaining variation can be attributed to the examination of the 2SLS model and the ME as shown in Table 10. For example, the magnitude of the interaction term between corruption and government investment turns from a negative effect in the 2SLS model to a positive effect in the ME in column (8), and this result is statistically significant. Similarly, schooling appears to alter in magnitude from positive to

Table 9
The reliability ratio of the 2SLS compared to the measurement error (ME) coefficient estimates.

	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)			
	2SLS	ME	2SLS	ME	2SLS	ME	2SLS	ME	2SLS	ME	2SLS	ME	2SLS	ME	2SLS	ME		
corruption	-0.56	-0.46	-1.05	-1.42	-1.82	-1.38	-1.32	-0.92	-1.35	-1.71	-1.36	-1.17	-1.38	-0.97	-1.37	-0.12	-0.22	
investment	0.49	0.47	0.12	0.31	0.137	0.17	0.81	0.137	0.17	0.81	0.13	0.29	0.16	0.38	0.14	0.36	0.39	
govcons	-0.41	-0.73	-0.51	-0.89	-0.56	-0.98	0.57	-0.92	-1.32	-0.97	-1.36	-0.504	-0.88	-0.76	-0.93	-0.65	-0.99	0.66
govinvestment	-2.29	-2.01	-2.01	-1.64	-1.99	-1.47	1.36	-1.99	-1.47	-0.97	-1.36	-2.01	-1.64	-2.04	-1.65	-2.41	-1.44	1.67
initial gdp per capita			-0.013	-0.01	-0.021	-0.01	2.10	-0.01	-0.01	-0.02	-0.01	-0.013	-0.01	-0.011	-0.01	-0.011	-0.01	1.10
trade			0.01	0.013	0.02	0.014	1.29	0.01	0.013	0.02	0.014	0.01	0.013	0.02	0.011	0.01	0.008	1.50
schooling			0.49	-0.40	0.67	-0.70	-0.96	0.44	-0.35	0.63	-0.71	0.49	-0.70	0.48	0.31	0.47	0.37	1.27
investment (t-1)					0.38	0.48	0.80			0.40	0.57	0.70						
govinvestment (t-1)							-0.57	-0.43	1.33	-0.58	-0.34	1.71						
cor*investment													-0.07	-0.09	0.79			
cor*govcons														-0.39	-0.25	1.56		
cor*govinvestment															-1.22	0.66	-1.84	

Notes: The dependent variable is regional GDP per capita growth rate. The asterisks represent the p-value significance levels (*p<0.1; **p<0.05; ***p<0.01). Standard errors are in parentheses. The reliability ratio is the ratio of the coefficient estimates of 2SLS estimator to ME. 2sls is estimation result from 2sls estimator. ME is estimation results from measurement error estimator.

Table 10
The instrumental variable estimation with measurement error (ME estimation).

Dependent Variable: regional GDP per capita growth	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
corruption	-0.460*** (0.157)	-1.422* (0.858)	-1.386** (0.659)	-1.355** (0.663)	-1.365* (0.776)	-1.382* (0.802)	-1.372* (0.775)	-0.218** (0.109)
investment	0.470 (0.550)	0.310 (0.590)		0.170 (0.570)		0.290 (0.530)	0.380 (0.570)	0.360 (0.590)
govcons	-0.725** (0.348)	-0.892*** (0.334)	-0.980*** (0.314)	-1.321*** (0.248)	-1.364*** (0.249)	-0.879** (0.351)	-0.929*** (0.336)	-0.988*** (0.344)
govinvestment	-2.007*** (0.680)	-1.643** (0.692)	-1.465** (0.665)			-1.644** (0.693)	-1.649** (0.696)	-1.440* (0.756)
initial gdp per capita		-0.01*** (0.0029)	-0.01* (0.0059)	-0.01* (0.0055)	-0.01* (0.0055)	-0.01** (0.0039)	-0.01** (0.0039)	-0.01*** (0.0029)
trade		0.013 (0.015)	0.014 (0.015)	0.013 (0.015)	0.014 (0.015)	0.013 (0.015)	0.011 (0.016)	0.008 (0.016)
schooling		-0.411 (1.117)	-0.721 (1.112)	-0.350 (1.115)	-0.710 (1.110)	-0.733 (1.116)	0.310 (1.114)	0.370 (1.114)
investment (t-1)			0.480 (0.720)		0.570 (0.710)			
govinvestment (t-1)				-0.435* (0.250)	-0.338 (0.549)			
cor*investment						-0.099 (0.574)		
cor*govcons							-0.253** (0.104)	
cor*govinvestment								0.662** (0.261)
Heteroskedasticity-robust	yes	yes	yes	yes	yes	yes	yes	yes
(1/df) Pearson	37.34	37.27	37.16	37.82	37.61	37.46	37.23	37.01
Deviance (Pearson)	7617	7492	7469	7601	7560	7491	7446	7403
Observations	209	209	209	209	209	209	209	209

Notes: The dependent variable is regional GDP per capita growth rate. The asterisks represent the p-value significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). Standard errors are in parentheses. At the bottom of each column, deviance (Pearson), 1/degree of freedom (Pearson), heteroskedasticity robust, and number of observations are reported. Estimation was performed using a code written by [Hardin and Schmiediche \(2012\)](#) for Stata.

negative, although this result is not statistically significant in columns (1)–(6). Moreover, we find that the significance levels of the lags of private investment and government investment expenditures are reduced in columns (3)–(5). They show statistically significant results in the 2SLS estimation, but are not significant when measured by the ME model.

5. Conclusions

This study suggested that measurement of the corruption threshold allows a better understanding of the effect of corruption on economic growth and takes into account the presence of different corruption regimes in Indonesia's provinces. From the estimation results, the evidence that corruption hampers the economic development of low-corruption provinces in Indonesia is convincing for provinces with a corruption level below the corruption threshold (1.765), and the effect appears more robust for high-corruption provinces with a corruption level above the threshold. The findings of the marginal effect of corruption on the economic growth that depends on private investment and government consumption expenditure reveal statistical insignificance in the threshold model and 2SLS estimation. In contrast, the marginal effect of corruption conditioned on government investment expenditure is found to be negative and statistically significant after controlling for the endogeneity problem by using the instrumental variable. The results show that the harmful effect of corruption is stronger when including the interaction between corruption and government investment expenditure.

The advantage of using the number of corruption cases as a measure is that corruption cases can measure both the level of corruption and the strength of law enforcement. The increasing number of corruption cases following the establishment of the KPK shows an interesting fact that law enforcement, which should be an instrument to eradicate corruption, does not work to prevent corruption from expanding. KPK could eliminate corruption through full support from the government (laws and justice officers). Reliable and competent judicial officers would speed up the legal process and increase certainty in law enforcement. Another

issue is that the number of corruption cases suggests a severe problem of unreported cases. The number of reported corruption cases investigated by the KPK reflects some limitations, such as limited personnel, budget, and investigation technology, whereas unreported cases are unobserved in this study.

We provide evidence in the robustness check section that the corruption data may suffer from measurement error. The reliability of the corruption coefficient in the 2SLS model indicates approximately 55–132 percent compared with the ME model. Although the estimation results indicate that the corruption data can explain, on average, 94 percent of the variation in corruption, we suggest that future research employ a longer period. Being restricted to using corruption cases as a measure must lead to cautious interpretations, particularly when it is used to create a corruption control policy or recommendation. A different corruption measure, such as a corruption survey, may complement and support this empirical finding for future research. In addition, this study serves as the first corruption study using corruption case data at the provincial level in Indonesia.

This study demonstrates that the corruption threshold can function as an indicator so that governments can act when the corruption effect impedes the economy. It can be a tool to evaluate whether a province's corruption cases have been increasing or declining. The corruption characteristics of Indonesia's provinces might differ from those of other countries. Hence, we recommend considering data specific to provinces in other countries. This study is limited by the choice of the instrumental available. The one-year lagged conviction rate may suffer from the accounting relationship where the number of corruption cases as the denominator may correlate with the dependent variable. Therefore, finding a different instrument may advance corruption and growth research in Indonesia. Another limitation is the calculation of the marginal effects in the interaction models, particularly in the threshold model. We suggest in future studies the development of postestimation tests in the threshold model including marginal effects and marginal plots to improve the research testing theories in the interaction models.

Declarations

Author contribution statement

A. Alfada: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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