ICT-driven Transparency: Empirical Evidence from Selected Asian Countries

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Abstract: We are living in the digital era and ICTs have become necessities in this contemporary world. The aim of this study is to investigate transparency in Asia through ICT's diffusion by using Driscoll-Kraay standard error technique. We used panel data for 17 Asian countries from 2010 to 2019 and we use control of corruption as a proxy for transparency checking. The results show that ICTs leave a positive effect on the control of corruption. Other determinants of transparency in this paper, such as political stability and effective governance, have a positive effect on control of corruption. ICT policy can play an important role in curbing corruption. So, there is a strong need for ICT diffusion, suggesting that effective governance helped to reduce corruption in the Asian region and establish a surveillance-based system in public institutions.

Keywords: ICTs, Transparency, Control of corruption, Governance, Political stability

Introduction

Transparency is an indispensable cornerstone of accountable governance. A diminishment of corruption within state or local spheres augments the imperative for enacting the tenets of efficacy and lucidity in the redistribution of social funds. However, corruption, a pervasive and endemic malaise, continues to afflict numerous Asian countries, impeding their socio-economic development and undermining public trust in governance (Adam & Fazekas, 2021). This entrenched venality, often manifested through bribery, extortion, collusion, fraud, embezzlement, misappropriation, trading influence, illegal enrichment, obstruction of justice, abuse of position, and money laundering, engenders a vicious cycle of unequal resource allocation, hindering equitable development. Therefore, corruption is a threat to economic progress in developing countries (Fisman & Svensson, 2007; Welsch, 2008). That is why it is very harmful to society, because it may generate poverty, decrease the availability of money, destroy the trust in government, and reduce economic growth.

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Nowadays, digital technologies are frequently perceived as a means to enhance trust, transparency, and accountability through the dissemination of information to the public. The dissemination of information can be done easily in the present world by Information and Communication Technology (ICT), such as computers, smart-phone, smart gadgets, fast Internet and networking connections (Maiti *et al.*, 2020). It brings individuals' and countries' interactions closer (Castellacci, 2006). Thus, this world is presently known as the world of ICT: it has turned the whole world into a global village. Innovations speed up automation through Artificial Intelligence (AI), reduce the level of difficulty in work, cut down the information gap among agents, decrease distance barriers, save time, spread knowledge easily, help in the governance system, improve transparency, empower the individual capabilities, and so on (Castellacci & Tveito, 2016). Moreover, ICT has a strong connection with all domains of life and can be used as a tool to solve problems. It is playing a vital role in the overall development of the world. The impact of ICT is very complicated from the past, both in depth and spread, due to modern innovations (Crafts, 2004; Sala-I-Martín *et al.*, 2012).

A common theme of different research strands shows the relationship among economic indicators but isolates other aspects of life. ICT diffusion does not only affect economic indicators, but also influences governance, accountability, transparency, and institutional policies. ICT tools that facilitate the gathering, storage, and processing of data can significantly contribute to the detection, prevention, and prosecution of corrupt practices. Some Asian countries, such as India, Bangladesh, and Pakistan, have shown a high trend of corruption with huge ICT diffusion in the last two decades, as the diffusion of ICT is not equally applicable to all countries for showing the impact on corruption. According to the report of Transparency International (2021), Bangladesh, China, India, and Pakistan are ranked low in transparency. The latest Global Corruption Barometer (GCB) survey (2020) shows that 74% of Asian citizens believe that corruption is a serious issue in their region and one out of five bribes public servants. Unfortunately, recent studies have shown that ICT has not been utilised effectively against corruption in Asian countries. This leads to a gradual increase in corruption in these economies. Corruption is a problem that has negative effects not only on Asian economies, but on other nations as well. Additionally, Transparency International Report (2021) shows that the Asian region stands second in terms of corruption. The system of these countries will be damaged if this situation continues for a long period.

Meanwhile, recent studies suggest that ICT is an important tool to curb corruption in Asia (Liu *et al.*, 2021; Suardi, 2021) and developed and developing economies (Bhattacherjee & Shrivastava, 2018; Gouvea *et al.*, 2022; Mouna *et al.*, 2020), such as ASEAN (Darusalam *et al.*, 2021; Hartani *et al.*, 2020), European Union (Androniceanu *et al.*, 2021), and Africa (Kouladoum, 2022). ICT is a tool that can help in the investigation against corruption through

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four distinct channels: generating electronic records; cyber investigation; whistleblowers; and institutional collaboration. Dirienzo *et al.* (2007) investigated whether the increase in access to ICT and the exchange of information make it easy to provide checks and balances for public officials and to check the effectiveness of government. Corruption has become risky under the shadow of ICT. This advances higher transparency and effective governance and decreases the menace of corruption (Adam, 2020). According to the International Telecommunication Union (ITU) Report (2021), the mobile markets in Asia are growing tremendously, which reveals a rising trend in Internet use. South Asian countries—India (84.3), and Pakistan (76.4)—have subscription rates per 100 people that are higher than those of the other Asian nations. Furthermore, the World Bank Report (2020) also argues that the move towards a digital government and revolutionary advancements in technology present opportunities and risks for the fight against corruption. Developing nations might develop and spread the use of novel technological innovations to solve problems in the public sector. The cost of corruption is lower in economies that have switched from a natural resource-based to a digital and innovation-driven economy. These initiatives have been effective in different countries. Some examples of digital platforms and tools raising people's concerns, gathering data, having an impact, and aiding in the fight against corruption are the OPEN systems in South Korea, the JAGA app in Indonesia, IPaidABribe in India, WhatDoTheyKnow in the UK, and K-Monitor in Hungary. Therefore, there is a dire need to examine the linkage between ICT and control of corruption using a robust technique.

This research contributes to the existing knowledge in multiple aspects. The empirical study of the impacts of ICT on corruption is in its infancy due to inadequate measurement (Žuffová, 2020). This topic is still debatable due to its inconclusive results in Asian regions — such as no relationship (Mouna *et al.*, 2020), negative (Hartani *et al.*, 2020), positive (Sassi & Ben Ali, 2017; Suardi, 2021), and U-shaped (Darusalam *et al.*, 2021) — whereas fewer studies used a composite index of ICT (Darusalam *et al.*, 2021; Kouladoum, 2022). In order to fill this gap in the literature, this study examines the impact of a composite index of ICT (fixed broadband, fixed phones, mobile phones, and Internet users) on corruption by analysing panel data of 17 Asian countries from 2010 to 2019 by employing Driscoll-Kraay standard error technique.

The rest of the paper is devised in the following way. The subsequent section describes the literature review on ICT and control of corruption. In the third section, this paper explains theoretical considerations, and the following section deals with methodology. The final section includes concluding remarks.

Literature Review

The literature has attempted to furnish the effect of ICT diffusion to make the world transparent, but the results are mixed and inconclusive in some studies. Empirical analysis of ICT development on corruption is very rare, due to a lack of measurements (Žuffová, 2020). Transparency is the key and crucial aspect of ICT adoption. These opportunities are now possible as a result of the rapid adoption of ICT across all economic relations. Corruption is reducing in developed countries with ICT diffusion, while the same trend is doubtful in the case of developing countries (Mahmood, 2004), and supported by the findings of Heeks (1998) and Wescott (2001). Heeks (1998) observed that, although ICT can occasionally deter corruption, it does not significantly reduce it. Investments in ICT infrastructure are frequently ineffectual at reducing corruption. This is due to the fact that ICT diffusion can give rise to "upskilling" of corruption and decrease competition for upskilled corrupt public officials and servants. Some of these workers possibly had access to private data, which they could use for their own benefit (Wescott, 2001). In the same vein, Sturges (2004) conducted a study in order to ascertain the impact of ICT on the widespread corruption of politicians, governments, higher administration, and the private business sector. He has also shown in his mixed and ambiguous findings that it is challenging to employ ICT for the benefit of the poor, making the needy and the poor the victims of corruption. Moreover, Vasudevan (2006) investigated whether or not ICT for development is helpful to reduce corruption and found mixed results.

Additionally, recent studies have also raised doubts regarding ICT's actual effectiveness in curbing corruption (Charoensukmongkol & Moqbel, 2014; Garcia-Murillo, 2013) due to the implementation of intra- and inter-institutional flows that ensure that only individuals with permission can access those data and information. Charoensukmongkol & Moqbel (2014) observed that ICT investment does, to some extent, minimise corruption, but excessive ICT expenditure may open up new opportunities for misconduct and corruption. Garcia-Murillo (2013) questioned the effectiveness of ICT in reducing corruption by claiming that such systems are frequently used to give the electorate a favourable impression of government operations in order to win re-election. He also claimed that these systems frequently have no impact on corruption outcomes because they are not accompanied by any significant process or role changes in the corrupt system that would not benefit the people in power.

Another strand of literature supporting ICT as a tool for reducing corruption also came into existence. The reason is that the ICT environment has shifted from being dominated by specialised systems to one that now comprises widely adopted and compatible solutions. Moreover, ICT infrastructure is undergoing rapid and pronounced development and it is helpful to make government effective and reduce corruption (Poliak *et al.*, 2020; Russell,

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2020). Thus, the use of ICT makes public officials more efficient and capable. It also improves monitoring mechanisms and increases transparency and human empowerment through the spread of information. Mostly, it is considered an anti-corruption instrument, but it also has some negative effects when ICT tools are used instead of anti-corruption. With the advancement in ICT infrastructure, E-signatures and time-stamping services create ease for management solutions.

Therefore, ICT is a source of reducing corruption through the theory of network society (Soper, 2007) and causes an increase in more information to the public (Castells, 2000). So, ICT tools are used to curb or determine corruption due to the advancement in ICT; their diffusion reduces the discretionary power of public administrators and consequently causes a decrease in corruption (Jha, 2020; Jha & Sarangi, 2014; Longe *et al.*, 2020). According to De Sousa (2018), corruption can be reduced in five major ways: 1) raising awareness through ICTs; 2) online monitoring; 3) reducing direct contact through mobile phones, the Internet, and telephones; 4) effective control of financial transactions; and 5) initiating anti-corruption campaigns. Thus, ICTs can be utilized by the government to reduce corruption. Moreover, Shim & Eom (2008) argued that corruption decreases with ICT due to a reduction in physical interaction; and fast Internet adoption has a positive relationship with the control of corruption (Lio *et al.*, 2011). In a similar line, Andersen (2009) discloses that the implementation of e-government is successful in reducing corruption for a selected panel of 100 countries by taking a timespan of ten years. A study in 2017 provided a massive argument about controlling corruption by ICT (Sassi & Ben Ali, 2017). Lidman (2011) and Sassi & Ben Ali (2017) argue that public officials can be traced through mobile phones and the Internet, and by recording their conversations to ask for a bribe; such fear also reduces corruption. These studies suggested that only policy-based technologies reduce corruption. This is why it is of the utmost importance to spread awareness of these technologies among the country's citizens so that they can use them to combat corruption.

However, that corruption can be reduced through ICT is doubtful (Kim *et al.*, 2009) but recent studies propose some distinct arguments that it curbs corruption. Lincényi & Čársky (2021) and Remeikienė *et al.* (2020) argued that the use of ICT improves governance and accountability, and reduces corruption because information diffusion in society enables government officials to have a higher chance of being caught and prosecuted (Cho & Choi, 2004). Ben Ali & Gasmi (2017) examined the relationships between the adoption of ICT and corruption utilising a panel of 175 countries for the years 1996 to 2014, and they reached the same conclusion: digital inclusion is a powerful instrument for fighting against corruption. Moreover, Androniceanu *et al.* (2021) investigated the influence of ICT integration on the control of corruption in the administrations of the EU by using panel data from 2010 to 2019, and showed that it has a significant effect on reducing corruption. According to Afzal *et al.* (2021), greater adoption of the Internet and mobile phones among selected Pacific-Asian economies fosters transparency and good governance.

In addition, Bhattacherjee & Shrivastava (2018) employed the hypothetico-deductive technique in a study using general deterrence theory (GDT). ICT use affects corruption by enhancing the certainty and swiftness of punishments associated with it, and ICT investments may have a limited impact on corruption without ICT laws. Other evidence showed that technology adoption slows the rate of corruption in low-income and high-income countries, while it is insignificant in the case of middle-income countries due to the digital divide (Mouna *et al.*, 2020). Kouladoum (2022) investigated the effects of ICT on corruption in Africa. As estimation methods, the fixed- and random-effects models are used. The two-stage least square (2SLS) and Lewbel techniques are chosen to deal with the issue of probable endogeneity due to the flaws in the fixed- and random-effects models. The results show that Internet use, mobile phone use, and the composite ICT indicator all favourably influence the improvement of corruption control in Africa. Furthermore, Hartani *et al.* (2020) examined the ICT-corruption nexus by using cross-sectional data on associated ASEAN country-related variables. For the purpose of estimating different relationships among variables, the studies include the IPS unit root test, Pedroni cointegration, and FMOLS estimate. The researchers verified that the use of ICT and e-government could lessen corruption in ASEAN nations and proved ICT as a tool to reduce corruption. Suardi (2021) examined the effect of ICT diffusion on the corruption perception index (CPI) in Asia and concluded that it reduces corruption. Its implementation has raised public perceptions of corruption, with telecommunications infrastructure having the most profound impact. According to Gouvea *et al.* (2022), countries that have made a transition from a resource-based economy to a system that is innovation-driven and digital have lower levels of corruption. This is based on panel data from 147 countries during a seven-year period from 2013 to 2019. Corruption is inversely related to ICT indicators like Internet usage and e-government.

The current strand of literature illustrates the limitations of technology as a way to guarantee transparency in government interactions. De Sousa (2018) argued that ICT cannot end corruption on its own. He contends that the proper institutional framework should be used to train public officials. His findings show that ICT dissemination works well with education and training. Darusalam *et al.* (2021) examined the impact of ICT on corruption control in Asian countries over a 33-year period from 1984 to 2016. ICT and the control of corruption have a non-linear, inverted U-shaped relationship, which suggests that ICT in these countries does not lower the rate of corruption. The findings of Darusalam *et al.* (2021) also show that government efficiency and education must be added to ICT in order to effectively combat corruption. Their findings of a non-linear effect suggest that ICT may make corruption easier.

As shown by the studies mentioned above, research on the relationship between ICT and corruption is not theoretically supported, somewhat inconclusive, and unable to clearly explain when ICT reduces corruption and when it does not. The previous literature on the impact of technology on the control of corruption has overlooked fixed telephone and fixed broadband indicators in favour of looking only at the Internet and mobile phone penetration (Darusalam *et al.*, 2021; Kouladoum, 2022) and mobile phone penetration (Sassi & Ben Ali, 2017), whereas Suardi (2021) examined the effect of ICT diffusion on the corruption perception index (CPI) in Asia and used the ICT infrastructure index as a proxy. Darusalam *et al.* (2021) used the panel ARDL model and Suardi (2021) used the fixed effect and random effect model to demonstrate their results. In order to fill this gap in the literature, this study examines the impact of a composite index of ICT (fixed broadband, fixed phones, mobile phones, and Internet users) on corruption, using panel data of 17 Asian countries from 2010 to 2019 by employing Driscoll-Kraay standard error technique.

Theoretical Considerations

Conceptual framework

The advancement in ICT enables human beings to perform efficiently in every field of life and it also changes the behaviour of individuals. Let us understand the functions of ICT which cause a change in the attitude and behaviour of people in the contemporary world.

Many influential research studies have shown the influence of ICT on human life (Jorgenson & Stiroh, 2000; Oliner & Sichel, 2000; van Ark *et al.*, 2008). Many pieces of evidence show all domains of life are affected by it, while domains of life such as working, private, and environmental life, human capabilities, psychological functioning, cultural values, and beliefs create a heterogeneity problem (Castellacci & Tveito, 2016); whereas there are many advantages of ICT development, it also has reverse effects on human well-being, such as cyberbullies, privacy risk, leakage of information, and increasing corruption. If it cannot be effectively used, it will leave negative impacts on governance, economic development, education, and corruption. On the other hand, leakage of information can also create a problem for individuals as well as the country. False information and rumours could be spread through it. ICT can be very advantageous and hence can be used efficiently. The following conceptual framework borrowed from Castellacci & Tveito (2016) and slightly changed is incorporated for this research agenda.

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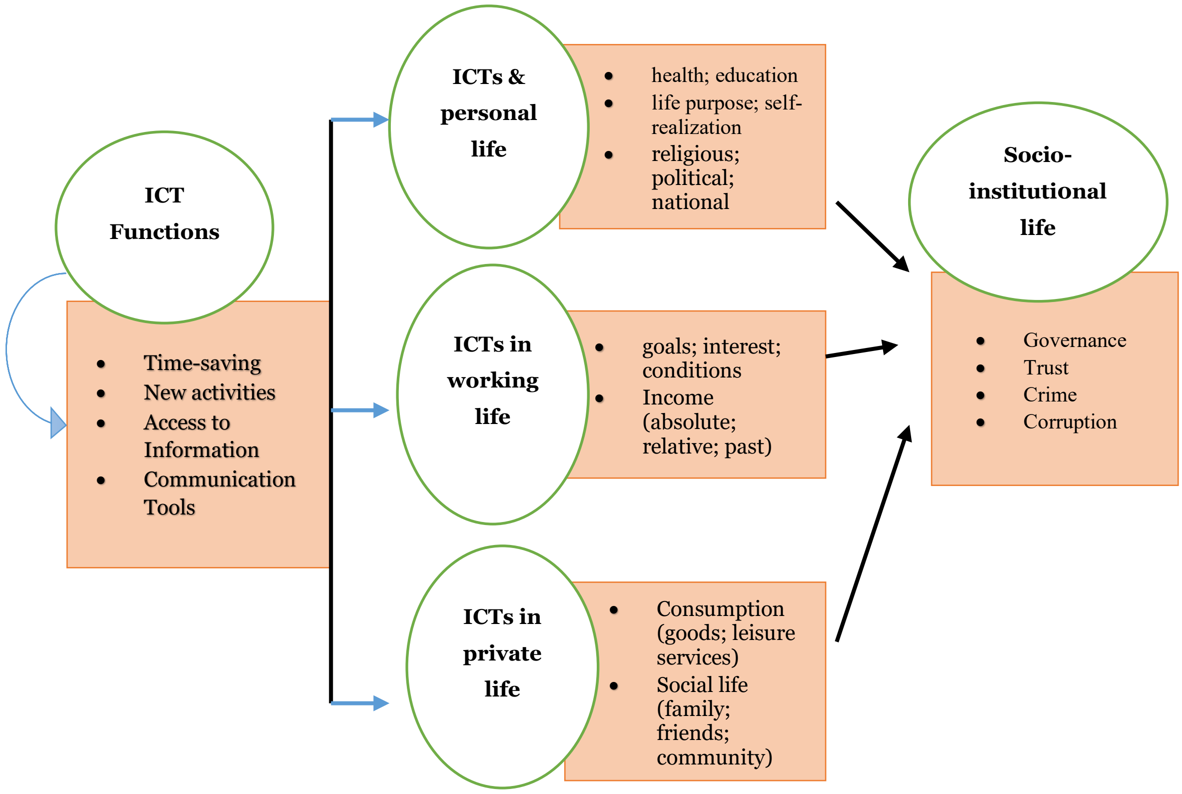

Figure 1. Conceptual Framework (Castellaci & Tveito, 2016)

In the realm of personal life, ICTs wield the power to disseminate information with unprecedented celerity. This unfettered flow of data can act as both a conduit for enlightenment and reduction in nefarious practices because corruption often thrives in the interstices of opacity. Citizens armed with instant access to government proceedings, budget allocations, and policy implementations are more likely to hold public officials accountable for their actions. In the domain of working life, the integration of ICTs has ushered in an era of heightened efficiency and interconnectedness. The expedited transfer of funds, procurement processes, and contract adjudications, can also bring down grounds for corruption to fester. Turning to the private sphere, the omnipresence of ICTs has indelibly altered the dynamics of personal relationships and communication. Automated record-keeping systems and digital audit trails engender an environment where transactions are subject to meticulous scrutiny, minimizing the interstices in which corrupt acts can flourish. Simultaneously, ICTs permeate the private lives of individuals, augmenting their ability to monitor and report irregularities. Crowdsourcing platforms and mobile applications enable citizens to report instances of bribery, extortion, or other corrupt practices with immediacy and anonymity.

Crime opportunity theory

This study is backed by Crime opportunity theory (COT). COT states that an offender does official matters that are very simple to perform but nonetheless offer great incentives and favourable returns (Faisal *et al.*, 2016). According to this theory, two factors have significance

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for the execution of a crime. The first element is the presence of a criminal or offender and the second is the state of a location where a criminal is physically present to do a certain crime. For committing a crime, these two elements must be present together (Grasmick *et al.*, 1993). In our study, crime refers to corruption, and the offender or criminals can be conceived of as government officials who are in charge of offering a range of services to the public. The belief that crime can be effectively averted by altering the circumstances in which it will occur is another crucial part of this theory. This can be accomplished by introducing various activities in the system. ICT interrupts the aforementioned two factors and reduces corruption. According to our study, the impact of ICT diffusion is being examined in relation to a decline in the rate of corruption (Hartani *et al.*, 2020; Jeffery & Zahm, 1993).

Data and Methodology

Data and data sources for the study

In this study, we investigate panel data for 10 years ranging from 2010 to 2019. Based on data availability, 17 countries from the Asian continent are taken for this study. The countries are Bangladesh, Cambodia, China, Cyprus, Indonesia, India, Iran Islamic Republic, Israel, Japan, Kuwait, Malaysia, Pakistan, Saudi Arabia, Singapore, Thailand, Türkiye, and United Arab Emirates. The main goal of this study is to check the relationship between ICT diffusion on control of corruption in Asian countries. The following question is addressed in this research:

1. Is ICT diffusion affecting the control of corruption?

Variables are borrowed from different research works. Control of corruption (CoC) is a dependent variable in this study which has been used by Darusalam *et al.* (2019). Four independent variables are taken as determinants of corruption, namely, political stability (PS), GDP per capita, effective governance (EG), and ICT. Bhattacherjee & Shrivastava (2018) used political stability and effective governance as determinants of corruption. GDP per capita is also used as a determinant and many studies used the ICT development index to analyze corruption, such as ICT exposure index, and different proxies (Internet users per 100 inhabitants, mobile cellular subscriptions per 100 people) (Androniceanu *et al.*, 2021; Darusalam *et al.*, 2021; Fisman & Svensson, 2007; Gouvea *et al.*, 2022; Hartani *et al.*, 2020). In this study, we used an ICT exposure index that has been constructed using the following four variables:

1. Mobile Cellular subscriptions (per 100 people)
2. Internet users (per 100 people)
3. Number of Secure Internet servers

4. Fixed telephone subscriptions (per 100 people).

To construct the ICT exposure index, Principal Component Analysis has been used. See Hanafizadeh *et al.* (2009) for ICT index construction. Definitions and data sources are described in Table 1.

Table 1. Measures and Indicators

Variable	Definition	Indicators/Scale/Source
CoC	Control of corruption	Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.
		Scale: -2.5 – 2.5 (High Corrupt – Low Corrupt)
		Source: The Worldwide Governance Indicators (WGI)
ICT	Information communication and technology exposure index	Mobile Cellular subscriptions (per 100 people) Internet users (per 100 people) Secure Internet servers Fixed telephone subscriptions (per 100 people)
		Source: World Development Indicators (WDI)
PS	Political stability	Orderly transfers, Armed conflict, Violent demonstrations, Social Unrest, International tensions, Cost of Terrorism, Frequency of political killings, Frequency of disappearances, Frequency of tortures, Political terror scale, Security Risk Rating, The intensity of Internal conflicts (Ethnic, religious, or regional), Intensity of violent activities (Political), Intensity of social conflicts (except Land)
		Scale: -2.5 – 2.5 (weak – strong) stability
		Source: The Worldwide Governance Indicators (WGI)
EG	Effective Governance	Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.
		Scale: -2.5 – 2.5 (weak – strong) governance
		Source: The Worldwide Governance Indicators (WGI)
GDP	Gross Domestic Product per capita	Source: World Bank Data (WB)

Estimable model

To analyze the relationship between control of corruption (CoC) and its explanatory variables, the function given below is constructed:

$$\mathbf{CoC} = \boldsymbol{f}(\mathbf{PS}, \mathbf{GDP}, \mathbf{EG}, \mathbf{ICT}) \tag{1}$$

Here, transparency is measured by the control of corruption (CoC), which is a function of the ICT Index, gross domestic product (GDP), effective governance (EG), and political stability (PS), which are expected to be linked to control of corruption.

Econometric specification of this function is as follows:

$$\boldsymbol{CoC_{it} = u_i + \delta_t + \beta_1(PS_{i,t}) + \beta_2(GDP_{i,t}) + \beta_3(EG_{i,t}) + \beta_4(ICT_{i,t}) + \varepsilon_{i,t}} \tag{2}$$

The subscript i is for countries and t is for time. All methods have been elaborated earlier in the literature, where $\boldsymbol{u_i}$, $\boldsymbol{\delta_t}$ take into account the unobserved country-specific effects and $\boldsymbol{\varepsilon_{i,t}}$ indicates the error terms, which are assumed to be i.i.d. with null mean and variance σ^2. $\beta_1, \beta_2, \beta_3,$ and β_4 are the coefficients of political stability (PS), gross domestic product (GDP), effective governance (EG), and ICT Index, respectively.

There are several pooling models, but panel effects such as fixed effect and random effect are mostly used for panel data analysis. This study consists of 17 Asian countries and entails balanced panel data ranging from 2010 to 2019 for 10 years. There are 170 (17x10=170) observations. See Mehmood *et al.* (2013) on how to estimate a panel effects model. Panel data estimation is discussed in the following section.

Panel Data Estimation and Discussion

The subsections below follow a sequence to estimate the panel dataset. To analyse the data, both descriptive and inferential techniques are used. The results of both techniques are described below with pertinent analysis.

Descriptive analysis

The dependent variable control of corruption (CoC) is used as a proxy for transparency in these analyses. Independent variables are PS, GDP, EG, and ICT. A set of descriptive results is shown in Table 2.

The mean value of CoC is .072 with an estimated standard deviation of .929 for all 17 Asian countries over 10 years from 2010 to 2019. The minimum value of CoC for the whole data set is -1.31 for Cambodia in 2018, which has the highest corruption, and the maximum value is 2.18 for Singapore in 2010, which has the lowest corruption. The ICT exposure index has a mean value of 0.009, which is very small, and the highest standard deviation of one.

Table 2. Descriptive Analysis

Variable	Mean	Standard Deviation	Minimum	Maximum
CoC	.072	.929	-1.31	2.18
PS	-.413	.991	-2.81	1.62
GDP	3.938	.567	2.95	4.787
EG	.399	.874	-.94	2.24
ICT	.009	1	-2.015	2.404

The minimum value of the ICT exposure index for the whole data set is -2.015 in 2010 for Bangladesh and the maximum value of ICT is 2.404 for UAE in the year 2016. The mean value of the whole data set of Political stability is -.413, which means that, on average, all countries are passing through political instability. The minimum value of the political stability index is

-2.81 in the year 2011 for Pakistan, which means the highest political instability was in Pakistan in 2011. The maximum value of the Political stability index is 1.62 for Singapore in 2017. Cambodia has the minimum values of GDP and effective governance in the year 2010 and Singapore has the maximum values for both in 2010. Singapore has a maximum value for four variables in our data set. Although the ICT exposure index has low values for Singapore, it has very strong control over corruption due to the highest values of the other four variables. In Cambodia, the CoC index has the highest negative values because of its bad performance in the three major indicators.

Inferential analysis

In inferential analysis, statistical estimation is done on the pre-defined econometric model. In this study, we use three estimation techniques for better results and choose which is the best. The primary goal of this research is to analyse the relationship between ICT and control of corruption (CoC) and how other control variables, political stability, effective governance, and economic development, affect corruption. Thus, CoC is used as a dependent variable. PS, GDP, EG, and, ICT exposure index were regressed on CoC, and econometric results are appended below.

Test for multi-collinearity

A primary goal of economic analysis is to determine whether there is multi-collinearity among the independent variables. As a general rule, variables have severe multi-collinearity if their variance inflation factors (VIFs) are greater than 10, which often occurs when R^2 reaches 0.90. According to Damodar Gujarati (2022), if the value of VIF is less than 5, a multi-collinearity problem does not exist. Table 3 shows the VIF results for investigating multi-collinearity in panel (a). The set of selected variables shows that there is no multi-collinearity.

Ordinary Least Squares (OLS) will be a partial specification if there is country-level heterogeneity (differing social and cultural norms, for example) and a fixed/random effects model should be estimated. The subsequent two tests are essential for developing a good estimation method for panel data analysis.

Breusch and Pagan Lagrangian multiplier test for random effects or OLS

The post-estimation test assists in selecting between an OLS and a random effects regression. The null hypothesis of the Lagrangian Multiplier (LM) test is that there is no significant difference across countries, or that variances across countries are equal to zero. Table 3 shows the results of LM for panel effects. Breusch and Pagan Lagrangian multiplier (1980) in panel (b) justifies that there is a panel effect because χ^2 (01) = 377.62 and Prob.> χ^2=0.0000. Variance across entities is zero and the probability value also affirms the panel effect.

Hausman test

The Hausman test is performed to select the best option between fixed effects model (FEM) and random effects model (REM) and the results are appended in Table 3, panel (c). FEM and REM are compared having the null hypothesis for the final decision. The result shows that FEM is preferred, because the p-value<0.01 and the null hypothesis is accepted. In this case, if we perform REM, it generates biased estimators. Therefore, we prefer the fixed effects model.

Table 3. Diagnostics Tests

Panel (a): Investigating multicollinearity			**Panel (b): Breusch and Pagan Lagrangian multiplier (LM) for exploring panel effects**	
Variable	VIF	1/VIF		
PS	4.56	0.219348	Ho: No panel effect	$\chi^2(01)$ = 377.62
GDP	4.47	0.2238	P-value >= 0.00000	
EG	2.67	0.37502	This test investigates the existence of the panel effects. The results shown in the left column justify the existence of panel effects, because the null hypothesis is not rejected.	
ICT	2.21	0.45291		
Mean VIF	3.48			
Panel (c): Hausman Test to choose between Fixed and Random effects				
Ho: Fixed effect H1: Random effect			$\chi^2(4)$ = 14.62	P-value > χ^2= 0.0056
Panel (d): Modified Wald Test for Group Wise Heteroskedasticity				
Ho: $\sigma(i)^2 = \sigma^2$ for all i			$\chi^2(17)$ = 594.27	P-value > χ^2 = 0.0000
Panel (f): Wooldridge Test for Serial Correlation				
Ho: no first order autocorrelation			F(1, ,16) = 30.030	P-value > F = 0.0001

Comparisons between POLS, RE, and FE models

Pooled OLS: Pooled OLS model's F-statistic value is 700.15 and at a 1% level of significance. R^2 explains the variation in the dependent variable, CoC, due to independent variables, PS, GDP, EG, and ICT. According to the value of R^2, independent variables (PS, GDP, EG, and ICT) explain 94.44% of variation in the dependent variable (CoC), though, with a high R^2, there may be a problem of autocorrelation. The value of adjusted R^2 shows that there is approximately no difference and its value is 0.9430. According to Pooled OLS estimation, slope parameters for all variables are $(\beta_{PS}^{POLS})_{1\%}$=.1125, $(\beta_{GDP}^{POLS})_{1\%}$=.436, $(\beta_{EG}^{POLS})_{1\%}$=.754, $(\beta_{ICT}^{POLS})_{1\%}$=.1099, respectively, and show their potential toward CoC.

Fixed Effects Estimates: A second technique of panel data analysis, regression estimation through the fixed effects model, also shows there is a positive relationship between ICT and CoC. Its results show that, except for GDP, all other variables are significant at a 1% level. By using FEM, GDP is insignificant, which suggests excluding this variable. The incline coefficients corresponding to each individual variable are observed to be as follows: $(\beta_{PS}^{FEM})_{1\%}$=.1678, $(\beta_{GDP}^{FEM})_{insig}$=-.0661, $(\beta_{EG}^{FEM})_{1\%}$=.4966, $(\beta_{ICT}^{FEM})_{1\%}$=.0599. Using FEM technique, ICT coefficient reduces to $(\beta_{ICT}^{FEM})_{1\%}$=.0599 from $(\beta_{ICT}^{POLS})_{1\%}$=.1099, and it also

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decreases the coefficient of EG but increases PS compared with POLS. The value of R^2 also decreased and independent variables explain the variation of 91.43% in CoC. The value of adjusted R^2 is 0.8990, which is slightly lower than R^2. FEM's F-statistics value is 22.94 and at a 1% significant level.

Table 4. Pooled OLS, Panel Effects & Driscoll-Kraay Method – A Comparison

Dependent Variable (CoC)			**Constant**	**Independent variables**			
				PS	**GDP**	**EG**	**ICT**
Coefficients	**Pooled OLS**		-1.899*** (.241)	.1125*** (.028)	.436*** (.0642)	.754*** (.0413)	.1099*** (.0253)
	Panel Effects	**FEM**	.203 (.954)	.1678*** .0514	-.0661 (.243)	.4966*** (.0682)	.0599*** (.0214)
		REM	-2.0443*** (.491)	.1478*** (.0448)	.495*** (.1259)	.568*** (.0618)	.0886*** (.0199)
	Driscoll-Kraay Method (DKM)		-.20317*** (1.738)	.1678*** (.0587)	-.0661 (.445)	.4966*** (.0999)	.0599*** (.024)
Techniques	Pooled OLS		Panel Effects		Driscoll-Kraay Method		
			Fixed Effects	Random Effects			
R^2	0.9444		0.9143	0.9529	0.8632		
Adjusted R^2	0.9430		0.8990	0.9398	0.8241		
Model Significance	F(4, 165) = 700.15 Prob. > F = 0.0000		F(4, 149) = 22.94 Prob. > F = 0.0000	Wald $\chi^2(4)$ = 336.00 Prob. >χ^2 = 0.0000	F(4, 9) = 59.64 Prob. > F = 0.0000		
*** Significant at 1%							

Random Effects Estimation: REM results are also given in Table 4, which shows that there is a positive relation between ICT and CoC. Pursuant to REM estimation, the slope coefficients for each variable stand at $(\beta_{PS}^{REM})_{1\%}$=.1478, $(\beta_{GDP}^{REM})_{1\%}$=.495, $(\beta_{EG}^{REM})_{1\%}$=.568, $(\beta_{ICT}^{REM})_{1\%}$=.0886, respectively. The value of R^2 is greater than the POLS model and FEM which explains 95.29% variation in the dependent variable (CoC) due to independent variables. For REM, the model significance is shown through the Wald chi-squared test and its value is 336. In this model, the value of coefficients for all variables is increased. For the best choice between FEM and REM, the Hausman test confirms that FEM is the best. Therefore, REM estimation to analyze the panel effect and its results may be spurious.

Test for serial correlation

Serial correlation is typically not anticipated when the time span is less than 20 years. Serial correlation lowers standard errors of coefficients and raises R^2. The micro panel data used in this study ($t = 10 < 20$) reduces the likelihood of a serial correlation. But this test is used for the sake of precision. Table 3's statistics are interesting in that they indicate that the null hypothesis is rejected because p-value is less than 1%, and that there is a serial correlation among the residuals. OLS coefficients are hence probably biased, inconsistent, and ineffective.

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Hence, we employ the Driscoll-Kraay standard error methodology to render OLS estimations robust and efficacious in addressing the aforementioned issue.

Test for heteroskedasticity

The error term ε can be heteroskedastic if the variance of the conditional distribution of ε_i given $X_i[\text{var}(\varepsilon_i|X_i)]$ is non-constant for i= 1, 2,…,n, and specifically does not depend on X; else, ε is homoscedastic. Heteroskedasticity can lead to inaccurate estimations of standard error coefficients and, consequently, of their t-values. OLS estimates may not be biased in this situation but generate wrong standard errors. The Modified Wald Test for Group Wise Heteroskedasticity in Table 3 suggested that there is a problem with heteroskedasticity.

Fixed effects estimates with Driscoll and Kraay (DK) standard errors

The Driscoll and Kraay (DK) standard error technique is regarded as one of the best approaches if there is a possibility of heteroskedasticity, spatial dependence, and serial dependency in the data. The fixed effects regression with Driscoll and Kraay standard errors (SE) is required by the results of the Wooldridge test for serial correlation and the Modified Wald test for group-wise heteroskedasticity. Therefore, the Driscoll & Kraay (1998) standard error technique is used to examine the effect of ICT on the control of corruption for a panel of Asian countries, because the DK methodology is a flexible, non-parametric method. Additionally, the DK covariance estimator performs with both balanced and unbalanced panel data and is capable of handling missing values. DK estimations can deal with cross-sectional and temporal dependency patterns. The results demonstrate no unexpected shift in the statistical significance of the fixed effects estimates. In two steps, the individual fixed-effects estimator is used. First, using xtreg command in Stata for OLS, all variables $z_{it} \in \{y_{it}, x_{it}\}$ are transformed.

$$\tilde{\mathbf{z}}_{it} = \mathbf{z}_{it} - \bar{\mathbf{z}}_{it} + \bar{\bar{\mathbf{z}}} \quad (3)$$

Equation (3) is about transforming a variable z_{it}, which could be either y_{it}(a dependent variable) or x_{it} (an independent variable). $\tilde{\mathbf{z}}_{it}$ is a newly transformed variable. Equation (4) calculates the average value, $\bar{\mathbf{z}}_{it}$, of the transformed variable, $\tilde{\mathbf{z}}_{it}$, across all time periods $\mathbf{T}_i$ for a given entity i.

$$\bar{\mathbf{z}}_{it} = \mathbf{T}_i^{-1} \sum_{t=1}^{\mathrm{T_i}} \mathbf{z}_{it} \quad (4)$$

$$\bar{\bar{\mathbf{z}}} = (\sum \mathbf{T}_i)^{-1} \sum \boldsymbol{i} \sum \boldsymbol{t}\, \mathbf{z}_{it} \quad (5)$$

Here, $\bar{\bar{\mathbf{z}}}$ is the constant term, which is calculated from equation (5).

Secondly, as a result, this work takes into account a linear model and uses Fixed Effects Estimates with Driscoll and Kraay Standard Errors for estimation of a linear model which can be expressed as follows:

$$\tilde{\boldsymbol{y}}_{i,t} = (\widetilde{\boldsymbol{X}'}_{i,t})\boldsymbol{\beta}+\tilde{\boldsymbol{\varepsilon}}_{i,t} \quad (6)$$

where $\tilde{\boldsymbol{y}}_{i,t}$ is the dependent variable, and $\widetilde{\boldsymbol{X}'}_{i,t}$ denotes independent variables. Also, i is the index of countries, i = 1, 2, 3 ...,17, and t is a study period, t = 2010, 2012,.....,2019.

To solve the above diagnostic problem, we use a Driscoll-Kraay standard error model and it shows more significant results than the previous two models. The Driscoll-Kraay model also shows that ICT reduces corruption in the case of Asian countries. Slope parameters for the Driscoll-Kraay technique are $(\beta_{PS}^{DKM})_{1\%}$=.1678, $(\beta_{GDP}^{DKM})_{insig}$=-.0661, $(\beta_{EG}^{DKM})_{1\%}$=.4966, $(\beta_{ICT}^{DKM})_{1\%}$=.4966, respectively. The coefficients of PS, GDP, EG, and ICT decreased as compared with other techniques. This model's significance is shown through F-test and its value is 59.64, which is very high compared with the previous two estimation techniques, and shows a high level of significance at 1% level. All previous variables are confirmed through the Driscoll-Kraay model.

The relationship of political stability with control of corruption is evident through their slope parameters in all techniques DKM, FEM, REM, and POLS, i.e. $(\beta_{PS}^{DKM})_{1\%}$=0.1678, $(\beta_{PS}^{FEM})_{1\%}$=0.1678, $(\beta_{PS}^{REM})_{1\%}$=0.1478, $(\beta_{PS}^{POLS})_{1\%}$=0.1125, respectively. Political stability leads to consistency in policies and regulations, contributes to a stronger rule of law and judicial independence, and raises the political will. When governments are constantly changing due to instability, there is a higher likelihood of policy flip-flops and ad-hoc decision-making. Such uncertainty can create opportunities for corruption as individuals may exploit regulatory loopholes or manipulate changing policies for personal gain. In stable political environments, bureaucratic processes and procedures are more likely to be streamlined and efficient, and can reduce opportunities for bribery and extortion.

The slope parameters for government effectiveness and control of corruption are positively related in all addressed techniques, i.e., $(\beta_{EG}^{DKM})_{1\%}$=0.4966, $(\beta_{EG}^{FEM})_{1\%}$=0.4966, $(\beta_{EG}^{REM})_{1\%}$=0.568, $(\beta_{EG}^{POLS})_{1\%}$=0.754, respectively. The results are consistent with the prior studies (Bhatnagar, 2000; Poliak *et al.*, 2020; Russell, 2020). The findings additionally suggest that the mastery over corruption escalates proportionally alongside the augmentation of governmental efficacy within the chosen Asian nations. The government's effectiveness further enriches institutional calibre, amplifying the enforcement of legal frameworks and the command over corruption within the corresponding assemblage of nations.

The purpose of this study is to check that the relationship between ICT and CoC is confirmed in all addressed techniques, i.e., $(\beta_{ICT}^{DKM})_{1\%}$=.0599, $(\beta_{ICT}^{FEM})_{1\%}$=.0599, $(\beta_{ICT}^{REM})_{1\%}$=.0886, $(\beta_{ICT}^{POLS})_{1\%}$=.1099, respectively. The ICT exposure index leaves a very small impact in this case, but the ICT exposure index again achieved its position at a 1% level of significance. Furthermore, ICT shows a positive relationship with control of corruption; this finding is corroborated by different regional studies. The magnitude of the ICT coefficient for reducing corruption is 0.87 in Europe (Androniceanu *et al.*, 2021), 8.254 for selected Asian countries (Suardi, 2021), and 0.0256 in Africa (Kouladoum, 2022). The finding is also corroborated by other studies (Darusalam *et al.*, 2021; Gouvea *et al.*, 2022; Hartani *et al.*, 2020). The first reason is that Internet technology improves the implementation of the law and regulations by limiting the public administration's discretion. Secondly, the ability of society to report corruption-related acts and the accelerated dissemination of information made possible by mobile phones make them effective instruments for detecting corruption. Third, online communication is faster than traditional processes, and, by implementing such technology, government agencies can take prompt preventative action in the event of suspicious or malicious activity.

Conclusion

This study delved into the impact of Information and Communication Technology (ICT) on control of corruption within a cohort of 17 Asian nations in a time span from 2010 to 2019. Employing the Driscoll-Kraay methodology for standard error computation, the research pursued the establishment of foundational outcomes, thereby confronting the challenges posed by autocorrelation and heterogeneity. The study adopted four measures of ICT that are the number of individuals using the Internet, fixed broadband subscriptions, mobile cellular subscriptions, and secure Internet servers.

Corruption hampers the growth track to pursue inclusive, equitable, and sustainable economic growth and development. Additionally, it affects the distribution of resources within and between regions. This study safely concluded, with a fixed effects Driscoll-Kraay OLS estimation, that ICT is a determinant of corruption and that ICT reduces corruption, contrary to other studies (Charoensukmongkol & Moqbel, 2014; Heeks, 1998), which show that there is no significant relation between ICT and CoC; whereas the results are substantiated by additional scholarly investigations (Darusalam *et al.*, 2021; Gouvea *et al.*, 2022; Hartani *et al.*, 2020). The amelioration of corruption within a nation through the adept application of ICT is poised to culminate in the augmentation of transparency and accountability. Consequently, this synergistic effect is anticipated to improve a nation's economic prosperity as well. It also shows that there is a positive relationship between effective governance and control of corruption, as in previous studies (Bhatnagar, 2000; Poliak *et al.*, 2020; Russell, 2020). ICT is significant at 1% in the final regression to support the objective. Hence, ICT is a potential variable to explain CoC.

ICT policy can play an important role in curbing corruption, so there is a strong need for ICT diffusion, as it has a strong positive relation with CoC. The results suggest that effective governance helped to reduce corruption in the Asian region and establish a surveillance-based system in public institutions. Access to ICT tools and platforms should be made easy for all parties to ensure the dissemination of information.

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