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IMPACT OF DIGITALIZATION ON THE SHADOW ECONOMY CONTROLLING FOR GOVERNANCE QUALITY

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ABSTRACT

Digitalization plays a pivotal role in enhancing transparency and efficiency. This study uses two models to examine the impact of digital transactions and government atomization on the informal economy, while controlling institutional quality and governance. The short panel data of 2014 & 2016 and unbalanced panel data from 2014 to 2020 are used in the models, respectively; 169 economies worldwide are selected for both models. Pooled OLS & fixed effects regression were applied, respectively, along with quantile regression. The findings suggest that governmental digitalization, e-payments, and economic integration have a negative effect on the shadow economy. While institutional & governance quality indicate that the effectiveness of digitalization can be achieved through a strong legal and governance system.

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Introduction

Around the world, the shadow economy is a fact of life (Schneider, 2005). The shadow economy is defined as all the obscure and hidden economic activities from official authorities for monetary, regulatory, and institutional reasons. Avoiding contribution to the tax base and social security is the monetary reason; regulatory reasons include avoiding the burden of the legal framework or avoiding governmental bureaucracy, and institutional reasons include the poor quality of political institutions and laws, leading to corruption (Medina & Schneider, 2018). The shadow economy is difficult and complex to explain and quantify but has a long-lasting influence on the economy and social life of the country (Vatavu et al., 2023). Tax optimization and tax evasion are the causes of the grey economy (Schneider et al., 2015). A study stated that informal production

and tax evasion can create a very dangerous cycle: individuals go underground to get away from taxes and social security contribution that leads to an increase in tax rates and budget deficit, the economic growth will decrease because of the conversion of resources from productive (production of goods and services) to non-productive uses (schemes to hide income, issuance and collection of penalties, and monitoring the tax system, etc.); and informal production can put constraints on companies' ability to gain finance, such as debt (Putnins & Sauka, 2015). Also, even if corruption is controlled, the shadow economy raises unfairness (Saha et al., 2021). Fedajev et al. (2022) explained four factors of causing shadow economy: wealth and development, open market, tax system, and political environment. It is important to study and control the shadow economy for development and growth. The efficiency of rules and laws can control the shadow economy and enhance economic growth (Kravchenko et al., 2023). The average share of the shadow economy as a % of GDP in 31 European countries is 17.3%, and Turkey has the highest share of 32% (Schneider, 2022). The integration of data and payment systems that improve the availability and processing of more reliable and accurate information, which creates unlimited opportunities, is digitalization (Kitsios et al., 2023). The use of digitalization in the transaction process through tools such as electronic invoicing can improve the tax system and reduce administrative costs (Heinemann & Stiller, 2024). The digital revolution provides new opportunities in public finance through better information, better systems, and better policies (Gupta et al., 2017). Zhou et al. (2022) also examined that digital transformation can have a significant influence in reducing tax evasion by enhancing tax avoidance. Nguyen et al. (2024) suggest that governments can use technology as a tool to restrict the expansion of the shadow economy, but with institutional reforms. The growing level of information and communication technologies can help to reduce the magnitude of the unofficial sector, along with improvements in human capital policies (Remeikiene et al., 2024). In another study, the authors suggested that adoption of e-government can be beneficial for both economies (official and unofficial), but the benefits of this exceeded more in official economies (Doan et al., 2025). Digitalization of the financial system also plays an important and influential role in reducing the shadow economy (Rahman et al., 2023). Powered by the internet, the connection between finance and digitalization has led to an increase in digital payments (Khando et al., 2021). With the use of digital payments, the misuse of currency and fraud can be easily detected (Aldaas et al., 2021), which can indirectly lead to a reduction in the informal sector. Along with the adoption of digitalization, the governance quality element is also considered in this study, which can be an important determinant in reducing the shadow economy. Institutional efficiency is very important in combating the shadow economy. Strong institutions reduce the size of the shadow economy and are very important for the formal growth of the country (Dada et al., 2022). Economies with inefficient institutions remain underdeveloped because they fail to eliminate informality (Huynh, 2020). Canh et al. (2021) also found the negative effect of institutional quality on the shadow economy. In light of the issues above, this study aims to examine the effect of digitalization and institutional or governance quality on the shadow economy. This study takes the dual dimensions of digitalization and institutional quality, on which there is very little amount of literature, and checks heterogenous effect of shadow economy across countries and these are the novelties of this research for this purpose study used two models. 1st to capture the governmental level digitalization and the level of governance, and

2nd to capture the individual level digitalization and institutional quality. In the 1st model, 2014 and 2016 short panel data of 169 countries are used and applied to pooled OLS, and in the 2nd model, unbalanced panel data is used of 169 countries from 2014 to 2020 are used and applied to fixed effects, with quantile regression. This study aims to find which are the more effective drivers of the shadow economy that can lead to its reduction.

Objectives:

The main objective is to capture the beneficial impact of increasing penetration and adoption of digital tools, e-transactions, and technology on the informal economy, which is the big restriction in growth of any country, especially in underdeveloped countries, also aims to estimate the effect of this across countries with high and low levels of the shadow economy. From this study, policymakers can also make policy recommendations to reduce the shadow economy through digital transformation and strengthen institutions.

Review of Literature

Setor et al. (2021) investigated the impact of digital payment to reduce corruption. The study fetched panel data from 111 developing countries from the period of 2010 to 2018, and a fixed-effects regression was applied. The corruption perception index was taken as the dependent variable and digital payment transactions as the independent variable, and three control variables were used such as GDP per capita, legal system, and internet access. They found a negative relationship between corruption and digital transactions. Adam and Fazekas (2021) reviewed existing literature from 2008 to 2019 to find out if emerging technologies are helping to reduce corruption. They stated that ICT tools act as influential ways to reduce corruption and make the government more transparent. ICT application tools that could help to fight against corruption, like Digital public services, crowdsourcing platforms, whistleblowing tools, transparency portals, distributed ledger technology, and artificial intelligence, were reviewed ICT tools. The conclusion was that ICT tools can positively impact the fight against corruption through improved reporting and monitoring. Mohsin Abbas et al. (2022) investigated the link between e-government, cyber security, and corruption on public service sustainability in Asian countries. Secondary data from 47 Asian countries from 2015 to 2019 was taken. Public service sustainability (proxy as public health service) was taken and dependent variable, E-government development index as independent and used corruption and cybersecurity as moderating variables. Fixed effects and Random Forest were used to estimate the results. The study concludes that the E-government development index enhances the quality of public service sustainability, and introducing corruption control and cybersecurity initiatives also promotes public service sustainability. Merhi (2022) investigated the effect of digital transformation on corruption and took secondary data from 139 countries globally. Corruption was taken as a dependent variable, and Government efficiency, E-participation, Online service, Telecommunication infrastructure, Human capital, Laws related to ICT, Importance of ICT to government, and GNI as independent variables. PLS-SEM (partial least squares structural equation modeling) was applied to test the

hypothesis. The conclusion was that digitization, and ICT tools have a significant influence in reducing corruption. A study by Yamen et al. (2022) investigated the impact of digital adoption on tax evasion and also tested the moderating effect of corruption. The cross-sectional data were used from 133 countries: 66 highly corrupt and 67 low-corruption countries, and applied OLS. Tax evasion was taken as a dependent variable, and the shadow economy was used as a proxy for tax evasion, and the digitalization adoption index as independent variable. Four control variables were used, such as inflation, unemployment, Economic freedom and urbanization and used corruption as moderating variable. There is a negative relationship between tax evasion and adoption of digitalization, and digitalization is more effective in reducing tax evasion in low-corruption countries as compared to high-corruption countries. Gouvea et al. (2022) investigated whether the transition to the digital economy leads to lower-level corruption. Panel data were collected from 147 countries in the period of 2013-2019, and OLS was applied. The Corruption Perceptions Index (CPI) was taken as a dependent variable, and the independent variables were innovation, Tech (tech readiness, e-government, ICT use, internet), and press freedom; education, GDP, and quality of institutions were controls. The study found that innovation from factor-based economy and ICT have a negative relationship with corruption, and ICT plays a significant influence on control variables, as they were also found to be helpful in combating corruption. Androniceanu et al. (2022) investigated the impact of public administration digitalization on the corruption in European Union member countries. The study used secondary data from 27 EU countries from 2019 to 2020. Control of corruption, competitiveness, regulatory quality index, government effectiveness index, and rule of law index were used as dependent variables, and E-participation, online service index, human capital index, E-government index, and government expenses were taken as independent variables. Canonical correlation analysis was applied and concluded that digitalization enhances the efficiency of public administration and can reduce corruption. Xiaoyan et al. (2022) studied the impact of digitalization on clean governance in China. The secondary data were collected from the 31 provinces (from the high and medium corruption case reporting areas) of China from the year 2019 to 2021. Clean governance was taken as the dependent variable, and open data status (policy ensuring, online platform availability, technological embeddedness, open data usefulness), organizational strength (fiscal capacity), and environmental constraints (pressure to the province and neighboring pressure) as independent. The study used Fuzzy-set Qualitative comparative analysis and found that not signal factor can clean governance in Chine contribution of every factor can put positive effect on it. Castro and Lopes (2023) also examined how e-government works as a tool to reduce corruption. The study used secondary source of data and collected the panel data from 175 countries from 2003-2019.The corruption perception index was used as a dependent variable, and e-government development index, political stability, voice and accountability, regulation, GDP, and use of the internet as independent variables. Generalized Method of Moments (GMM) was applied and concluded that all the variables helped significantly to reduce corruption but e-government exceed the threshold in this. Khelil et al. (2023) investigated the relationship between digitalization and money laundering and examined the moderating effect of ethical behavior and money laundering on it. Secondary and cross-sectional data of 114 countries in 2016 was taken. The study used ML (score for money laundering risk) as the dependent variable and the

digital adoption index as the independent variable; it used two moderating variables ethical behavior and corruption and the level of judicial independence, investor protection score, market size, degree of policy instability and strength of financial auditing and reporting were used as controls. A multiple regression model was applied and concluded that there is a negative and significant relationship between money laundering and digitalization, and it is more effective in low-corruption and high-ethical countries than in others. A study by Oleksandra et al. (2023) examined the influence of economic and digital factors in combating corruption. The panel data were fetched from 40 European countries from the year 2016 to 2020. Corruption Perception Index (CPI) was a dependent variable in this study, and economic factors such as GDP, inflation, crime rate, level of education, tax rate, and imports, and digital factors like internet users and percentage of volunteers were used as independent variables. The Panel data regression was applied for the estimation. The conclusion was that the digital factors played a significant role in fighting against corruption, and economic factors also had a negative influence on corruption as well, except the tax rates and imports these two tend to increase the corruption. Boitan and Stefoni (2023) examined the impact of digitalization on the shadow economy in European countries. The study collected secondary data from 28 European Union countries in the time period of 2013 to 2020.The shadow economy was taken as dependent variable and digital indicators like internet used by individuals, enterprises turn over from e-commerce, digital competitiveness index, ICT and highspeed internet coverage as dependent and also the study introduced GDP, unemployment rate, government debt, Euro-zone OECD membership as controls. A dynamic panel regression model was used to estimate the relationship. All the variables were found to be negatively associated with the shadow economy except high-speed internet coverage. Bajestani et al. (2024) investigated whether digital technologies are anti- or pro corruption? The panel data were used from 72 countries over the period of 2012 to 2020.The corruption perception index (CPI) took as a dependent and Digital intelligence index (DII) as independent and used one moderating variable Government environment index (GEI) in three dimensions one is rule-based country, second is non-rule based country, and other one is clan-based county. The study used cultural dimensions, GNI, International openness, government size, and FDI as controls. GMM models were applied and found a negative and significant relationship between corruption and digitalization, and also found that digitalization is less effective in non-ruled-based countries than the rule-based countries, more over digitalization expanded the corruption in clan-based countries. Sadik-zada et al. (2024) examined the relationship between e-government and petty corruption and its impact on public service delivery as well in developing and transitioning economies. Panel data from 121 countries from the period of 2008-2018 were used. Corruption perception index (CPI) was taken as dependent variable and E-government development index (EGDI), per capita income, infant mortality (as proxy for socio-economic development), political right index, civil liberties index, natural resource dependence as independent. Random Tobit and linear random-effects panel were the techniques that were used for estimation in this study, and the conclusion was that e-government has a negative relation with petty corruption.

Data & Methodology

This study investigates the digitalization and regulatory impact on the shadow economy with the help of two separate empirical models, with the shadow economy as the same dependent variable. The explanatory variables were selected according to data availability and different conceptual focuses. The 1st model focuses on governmental digitalization and level of governance, along with corruption, and the 2nd model includes determinants like individual expansion of digitalization, laws & regulations, along with economic growth of countries. These two models help to understand the impact of personal-level digital adoption and governmental-level digital adoption, along with some other variables, separately on the shadow economy so we can compare them both. So, model 1 explains micro-level digitalization, and model 2 explains macro-level digitalization. I prefer two models because the shadow economy is a multidimensional phenomenon which can be influenced by both types of digitalization.

Sample selection:

This study uses data from 169 countries for both models, which approximately cover the whole world, but this study separates the time framework for both of the models, taking data from 2014 to 2016 in the 1st model and from 2014 to 2020 in the 2nd. The purpose of taking 7 years for the 2nd model and 2 years for the 1st is that, in this period after 2010 there is rapid growth in digital adoption was seen. According to data, account ownership from 2011-2021 increased by 50% around the world and 8% in sub-Saharan Africa; this is all because of the expansion of mobile money (Global Findex Report, 2021). All countries who are the members of the united nation have the national websites by 2014, enables individuals to create accounts, to file income taxes or for the registration of the business (World Development Report, 2016). So, by 2014, countries moved towards governmental digitalization, so these years can better explain the transformation and its impact on the informal sector.

Dependent variable:

This study uses two distinct models with different independent variables and the shadow economy as dependent on both of the models. According to the IMF, the shadow economy is the combination of all those activities that can be part of tax revenue and GDP if they are recorded. The source of this variable is Elgin et al. (2021), which employed the Multiple Indicator & Multiple Cause model to calculate the shadow economy. This study takes the shadow economy data from 2014-2020 and uses this data in two models.

Model 1: Governmental digitalization & governance:

This model examines the impact of governmental-level digitalization and the strength of governance on the shadow economy and also examines the effect of corruption on the shadow economy. This model uses short panel data for the years 2014 & 2016 of 169 countries from different secondary sources and uses the independent variables like Government digitalization

index, Corruption perception index, Accountability, Ethical behavior of firm, and Strength of investor protection, with the dependent variable of the shadow economy as % of GDP. All the variables in the dataset are reported periodically, and 2014 & 2016 are the years when complete data are available for all the variables. There is also a reason to select the two years because the e-government survey report by the UN, which started in 2011, is conducted every two years. The data on the E-government development index and E-participation index, which are used to make the governmental digitalization index, are also available for 2014 & 2016, and these years also align with the global digital expansion in governance. World Development Report (2016) also reported data on the digital adoption index for two years (2014 & 2016).

Independent variables:

This study uses the Corruption Perceptions Index (CPI) to investigate the impact of corruption on the shadow economy. CPI explains the level of corruption in a country, and it ranks the countries accordingly (Transparency International). Corruption is "an abuse of entrusted power for private gain" (Transparency International, 2020b). So, according to the definition, an increase in corruption can increase the shadow economy. Nemec et al. (2021) investigated the impact of corruption on the shadow economy and found out that corruption can increase the growth of the shadow economy. Accountability, Ethical behavior of the firm, and strength of investor protection were also taken as independent variables to show the level of governance and governmental behavior towards citizens. According to the World Economic Forum, accountability is the concept where one is held responsible and questionable of an action. It is equivalent to being answerable; it also helps people to hold government accountable (World Economic Forum). Ethical behavior of a firm shows the behavior and ethics of business and firms with the politicians and government officials (World Economic Forum, 2018). Ethics of individuals and firms can increase or decrease the shadow economy; e.g. tax moral better tax morale in a country can lead to a reduction in the shadow economy. The study by Torgler and Schneider (2009) also investigated this phenomenon (impact of tax morale on shadow economy) and concluded that tax morale, with greater institutional quality, can lead to a reduction in the shadow economy. The strength of investor protection is also taken as an independent variable in this study, which is the combination of the three different indices: the index for transparency in transactions (Discloser index), the index for liabilities for self-dealing (Director liability index), and the index for the ability of any shareholder to sue any officer for any kind of misconduct (Shareholder suit index) (World Economic Forum, 2018).

Construction of Governmental Digitalization Index:

The government digitalization index is based on three variables that show the expansion of digitalization in the public sector and governmental institutions. **The first variable** is the e-participation index. According to the United Nations, it indicates how well the government engages their citizens to use digital tools in governance. It is the combination of three things: electronic information (providing citizens with transparent and complete access to public information through digitalization), e-consultation (engaging citizens in discussing and making

public policies), and e-decision making (participating individuals to product and designing public policies through which public services can become efficient) (UN Department of Economic and Social Affairs). **The second variable** is the E-government development index (EGDI). According to the United Nations, it is the growth and progress of governmental digitalization in different countries. It is the combination of three components: online service index, telecommunication infrastructure index, and human capital index, and also includes the development of governmental websites, technological infrastructure, and education. **The third variable** is the Digital Adoption Index of government. Digital Adoption Index, measured in the World Development Report, 2016, calculates the adoption level of digitalization of countries in three dimensions: digital adoption of people, digital adoption of business, and digital adoption of government (World Development Report, 2016). The sub-index of governmental-level digital adoption is used to generate the index for this study. The government digitalization index is constructed with the help of **Principal Component Analysis (PCA).** PCA is a method used in multivariate analysis to explore data and to develop a predictive model. It orthogonally transforms the correlated variables into an uncorrelated set, which are called **Principal Components (PCs),** while retaining the maximum variation in the data it reduces the number of dimensions (Abdi & Williams, 2010)

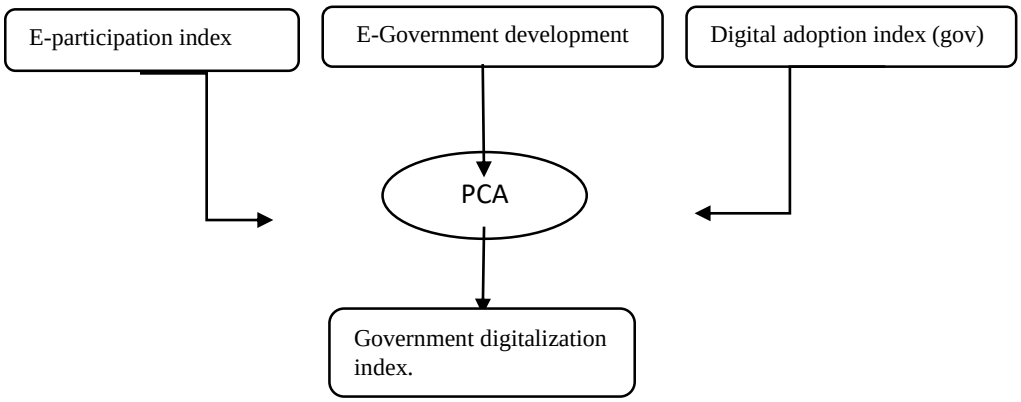

Table 1: Principal components (eigenvectors):

Variables	Comp1	Comp2	Comp3
EPI	0.587	-0.311	-0.784
EGDI	0.581	-0.481	0.656
DAIg	0.564	0.820	0.101

Table 2: Component Variance:

Components	Proportions
Comp1	0.8733
Comp2	0.0824
Comp3	0.0442

According to Mishra (2008) the PCA is a popular method to create an index with having the properties of showing strongest relationship with original variable, and if you make another index with same data, it will be orthogonal to any other index. There is a wide amount of literature which uses PCA to construct indexes for different purposes like a study by Shah et al. (2021) construct the of Dynamic cryptocurrency index and this index track the entire cryptocurrency movement in the market. Table 1 shows the output of the PCA and makes the three components, the components loadings which are the elements of the eigen vectors, which shows the contribution of each variable in the components (T. Jollife & Cadima, 2016). The first component of PCA contains maximum variance is an important property of PCA, and first component is good for index (Mishra, 2007). This study chooses comp1 because the component 1 captures the maximum variance (Table 2), and the component loadings has positive values which shows higher the value of E-participation index, E-government development index, Digital adoption index of government the higher the value of the index which is Governmental digitalization index and suitable for the interpretation of this study as well.

Table 3: Variables:

Ind. Variables	Measurements	Sources
Governmental Digitalization Index	1: EPI ranges from 0-1, where 1 indicates best and 0 indicates poor.	1: UN (Department of Economics and Social Affairs).
1: E-participation index	2: EDGI ranges from 0-1, Where 1 indicates high and 0 indicates low.	2: UN (Department of Economics and Social Affairs).
2: E-government development index	3: DAIg provides overall score for each country.	3: World Development Report (Digital Dividend), 2016 by World Bank.
3: Digital adoption index of government		
Corruption Perception Index	It ranges from 0-100, where 0 indicates highly corrupt and 100 indicates clean.	Transparency Internationals.
Accountability	It ranges from 1-7, where 1 indicates low and 7 indicates high	World Economic Forum (The Global Competitiveness Report, 2017-18).

	accountability.	
Ethical Behavior of Firm	It ranges from 1-7, where 1 indicates bad and 7 indicates good ethics.	World Economic Forum (The Global Competitiveness Report, 2017-18).
Strength of Investor Protection	It ranges from 0-10, where 0 indication no protection and 10 indicates high.	World Economic Forum (The Global Competitiveness Report, 2017-18).

Model 2: Digital behavior & institutional capacity:

This model investigated the impact of personal-level digital adoption, institutional efficiency, and economic growth on the shadow economy. In this model, this study uses panel data from 169 countries from the period of 2014 to 2020. This model covers a span of 7 years, involving the short- to medium-term factors of the shadow economy, and aims to show the dynamic effect of the digital and institutional factors on the shadow economy. According to the OECD Digital Economy Outlook (2020) report, from 2014 to 2019 there is a rapid increase in the use of the internet by individuals. According to this report, daily use of the internet increased by 30 minutes on average among individuals from 2014 to 2019 (Digital Economy Outlook, 2020). In this study, the model uses made or received digital payments by individuals using the internet, which shows individual-level digital behavior, and the rule of law, regulatory quality, and government effectiveness show institutional capability. This model investigates the dynamic effect of these variables on the shadow economy, and the impact may vary from country-to-country development, so that's why this study employed the panel data of 169 countries.

Independent variables:

This study employs made or received digital payments, which indicates the % of the 15+ population in the 60% richest households who used digital payments like mobile money, debit and credit cards, receiving salaries & pensions, including remittances or government transfers, in the past 12 months (World Bank Group). According to Syed et al. (2021), the study's results show that digital finance reduces the shadow economy, and the study takes the variable mobile money transactions as % of GDP. In this study, making or receiving digital payments are employed, expecting that it should reduce the shadow economy. And also used individual using the internet to show the behavior of digitalization privately, the individual using internet shows the percentage of individuals who uses internet via computer, mobile phone, digital TV & digital assistant is shown (World Bank Group). Per-capita GDP, which shows the value added in the gross domestic product by local individuals and producers plus product tax, is measured by dividing the mid-year population by GDP (World Bank). This study used per-capita GDP to show the income level of individuals and to show its possible impact on the shadow economy. Regulatory quality captures the efficiency and effectiveness of government policies & regulations that support

private sector development and the level of their implementation (World Governance Indicator). Barra and Papaccio (2024) investigated the impact of regulatory quality on the informal economy and found a significant and negative relation. This study also employed the variable rule of law to highlight the institutional capacity in the model. Rules of law capture the confidence and trust of individuals in the social rule regarding the level of contract enforcement, fairness of property rights, and the level of crime, as well as the functioning of the police and judiciary system (World Governance Indicator). Government effectiveness, which shows the efficiency of government workings in sectors like public service and civil service, as well as in policy formulation and implementation, also shows how much government stands rigid to its policies (World Governance Indicators). This study expected that institutional capacity can help to reduce the shadow economy, so regulatory quality, rule of law & government effectiveness are the measures that the study uses for institutional quality. According to Dreher et al. (2009), institutional quality can reduce the shadow economy and can also put limitations on corruption.

Table 4: Variables:

Ind. Variables	Measurements	Sources
Made or Received Digital Payment	shows as % of 15+ population.	Global Findex Index by World Bank.
Individual Using Internet	% of in~ scope individuals.	World Development Indicators
Per~capita GDP	Of constant year 2015.	World Development Indicators.
Regulatory Quality	It ranges from ~2.5 to +2.5. ~2.5 indicates very weak quality and +2.5 indicates very strong.	World Development Indicators
Rule of Law	It ranges from ~2.5 to +2.5. ~2.5 indicates very weak rule of law and +2.5 indicates very strong.	World Development Indicators
Government Effectiveness	It ranges from ~2.5 to +2.5. ~2.5 indicates very weak government effectiveness and +2.5 indicates very strong.	World Development Indicators

Model specification:

Model 1: To study the impact of governmental digitalization & level of governance on the shadow economy, the regression will be performed, written down below, which is for Model 1:

$$SE = \beta_0 + \beta_1 GDI + \beta_2 CPI + \beta_3 ACC + \beta_4 EB + \beta_5 SOIP + \gamma$$

Where;

- $SE = shadow\ economy\ as\ \%\ of\ GDP.$
- $\beta_0 = Constant.$
- $\beta_1, \ldots \beta_5 = Co\_efficients\ of\ variables.$
- $GDI = Governmental\ digitalization\ index.$
- $CPI = Corruption\ perception\ index.$
- $ACC = Accountability.$
- $EB = Ethical\ behavior\ of\ firm.$
- $SOIP = Strenght\ of\ investor\ protection.$
- $\gamma = Error\ term.$

Model 2: 2nd model captures individual-level internet behavior and the level of institutional quality to study the shadow economy; the following regression will be performed for Model 2:

$$\boldsymbol{SE = \alpha_0 + \alpha_1 MRDP + \alpha_2 IUI + \alpha_3 PCGDP + \alpha_4 RQ + \alpha_5 ROL + \alpha_6 GE + \varepsilon}$$

- $SE = Shadow\ economy\ as\ \%\ of\ GDP.$
- $\alpha_o = Constant.$
- $\alpha_1, \alpha_2, \ldots . \alpha_6 = Co\ efficients\ of\ variables.$
- $MRDP = Made\ or\ recieved\ digital\ payments.$
- $IUI = Individual\ using\ internet.$
- $PCGDP = Percapital\ GDP.$
- $RQ = Regulatory\ quality.$
- $RQ = Rule\ of\ law.$
- $GE = Government\ effectiveness.$
- $\varepsilon = Error\ term.$

Estimation techniques:

To estimate the impact of digitalization, controlling for institutional quality and governance on the shadow economy, this study employed two models to capture the dual dimensions of digitalization. A short-term panel of 2 years, in model 1, and an unbalanced panel of 7 years in model 2. Utilizing panel data helps to ensure the estimation efficiency of the model because of the larger degrees of freedom and data variability than cross-sectional and time-series data (Hasio et al., 1995). It also helps to capture the dynamic effect of human behavior and controls the impact of omitted variables (Hasio, 2007). **Pooled OLS regression** was chosen for Model 1 because it has short panel data of two years (2014 & 2016) of 169 countries. We want to see the average effect of governance and governmental digitalization rather than within-country variation, and pooled OLS is suitable for estimating the average effect. Pooled OLS combines the cross-sectional and time series data, which in result increase the number of observations, and this helps in expressing the dynamic analysis of political processes because the data is not static in time (Janoski & Hicks, 1994a). To see if these digitalization and governance indicators vary across different sizes of the

shadow economy, the study also employed **Quantile regression** on both of the models. Quantile regression was introduced by Koenker & Bassett in 1978; this describes how different percentiles, or quantiles, of the dependent variable depend on the values of independent variables (Koenker & Hallock, 2001). It extends the well-known traditional mean regression to quantile regression (conditional quantiles); this method does not show the average effect but shows how covariates influence the dependent variable's distribution at different points (Koenker, 2005). This model examined the impact of governmental digitalization and governance, along with ethical behavior, on the shadow economy and also estimated this relationship at 25, 50 & 75 percent quantiles, which tells how these indicators become effective or ineffective at different sizes of the shadow economy. This model also employed **Principal component analysis (PCA)** to make the index of governmental digitalization with the three very corelated variable which are E- participation index, E- government development index, & Digital adoption index of government these variables explain the better that how efficient a government of any country in the development, participation, & adoption of digitalization. The reason why this study employed the **Pooled OLS** in Model 1 on short panel data is that, in this model, the study does not want to see the country-specific & time-specific characteristics on the shadow economy and wants to investigate the average effect of governmental digitalization & quality of governance on the shadow economy. In the 2nd model, this study wants to capture the impact of individual-level digitalization & institutional quality on the shadow economy at a dynamic level; that's why this model takes panel data of 7 years from 2014 to 2020 of 196 countries. Another reason is to see the effect of this model over time because, when individual-level digitalization increases, the impact will not be sudden on the shadow economy; individuals can access digital tools but take time to shift from informal to formal activities. The **fixed-effects regression and quantile fixed effects** are used to estimate the results for this model. Fixed-effects regression is a method that is very useful in studying causal relationships (Gangl, 2010). Fixed effects are useful for panel data, sometimes when there are omitted or hidden variables that are missing in the model and affect the results; it is useful for this kind of problem and gives unbiased and efficient estimation (Brudrel & Ludwig, 2015). Fixed effects also control for unobserved heterogeneity, which creates problems in the cross-sectional analysis (E. Moody & B. Marvell, 2020). I applied **robust standard errors** to both of the models. To account for heteroscedasticity and serial autocorrelation, robust standard errors are essential (Wooldridge, 2010). Then I applied quantile regression at 25, 50 & 75 percent quantile with fixed-effects regression. A study by Kendo and Tchakounte (2022) also used quantile regression with fixed effects to see the impact of asset size on financial performance. In the second model, where I want to see the impact of individual-level digitalization adoption along with institutional quality in the shadow economy, I fetched the data for 7 years, but the Made or received digital payments have only three years of data (2014, 2017, and 2021) according to the Global Findex index, so I interpolated the data on this variable using **linear interpolation** in Stata and aligned the data with my sample size.

Results and Discussions

Results from model 1:

The impact estimation results of governmental digitalization and level of governance on the shadow economy are presented in Table 5. The governmental digitalization index was designed to cover government-level digitalization, and the corruption perception index (CPI), accountability (ACC), and strength of investor protection (SOIP) indicators are included to cover the efficiency of governance in a country, along with the ethical behavior of firms to show the morals of business. Pooled OLS is used to estimate the results, and robust standard errors are used to ensure the accuracy of the results. Also, the relationship is estimated at the 25%, 50%, & 75% quantiles to capture the heterogeneous effects of the shadow economy across countries. The governmental digitalization index has a negative and significant relationship with the shadow economy in the pooled OLS, also across all quantiles. This indicates that if governments of different countries adopt digitalization, the size of the shadow economy will reduce; it ensures transparency, and digitalization is unbiased.

Table 5:

Variables	Pooled OLS	25% Quantile	50% Quantile	75% Quantile
GDI	-2.431	-2.535	-2.079	-2.568
	(0.832)***	(1.012)**	(0.929)**	(1.117)**
CPI	-3.05	-0.146	-0.326	-0.38
	(0.057)***	(0.069)**	(0.064)***	(0.077)***
ACC	4.41	1.801	2.504	7.516
	(2.024)**	(2.464)	(2.26)	(2.719)***
EB	-3.719	-5.178	-2.808	-3.884
	(1.404)***	(1.709)***	(1.567)*	(1.886)**
SOIP	-0.775	0.378	-0.367	-2.521
	(0.61)	(0.742)	(0.681)	(0.819)***

***<P.01, **<P.05, *P<.1

According to Table 5, the corruption perception index also has a negative and significant relationship with the shadow economy. This suggests that as the perceived level of corruption decreases (high CPI value), the size of the shadow economy declines. The effect remains consistent across all levels of the shadow economy, which means corruption control can lead to a better economy and reduce its informality because a lower level of corruption ensures integrity and fairness. Accountability varies across the different quantiles, reflecting the heterogeneous effect of the shadow economy. In the pooled OLS, it has a positive and significant relationship, which indicates that the increased level of accountability increased the size of the shadow economy in OLS, but it has a positive but not significant effect in the 25% and 50% quantiles, and interestingly it has a positive and very significant relationship in the 75% quantile, which means

that where the penetration of the shadow economy is high, the increased level of accountability will increase the size of the shadow economy. The reason for this if accountability and regulation are high and efficient, it will discourage people from being part of the formal economy because higher restrictions and regulation reduce the freedom of choice, and people choose the exit option (Schneider & Enste, 2002); and, with the other factor remaining constant, government intervention in the economy can increase the shadow economy (Torgler & Schneider, 2007). So, accountability wants people to file their assets and wants an explanation of how they got them; that's why people are discouraged from showing their income and assets, which indirectly leads to an increase in the shadow economy. The variable ethical behavior of firm has the negative and statistically significant relationship in the pooled OLS and in 25% quantile which indicates that the if the ethical behavior of a country is strong it will lead to lower level of shadow economy because firms with good ethical register their assets, stay away from bribery and plays an active part in the tax base which reduce the size of shadow economy but the significance of ethical behavior is lower in 75% and 50% quantiles as in 25% quantile because even if firm have good ethics the large penetration of shadow economy may induce them to be part of it partially. Strength of investor protection do not have statistically significant impact on shadow economy in pooled OLS and in 25% and 50% quantile but it has negative statistically significant impact on shadow economy in 75% quantile it means strength of investor protection reduces the size of shadow economy where the penetration of the shadow economy high, the investor protection in that economies is weak, business and firm may become part of shadow economy due to lack of trust on institutions but when the institutions and government support investors it increase their trust levels now they participate in the legal framework and now have good relations with the legal institutions of the country. This model emphasizes that governmental-level digitalization can restrict the size of the shadow economy; corruption control and ethical behavior also have a significant impact, but the governance indicators, which are accountability and the strength of investor protection, vary. As Dreher and Schneider (2010) argued, the more efficient the level of governance, the higher the risk of getting caught, so this can be the reason for the positive and low impact of governance indicators found by this study.

Results from model 2:

Table 6 shows the results of the 2nd model, which captures the individual-level digitalization and institutional quality along with the impact of economic growth on the shadow economy. The fixed effects are used to estimate the results, and robust standard errors are used for accuracy; the model also estimates the results at the 25th, 50th, and 75th quantiles to capture the heterogeneous effects of the shadow economy across countries

Table 6:

Variable	Fixed effects	25% Quantile	50% Quantile	75% Quantile
MRDP	-0.027 (0.009) ***	-0.024 (0.007) ***	-0.025 (0.006) ***	-0.027 (0.008) ***

IUI	0.01	0	0.009	0.02
	(0.006)	(0.007)	(0.005)*	(0.008)***
PCGDP	-0.214	-0.15	-0.175	-0.208
	(0.067)***	(0.049)***	(0.038)***	(0.055)***
RQ	-1.016	-0.916	-0.953	-1.002
	(0.412)**	(0.384)**	(0.292)***	(0.424)**
ROL	-0.042	0.359	0.33	0.292
	(0.415)	(0.377)	(0.287)	(0.417)
GE	-1.254	-1.295	-1.126	-0.901
	(0.329)***	(0.333)***	(0.254)***	(0.369)**

***<P.01, **<P.05, *P<.1

According to Table 6, made or received payments and individuals using the internet are indicators of individual-level digitalization. The variable made or received payments has a negative and very significant relationship with the shadow economy across all the quantiles and also in the simple fixed effects regression. This suggests that if the individual adopts digital transactions, this will help to curb the size of the shadow economy and improve the inclusion of the formal sector because cash in hand will reduce. The individual's use of the internet has an insignificant relationship in the simple fixed-effects regression and also in the 25% quantile, but in the 50% and 75% quantiles it has a positive relation and is strongly significant in the 75% quantile. This means that where the penetration of the shadow economy is high, it can encourage the shadow economy to a certain level. Fleming et al. (2000) stated that the advanced level of internet usage can encourage e-gambling, cybercrime, unregulated digital work, & illegal e-commerce (containing illegal goods & services); all these activities will directly or indirectly contribute to the shadow economy. The relationship between individuals using the internet and the shadow economy is multifaced phenomena, and the relationship is U-shaped (Nguyen et al., 2024). The per-capita GDP has a consistent negative and very strongly significant impact on the shadow economy, which indicates that countries with higher economic growth and development tend to have a lower percentage of the shadow economy. So, to reduce the expansion of the shadow economy, nations should also work on their economic growth. Regulatory quality has a negative and statistically significant relationship with the shadow economy, which suggests that efficient and fair regulation has a negative effect on the shadow economy, but the rule of law does not have a significant effect on the shadow economy, which means its impact is inconsistent and weak. Government effectiveness has a negative and significant relationship with the shadow economy. Dreher et al. (2009) also found the negative association of government effectiveness with the shadow economy. An efficient government enables better policy implementation and public services, which will lead to the exclusion of the informal sector. To sum up our findings, this study put emphasizes on the digitalization whether it can be at individual level or at government level the digitalization plays important role to reduce the inclusion of the informal sector along with the institutional quality and better governance. Adoption of governmental digitalization in their work and institutions, and encouraging people to select electronic tools for transactions, along with efficient governance that can improve the quality of policies, make implementation

better, and enable fair rules and regulations which will eventually curb the shadow economy. By this, the trust of the people in the public sector will be regained, and everything will be more transparent to individuals then informality will reduce.

Conclusion

This study investigates the impact of digitalization and governance quality on the shadow economy. Individual and governmental level digitalization are taken separately to capture the multidimensional effect along with the influence of governance and institutional quality. Two models were used for this purpose, with the same dependent variables but with different ranges and independent variables. 1st Model is to capture the governmental digitalization and governance, which covers data for 2 years 2014 & 2016 and the 2nd model captures individual-level digitalization and institutional quality and covers data for 7 years from 2014 to 2020. This study suggests that the expansion of digitalization in the government sector has a very strong influence on the shadow economy, and digital payment tools used by individuals also have a strong negative effect on the level of the shadow economy because it encourages the cashless economy, and fraud and illegal activities in terms of currency can be easily caught with the help of technology. Anand and Kumar (2016) stated that in 2014, Indian Prime Minister Narendra Modi imposed a ban on India's biggest currency to reduce corruption and reduce the cash in hands which people used for bribery and tax evasion, and to encourage people to move towards digitalization. According to the data after the ban digital adoption index of India increased from 44% in 2014 to 51% in 2016 (World Development Report, 2016), also percentage of made or received payments was also increased from 22% in 2014 to 31% in 2019 (Global Findex Index) that eventually reduce the shadow economy from 21% in 2014 to 19% in 2019 (Elgin et al. 2021). So, in this context, digital payments are considered very helpful in fighting against the informal sector. But according to this study, the expansion of individuals using the internet has a positive effect, especially in countries where the penetration of the informal sector is high because, in that region, the economy supports the informal sector more. This study also finds a negative relation between the income level of individuals and the ethical behavior of firms in the shadow economy. This suggests that economies with more development and ethics tend to have less participation in the informal economy because they have good tax morals; they do everything according to the rules & regulations. The findings of this study also state that the corruption level is high; then the shadow economy also gets high because corruption is also a part of the shadow economy, and corruption are complements (Dreher & Schneider, 2010). The indicators used for institutional quality like regulatory quality and government effectiveness in 2ndmodel, put negative influence on the shadow economy this implies that along with the digitalization a country should also make their institutions strong and should work on the governance because if the institutions are strong and the rules or regulations are unbiased the people will trust more on the public sector of the country then they will encourages to participate in the official or formal sector of the economy then eventually shadow economy will reduced which is the big hinder in the development & growth of any country, but the rule of law is having an insignificant impact in the results. The strength of investor protection has a negative and very strong impact on the shadow economy. In

countries where the size of the shadow economy as a percentage of GDP is large, it means that if we protect investors in regions like this, the shadow economy will reduce significantly. So, this study puts emphasis on the adoption of digitalization, as well as digital payments, along with institutional quality. This study highlights the importance of policy making and implementation of them, public sector should make policies that can encourage people to trust the public sector so that the informal sector can be reduced. This analysis captures multidimensionality, which is very new and novel as per my knowledge.

Policy recommendations

The government should emphasize regulatory quality and efficiency; rules and regulations should be unbiased, fair & transparent so that people can trust the institutions and make their assets and activities formal. The government should adopt digitalization in its workings and also should promote digital financial inclusion in the economy so transactions can be transparent, and the economy moves from cash to e-accounts; then the checks and balances will get easier through digitalization. The government should promote incentive-based programs in which they should give tax relief, promote ease of doing business, and also provide a simplified registration process so people will not discourage to keep their assets filed because of high accountability. Internet usage has mixed effects, so the government should also regulate its usage of it so that illicit activities can be controlled.

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