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Fiscal Decentralization and Public Infrastructure Maintenance Expenditures: A Cross-Country Panel Analysis

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Abstract

The often-forgotten dimension of public infrastructure finance is the difficulty of maintaining a proper level of infrastructure in good condition. Given that increasing responsibilities for public infrastructure investment have been decentralized worldwide, this study investigates the impact of fiscal and political decentralization on infrastructure maintenance expenditures using a panel cross-country analysis from 1995 to 2020. To address the endogeneity concerns and estimate the causal impact of fiscal decentralization (revenue and expenditure decentralization), this research uses the Geographic Fragmentation Index (GFI) and country size as two valid instrumental variables for fiscal decentralization. Our main results confirm that fiscal and political decentralization measures are found to increase public spending on road maintenance. The findings are robust to alternative model specifications and different measures of fiscal and political decentralization.

Keywords: fiscal decentralization, road infrastructure maintenance, cross-country analysis

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Introduction

Infrastructure provides the foundation for modern economies and societies. From roads to water, to broadband, to the power grid, infrastructure enables the economy and society to function. A robust, efficient, and well-maintained public infrastructure system is critical to support and sustain the nation's economy, improve quality of life, and strengthen global competitiveness. However, sufficiently investing in new public infrastructure and adequately maintaining existing public infrastructure is one of the most challenging dimensions of public financial management at all levels of government and across countries, both developed and developing.

Neglecting property maintenance leads to a decline in infrastructure condition and service. Despite its importance for service delivery and economic development, there are multiple political economy explanations for the underspending on the proper level of infrastructure maintenance. This paper examines the role of decentralized governance in ameliorating or deepening the universally observed problems related to inadequate levels of infrastructure maintenance. Across the globe, there has been a great decentralization movement in the public infrastructure field (Frank and Martinez-Vazquez, 2016). Currently, subnational governments play an important and growing role in the provision of public infrastructure services. According to Frank and Martinez-Vazquez (2016), in the OECD countries, subnational governments account for an average of 63% of public fixed capital formation and about 40% in developing countries. The main research question we address in this paper is: *How has increased decentralization worldwide affected the proper maintenance of public infrastructure?* The advantage of decentralization, at least in theory, is that it can lead to more efficient outcomes because the preferences and needs of subnational governments in terms of infrastructure development are generally diverse, and therefore can be better addressed through decentralized

governance, as opposed to uniform provision from the central government. Generally, the devolution of decision-making powers from central governments to subnational governments is expected to have a positive effect on infrastructure maintenance because it not only allows governments to better adapt to local infrastructure preferences, but it also brings more direct accountability mechanisms to the citizen-residents and firms. In addition, subnational government fiscal competition can generate additional incentives for subnational governments to increase infrastructure maintenance spending and improve infrastructure quality to attract new residents and businesses (Keen and Marchand 1997). On the other hand, decentralized governance may face challenges related to multi-level infrastructure coordination, weak subnational infrastructure planning and management capacity, and constrained subnational financial resources. Empirically, there is a rich literature of research on infrastructure investment across countries. However, there is a paucity of cross-country research on the effects of decentralized governance on infrastructure maintenance (Martinez-Vazquez, Lago-Penas, and Sacchi, 2017). This is the gap in the literature this paper attempts to help fulfill.

In this paper, we build a simplified theoretical framework to explain how decentralization may affect infrastructure maintenance. Empirically, our research employs a large panel data set of countries to test the role of decentralized governance (fiscal and political decentralization) on the level of public road infrastructure maintenance, after controlling for other institutional variables that may be expected to play a role based on the existing literature on this subject. Our main finding is that overall fiscal or political decentralization largely increases road infrastructure maintenance expenditures. These key results are robust to different specifications of the main explanatory variables and alternate estimation methods.

The rest of the paper is organized as follows. Section 2 provides a literature review of decentralization and infrastructure as well as the general determinants of infrastructure investment and performance. Section 3 develops a simple theoretical framework. Section 4 discusses the data, variables, and research methods. We present the main empirical results in Section 5 and robustness checks in Section 6. The final section concludes with discussion and policy implications.

Review of Relevant Literature

Previous Studies on Fiscal Decentralization and Infrastructure Finance

There is a limited number of empirical studies on the effects of decentralization on infrastructure investment, composition, and performance (Martinez-Vazquez et al. 2017). Most of the existing empirical studies on the effect of fiscal decentralization on infrastructure have focused on a cross-country setting. In 1994, the World Bank released the *World Development Report 1994—Infrastructure for Development*. The main messages of this report were that infrastructure provides public goods of a localized nature and decentralization offers a good opportunity to improve the provision of infrastructure. Based on a review of infrastructure development in 42 developing countries, that report found that decentralized road maintenance leads to lower backlogs and costs, and better road conditions. Similarly, decentralized governance results in better performance and maintenance in the water and sanitation sectors than would be the case in more centralized settings (World Bank, 1994). Estache and Sinha (1995) explore the impact of fiscal decentralization on per capita infrastructure expenditures from 1970 to 1992 using a panel of two samples of countries (ten industrialized and ten developing countries). These authors find that decentralization matters, increasing total and subnational expenditures on infrastructure services in both developed and developing countries. Estache and Sinha (1995) further compare

the findings between developed and developing countries and conclude that an increase in the degree of decentralization results in larger increases in infrastructure expenditure in developing countries than in industrialized countries. Kappeler and Valila (2008) investigate the role of fiscal decentralization on the composition of public investment in a panel of 10 EU countries during the period 1990–2005. Their results suggest that fiscal decentralization increases economically productive public investment (infrastructure) and reduces economically less productive investment (recreational facilities).

More recently, Viñuela (2015) utilized an expanded cross-country sample of 87 developed and developing countries from 1990 to 2010 to analyze the effect of fiscal decentralization on the quantity and quality of public infrastructure. The author concludes that fiscal decentralization is positively associated with the quality of infrastructure but is negatively associated with aggregate levels of fixed capital formation. Viñuela (2015) suggests that lower levels of capital investment may be reflective of efficiency gains or due to the potentially insufficient access to financing and stable infrastructure funding sources for subnational governments. Kappeler, Solé-Ollé, Stephan, and Valila (2013) examine the effect of revenue decentralization on regional infrastructure investment using panel data covering 20 European countries over the period 1990-2009. The authors find regional infrastructure investment generally increases with decentralization, and that this impact decreases with the level of (capital) transfer dependence by subnational governments.

Several studies have focused on examining the effect of fiscal decentralization on infrastructure in specific countries. Faguet (2004) examines whether decentralization increases the responsiveness of public investment to local needs using a unique database from Bolivia. The author finds that decentralization significantly changed public investment patterns in Bolivia. In particular, decentralization led to higher investment in human capital and social services because

the poorest regions of the country chose projects according to their greatest needs. Esteller and Solé-Ollé (2005) use a unique Spanish database (at the NUTS-3 level) to explore the effect of decentralization reforms on road and educational infrastructure investment and capital stock. They find that road and educational investments made by subnational governments in Spain are much more sensitive to changes in output, users, and costs than those investments made by the central government. Escaleras and Calcagno (2018) analyze the role of fiscal decentralization on the quality of highway infrastructure in the US 50 states. Based on generalized linear model estimation on state data from 1992 to 2012, the authors find evidence that fiscal decentralization improves the quality of state highways and bridges.

Previous Studies on the Determinants of Infrastructure Investment and Quality

There are three main strands of literature on the determinants of infrastructure investment and quality. Among the first strand of related literature, many scholars find the quality of government institutions is an important factor in affecting the quantity and quality of infrastructure investment across countries (e.g., Tanzi and Davoodi, 1997; Keefe and Knack, 2007; Kyriacou et al., 2015; Grigoli and Mills, 2014). For instance, Tanzi and Davoodi (1997) provide anecdotal evidence on the negative effects of corruption on transport infrastructure, which captures the quality of transportation through an examination of paved roads in good condition and railway diesels in use. Keefer and Knack (2007) show public infrastructure investment is dramatically higher in countries with low-quality governance and limited political checks and balances, or no competitive elections. They suggest, in line with previous findings on the role of corruption, that these unaccountable governments use public investment as a vehicle to increase their rent-seeking activities. Grigoli and Mills (2014) analyze the effect of institutional quality (corruption, bureaucracy quality, and law and order) on the volatility and

quality of public investment using a panel dataset for 144 countries over the period 1984–2008. They find lower quality of governance increases the volatility of public investment and reduces the quality of infrastructure investment (measured by paved roads, electric power system losses as a percentage of total power outputs, and faults per 100 main fixed lines per year).

Regarding the second strand of literature, studies on the political determinants of the quantity and quality of infrastructure investment have increased in recent decades (e.g., Van Dalen and Swank, 1996; Vergne, 2009; Gupta et al. 2016). For example, Gupta et al. (2016) find that left-wing governments are associated with a higher level of public infrastructure expenditures. By contrast, Van Dalen and Swank (1996) conclude right-wing governments spend more on public infrastructure because right-wing governments spend less on health care and social transfer and have more fiscal space for public investment. Vergne (2009) points out that governments tend to lower public infrastructure investment during election years to compensate for higher current expenditures on wages and subsidies. Crain and Oakley (1995) focus specifically on the political process of infrastructure decisions in the American states. They find that the stability of party control in the legislature is negatively related to the state's public capital and that volatility of the state electorate is positively correlated with the state's public capital. Goeminne and Smolders (2013) use data for 307 out of 308 Flemish municipalities covering the period 1996–2009 to analyze the political determinants of local public infrastructure investment. Their results reveal that political fragmentation (measured as the presence of multiple competing parties in the local government) positively affects the level of local public infrastructure investment.

Concerning the third strand of literature, public finance scholars have increasingly analyzed the economic and fiscal determinants (fiscal conditions, fiscal rules, and fiscal capacity) of public infrastructure investment and quality (Bumgarner, Martinez-Vazquez, and Sjoquist, 1991;

Walden and Eryuruk, 2012; Deller et al., 2013; Chen, 2016; Tong et al., 2018; Wijsman and Crombez, 2021). For example, Bumgarner et al. (1991), using a cross-sectional expenditure dataset collected from 42 city budgets from 1978 to 1979, find that fiscally distressed cities engage in significantly lower capital and maintenance expenditures relative to expenditures on non-capital expenditures. Similarly, Chen (2016) examines how the deteriorating fiscal conditions of state governments affect state highway capital and maintenance spending. Based on a panel data analysis of 48 states in the US, from 1999 to 2009, his empirical findings give support to the fiscal stress hypothesis that state highway maintenance spending is negatively affected by the lagged values of state fiscal stress. Costas-Perez et al. (2011) document a disproportional fall of investment at the subnational level in Spain during fiscal adjustment periods.

Wijsman and Crombez (2021) analyze the relationship between fiscal rules and public investment using European countries' panel data covering the 1997-2016 period. The authors conclude that stringent fiscal rules decrease the level of the country's public investment. Deller et al. (2013) empirically test the relationship between American state-level tax expenditure limits (TEL) restrictiveness and state highway bridge conditions for 50 states from 1992 to 2009. They conclude that more restrictive TELs lead to an increase in the percentage of bridges deemed functionally obsolete. Tong et al. (2018) investigate the patterns and drivers of capital investment in urban infrastructure (CIUI) in China from the period of 2000 to 2008. These authors find that Chinese cities with higher fiscal capacity and a larger share of the tertiary economy made higher levels of infrastructure investment.

A sizable number of researchers have explored the other determinants of infrastructure spending and quality such as natural resource dependence. Tadadjeu, Ningaye, and Njangang (2022)

analyze the effect of natural resource dependence on infrastructure quality. They find that the presence of natural resources lowers the overall quality of infrastructure, including the quality of various types of infrastructure such as roads, ports, railroads, airports, and the quality of electricity supply.

Compared with the abundant research on the determinants of infrastructure investment and quality, the maintenance of infrastructure has received less attention in the literature. Blazey, Gonguet, and Stokoe (2020) point out the four reasons why infrastructure maintenance has often been neglected: political economy reasons (infrastructure maintenance expenditures are not politically favored—there are no ribbon cuttings for pothole repairs), fiscal reasons (maintenance expenditures are often viewed as discretionary spending and can be easily cut during periods of fiscal stress), institutional reasons (separate agencies prepare capital investment and maintenance without an integrated medium-term perspective), and capacity reasons (lack of up-to-date information on assessing the condition of capital assets and maintenance needs and weak capacity in life-cycle asset management) (pp. 265-266). Empirically, a few studies have investigated the determinants of infrastructure maintenance spending. Walden and Eryuruk (2012) examine county highway capital and maintenance spending in North Carolina during the period 1990–2005 and compare three models of public spending: the median voter model, the special interest model, and the political model. They find that the employment market condition and the county’s relative vote in the most recent election for the state’s dominant political party are the strong determinants of county highway capital spending. County highway maintenance spending is found to be positively affected by median household income, vehicles per capita, and road size, while they found no evidence of political influence factors. As we mentioned earlier, Bumgarner et al. (1991) and Chen (2016) find that fiscal stress reduces state and local

maintenance expenditures. Kim (2022) employs a panel data analysis covering 47 states from 1995 to 2009 to investigate the effects of politics on state highway routine maintenance spending. The author confirms that political election incentive and divided governments are the key factors delaying state highway routine maintenance spending. It should be noted that to the best of our knowledge, to date, there is a lack of an empirical analysis of the determinants of infrastructure maintenance at the country level.

In summary, despite the plentiful evidence in the related literature, previous studies are generally limited in at least three respects: (1) the literature on infrastructure finance has largely neglected the analysis of public expenditure in infrastructure maintenance, (2) evidence for the effect of both fiscal and political decentralization on infrastructure maintenance is scarce, and (3) potential endogeneity problems are prevalent in existing studies. This research addresses these limitations by applying instrumental variable (IV) estimation and system GMM to a longitudinal data set of cross-countries to scrutinize the effect of fiscal and political decentralization on infrastructure maintenance.

A Simplified Theoretical Framework

In this section, we build a simplified theoretical framework to explain how decentralization may affect infrastructure maintenance. In general, decentralization means the devolution of decision-making powers (e.g., political, fiscal, administrative) from central governments to subnational governments (Martinez-Vazquez et al., p. 1096). Oates' (1972) classical decentralization theorem states that in the presence of heterogeneous preferences and needs across jurisdictions and localities, the provision of public services in a decentralized governance structure will generally increase citizen welfare and improve public service performance (barring large economies of scale and externalities).

Following the logic of Oates' decentralization theory, decentralized governance offers significant advantages for improved infrastructure maintenance. First, decentralization moves infrastructure maintenance decision-making and project implementation closer to localities and enhances the ability of governments to reflect and match local infrastructure maintenance needs. Central governments are typically far away from localities. The centralized decision on infrastructure maintenance may not allow for variations in local infrastructure preferences. By contrast, local governments are closer to citizens. Local government officials possess information advantages about the usage, depreciation, needs, and condition of local infrastructure. Hence, local governments have more knowledge and flexibility in accommodating citizens' preferences for routine infrastructure maintenance and repair (Viñuela, 2016). Second, decentralization improves the incentive of local government officials to adequately maintain public infrastructure in good condition. When the infrastructure responsibilities are more localized, local governments have strong incentives for efficiently operating and maintaining infrastructure. This is because infrastructure maintenance decisions will be closer to those who benefit more from improved infrastructure quality (Fox and Murray, 2016). Furthermore, as Tiebout (1956) contends, citizens can vote with their feet and sort themselves into taste-homogeneous jurisdictions where their preferences are maximized. From this theoretical perspective, greater fiscal autonomy in subnational governments fosters competition among jurisdictions to attract citizens and business investors. A carefully maintained public infrastructure system is of critical importance to ensure economic growth and quality of life. Therefore, inter-jurisdictional competition can increase the responsiveness of local governments to maintain proper levels of infrastructure (Keen and Marchand, 1997). Third, decentralization facilitates citizen participation and monitoring of infrastructure maintenance and ensures greater

direct accountability mechanisms enjoyed by subnational governments. In reality, infrastructure maintenance funding is determined through the political process in competition with other public service demands. Decentralized governance can strengthen accountability in infrastructure maintenance by involving local communities and citizens in monitoring infrastructure conditions and ensuring funding for routine maintenance is not neglected.

Despite the stated benefits of decentralization for maintaining infrastructure, there are also challenges of decentralized governance facing the provision of infrastructure. First, decentralized governments may pursue the tactic of implementing low maintenance in the hope that central governments will intervene and replace the obsolete infrastructure. For example, local infrastructure financed by the central governments with capital grants and other means may not be properly maintained by subnational governments because local governments do not take ownership of centrally financed projects, or gamble that the deteriorated improperly maintained infrastructure will be eventually replaced with central government funds. Subnational governments also may be more prone than central governments to underestimate and underbudget infrastructure maintenance expenditure needs. And generally, they are more exposed to budgetary pressures because of their lower ability to borrow and generate increased tax revenues. Second, infrastructure maintenance may generate spillovers to other geographical areas and jurisdictions. Decentralized governance for infrastructure maintenance requires coordination and cooperation across levels of governments. However, in the absence of sound vertical and horizontal coordination across levels of government, decentralization may exacerbate coordination failures and discourage the prioritization of routine infrastructure maintenance needs (Viñuela, 2016). Third, across countries, it is a common practice to decentralize infrastructure maintenance responsibility to subnational governments without the

corresponding funding support from the central governments. Subnational governments, especially in developing countries may lack the financial resources and asset management capacity to properly maintain infrastructure (Pierskalla and Sacks, 2018). In addition, local policymakers may have little incentive to allocate sufficient funding toward infrastructure maintenance because the negative consequences of deferred maintenance are not immediately visible to the public (Fox and Murray, 2016; Chen, 2016). Last, infrastructure maintenance expenditure represents an opportunity for rent extraction through the maintenance contracting process (Fox and Murray, 2016). In presence of weak government institutions, decentralization may increase opportunities for corruption and divert infrastructure maintenance funding to other uses (creating waste and inefficiencies).

In sum, following the two contrasting lines of argument, in this paper, we hypothesize that the positive efficiency gains and benefits of decentralization are large enough to offset the negative effects of decentralization, especially in developed countries with sounder institutional development. Therefore, our basic research hypothesis is that greater subnational fiscal and political autonomy is expected to enhance the proper maintenance of public infrastructure due to the main advantages of proximity and better information about infrastructure conditions and needs, and closer accountability mechanisms in maintaining infrastructure in good shape. We further provide empirical evidence in support of this hypothesis in the following sections.

Empirical Analysis: Data and Variables

In this section, we present a quantitative analysis to test our research hypothesis. For such purpose, we investigate whether the level of fiscal decentralization of a country is a significant explanatory variable of public infrastructure maintenance expenditure, after controlling for the country's different economic, socio-demographic, institutional, and fiscal features.

Dependent Variables—Road Infrastructure Maintenance Expenditures

We construct a comprehensive panel (time-series and cross-country) of 42 countries from 1995 to 2020. Appendix Table 1 provides the list of countries. The actual sample used in our model estimations varies depending on the specification and variables used due to differing data availability. Infrastructure maintenance outlay consists of expenditures associated with infrastructure systems preservation, rehabilitation, and restoration. It differs from capital outlay which includes expenditures associated with infrastructure improvements and construction. Infrastructure capital and maintenance expenditures are different types of expenditure categories and usually receive different levels of public visibility and attention (Walden and Eryuruk, 2012).

Appendix Table 1. Sample of Countries

Country	Country
Albania	Korea
Armenia	Latvia
Austria	Lithuania
Azerbaijan	Luxembourg
Belgium	Malta
Bulgaria	Mexico
Canada	Moldova
Chile	Netherlands
Croatia	New Zealand
Czech Republic	Norway
Denmark	Poland
Estonia	Portugal
Finland	Romania
France	Serbia, Republic of
Georgia	Slovak Republic
Hungary	Slovenia
Iceland	Sweden
India	Switzerland
Ireland	Turkey
Italy	United Kingdom
Japan	United States

Because of scarce general data availability of maintenance expenditures, this research uses two dependent variables to measure road infrastructure maintenance: road maintenance expenditure real per capita and the share of road maintenance expenditure in total road expenditure.

Comparable data on public infrastructure maintenance are still not available for many countries, or in many cases, there is only information for transportation infrastructure for a limited number of years. For those reasons, we use the Transport Statistics database, which comprises statistics collected by the International Transport Forum (ITF) at the OECD on annual investment and maintenance spending on transport infrastructures since 1995 for about 42 countries.

Key Explanatory Variables—Fiscal and Political Decentralization

Our main explanatory variables are the aggregate measures of fiscal decentralization. Following previous studies (e.g., Shrestha, Martinez-Vazquez, and Hankla, 2023; Viñuela, 2016), the degree of fiscal decentralization is measured by revenue decentralization and expenditure decentralization. Revenue decentralization captures the share of revenue of subnational governments (local and regional) as a share of general government revenue. Similarly, expenditure decentralization captures the share of expenditure of subnational governments (local and regional) as a share of general government expenditure. The data source for revenue and expenditure decentralization measures comes from the International Monetary Fund (IMF)'s Government Finance Statistics (GFS). It is worth noting that the GFS data on our revenue and expenditure decentralization measures are not without limitations. The key weakness of these measures is the failure to account for the multiple dimensions of decentralization, especially the level of autonomy exercised by subnational governments (Martinez-Vazquez et al., 2017).

Despite this key limitation, the IMF's GFS data source has the significant advantage of allowing

a comparison of subnational government expenditures and revenues for a sample of industrialized and developing countries.

In light of the above considerations, we also utilize the regional authority index (RAI) as an alternative fiscal decentralization measure. The RAI measures were developed by Hooghe et al. (2016) to capture the authority of regional governments to exercise explicit rules that are not necessarily written in constitutions and other legislation. RAI is composed of two core elements—self-rule and shared rule. Self-rule captures the capacity of regional governments to function autonomously under their jurisdictions. It assesses the five different institutional dimensions: institutional depth, policy scope, fiscal autonomy, borrowing autonomy, and representation. Meanwhile, shared rule measures the co-dependence of regional governments to shape national policies. It captures the influence of subnational governments have over central governments' decision-making and consists of four components: normal legislation, executive control, fiscal control, and constitutional reform (Hooghe et al., 2016).

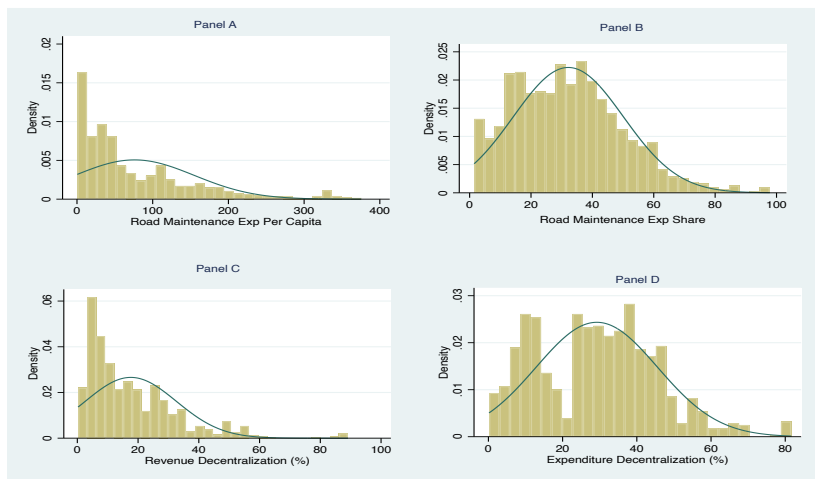
There are many dimensions to decentralization and the fiscal aspect is only one of them. Following Hankla et al. (2019), political decentralization variable is measured as a dummy variable to capture whether countries hold independent local elections. This variable captures the strength of accountability of subnational officials to their residents.

Figure 1 plots the distributions of road infrastructure maintenance and fiscal decentralization variables across countries. As seen in Figure 1, road infrastructure maintenance variables vary widely across countries. The share of road maintenance spending in total road spending ranges from 1.5 % (Azerbaijan 2010) to 97.82% (Latvia in 1998), with a mean value of 32.17%.

Similarly, the size of road maintenance spending in real per capita ranges from \$ 0.44 (Turkey in 1995) to \$ 375 (Norway in 2005), with an average value of \$76. Regarding our fiscal

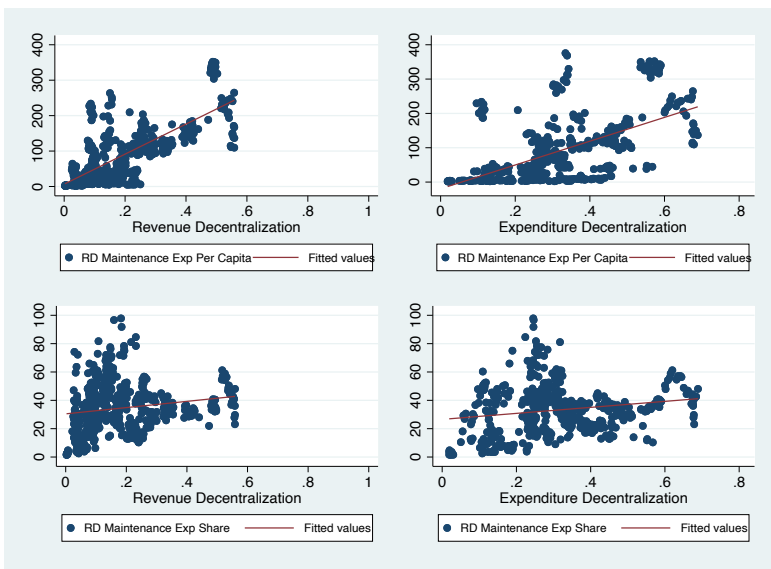
decentralization measures, revenue decentralization ranges from 0.3 % (Afghanistan in 2014) to 89% (United Arab Emirates in 2013), with an average of 18%. Expenditure decentralization ranges from 0.2 % (Afghanistan in 2014) to 82% (United Arab Emirates in 2013), with an average of 29%. Figure 2 presents the scatterplots between fiscal decentralization and road infrastructure maintenance across our sample.

Figure 1. Distribution of Road Maintenance Expenditures and Fiscal Decentralization Measures



Data source: IMF GFS and ITF.

Figure 2. Scatterplots Between Fiscal Decentralization and Road Infrastructure Maintenance



Control Variables

We control for a set of additional covariates that are expected to also affect the provision of infrastructure services and maintenance expenditures. The political controls include political regime and political ideology. We use the Polity-IV data to measure the presence of democracy or autocracy. It ranges from -10 (autocracy) to +10 (democracy). Political ideology matters in infrastructure decision-making since the previous literature generally has found that infrastructure investments are higher under left-leaning administrations (e.g., Gupta et al. 2016). To measure government political ideology, we employ the largest government party orientation (1=Right, 2=Center, 3=Left) from the Database of Political Institutions (DPI). DPI provides annual information about the party composition and political orientation of governments in 177 countries for over the 1975 to 2020 period.

Several past studies also provide strong evidence for social and economic development as a major factor in infrastructure development. To account for the effect of economic development, we use annual real GDP per capita. The covariates also contain three demographic controls—urbanization, population density, and population growth. Rapid urbanization, population growth, and higher population density are expected to increase demands for infrastructure services. The extant infrastructure literature also suggests that beyond the level of decentralization the overall level of institutional quality and degree of accountability matter in infrastructure decision-making. Thus, we use voice and accountability, control of corruption, rule of law, and political stability index from the Worldwide Governance Indicators (WGI).

Empirical Methodology: Panel Instrumental Variable Estimation

There is an important concern in empirical modeling that fiscal decentralization measures might be subject to endogeneity (e.g., Martinez-Vazquez et al., 2017). The endogeneity concern could

arise because of the simultaneous effects of omitted variables on both fiscal decentralization and our endogenous variables. For example, an increase in infrastructure maintenance expenditure could result in a government response for fiscal decentralizing further as subnational governments could better match the infrastructure needs. Following the most recent study (Canavire-Bacarreza, Martinez-Vazquez, and Yedgenov, 2020), this research uses a panel instrumental variable (IV) estimation (Two-Stage Least Squares) as the main empirical strategy to address the endogeneity concern between fiscal decentralization and infrastructure maintenance. Specifically, the estimation of the impact of fiscal decentralization on public infrastructure maintenance expenditure is done in two stages:

First stage:

$$FD_{it} = \alpha_0 + \gamma X_{it} + \delta Z_{it} + \lambda_i + q_t + \varepsilon_{it} \quad (1)$$

Second stage:

$$Y_{it} = \rho_0 + \eta \widehat{FD}_{it} + \theta X_{it} + \lambda_i + q_t + \varepsilon_{it} \quad (2)$$

Where FD_{it} represents our fiscal decentralization variables on both revenue and expenditure sides in country i in year t ., while \widehat{FD}_{it} is the predicted values from the first stage equation. Y_{it} represents one of two infrastructure maintenance variables—the level and share of infrastructure maintenance activities (maintenance expenditure) for country i during year t ; X_{it} stands for the matrix containing a set of country control variables; Z_{it} is the set of country-specific geography instrumental variables— the Geographic Fragmentation Index (GFI) and country size; λ_i stands for country fixed characteristics that do not change over time (time-invariant factors); and q_t captures time effects common to all countries. We cluster standard

errors at the country level. Our primary interest is in the coefficient η , which represents the exogenous causal effect of fiscal decentralization on infrastructure maintenance.

Following previous studies (e.g., Shrestha, et al., 2023; Canavire-Bacarreza, Martinez-Vazquez, and Yedgenov, 2017), this research utilizes two different instrument variables for fiscal decentralization. The first instrumental variable is the “Geographic Fragmentation Index (GFI)”, which was developed index by Canavire-Bacarreza et al. 2017. The GFI measures the weighted probability that two randomly chosen individuals do not live in similar altitude zones with the weight matrix derived from the average distance between altitudes. It is calculated as follows:

$$GFI = 1 - \sum_{j=1}^J \sum_{i=1}^N (w_{ij} \frac{n_i}{N})^2 \quad (3)$$

Where $\frac{n_i}{N}$ is the share of the population by elevation and w_{ij} measures the distance between altitude i and altitude j . The value of GFI ranges from the lowest point of 0 (all individuals residing in the same altitude zone) to the highest point of 1 (all individuals residing in different altitude zones). The GFI data were acquired from NASA’s Earth Observing System Data and Information System (EOSDIS) hosted by the Center for International Earth Science Information Network (CIESIN) at Columbia University.¹

The second instrumental variable is the geographical size of a country measured by the land area of a country. Scholars such as Arzaghi and Henderson (2005) and Jilek (2018) argue the geographical size of a country is an important and exogenous determinant for country

¹ The GFI data were available for the years 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, and 2020. Given the low level of variation in the GFI over time, we assigned the value of 1995 to the years of 1996 to 1999, the value of 2000 to the years of 2001 to 2004, the value of 2005 to the years of 2006 to 2009, and the values of 2010 to the years of 2011 to 2014, and the values of 2015 to the years of 2016 to 2019.

decentralization. Table 1 shows the summary statistics for all variables used in the empirical estimation. The variable descriptions and sources are listed in Appendix Table 2.

Table 1. Summary Statistics

Variable	N	Mean	SD	Min	Max
Road Maintenance Spending Real Per Capita	945	76.03	78.79	0.44	375
Road Maintenance Share (%)	941	32.17	17.94	1.5	97.82
Revenue Decentralization (%)	1005	18	15	0.3	89
Expenditure Decentralization (%)	995	29	16	0.2	82
Regional Authority Index	1005	11.5	10.02	0	37.72
Pop Density	1092	129	180	1.51	1610
Political Decentralization Dummy	988	0.86	0.341	0	1
Local Government Index	968	0.817	0.296	0	0.996
Pop Growth %	1092	0.72	1.27	-3.85	18.13
Urbanization %	1092	65.5	18.3	10.89	98.1
Land Surface Area	1092	1,131,741	2,780,797	320	16,389,950
GFI Index	1092	35.1	7.51	8.34	47.52
Political Regimes (Polity2)	1005	6.66	5.41	-9	10
Political Ideology	945	1.9	0.92	1	3
GDP Per Capita 2015	1092	19395	21041	231	112417
Voice and Accountability Index	1092	0.41	0.96	-2.23	1.80
Political Stability Index	1092	0.18	0.92	-2.80	1.76
Rule of Law Index	1092	0.37	1.05	-1.92	2.12
Control of Corruption Index	1092	0.35	1.09	-1.67	2.46

Appendix Table 2. Description and Sources of Variables

Variable	Description	Source
Road maintenance size	Real per capita government road maintenance expenditure	International Transportation Forum (ITF)
Road maintenance share	Share of road maintenance expenditure in total road spending	ITF
Expenditure decentralization	Share of subnational expenditure in total government expenditure	IMF GFS
Revenue decentralization	Share of subnational revenue in total government revenue	IMF GFS
RAI	Regional Authority Index	Hooghe (2021)
Political Decentralization	Dummy variable whether countries have local elections	Hankla et al. (2019)
Local Government Index	Extent to which elected local governments can operate without political interference from upper-level governments.	V-Dem Dataset
GFI	Geographic Fragmentation Index	Canavire-Bacarreza et al. (2016)
Country size	Log of total country land surface area	Canavire-Bacarreza et al. (2016)
GDP per capita	Real GDP per capita 2015 constant value	WDI
Pop density	Population per square mile	WDI
Pop growth	Annual population growth rate	WDI
Urbanization	Share of population living in urban area	WDI
Political Regime	Regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy)	Polity IV Project
Political ideology	The largest government party orientation (1=Right, 2=Center, 3=Left)	Database of Political Institutions
Voice and Accountability Index	Perceptions of the extent to which a country's citizens can participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	WGI
Political Stability Index	Perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.	WGI
Rule of Law Index	Perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence	WGI
Control of Corruption Index	Perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, & "capture" of the state by elites and private interests	WGI

Empirical Results

Baseline Results of Fiscal and Political Decentralization

As it was argued above, road maintenance expenditures are distinct from road capital spending, and they are a critical link in the provision of public infrastructure services. Table 2 provides the empirical results for the linkage between fiscal decentralization and road maintenance activities.² Recall that the road sector is the only public infrastructure sector in which maintenance expenditure data are consistently available across countries. The estimates show the baseline panel IV results. The key independent variable in Models 1 and 2 is revenue decentralization. Models 3 and 4 use expenditure decentralization as the key independent variable. Across all four models, revenue and expenditure decentralization measures display positive coefficients, but our fiscal decentralization variables are only statistically significant in the models of the level of road maintenance expenditure. None of them are statistically significant in the models of the share of road maintenance expenditures. In Model 1, the variable of revenue decentralization displays a coefficient of 1.582 at the 5 percent significance level. This indicates that all else equal, a one-point increase in the share of revenue implemented by the subnational level is associated with an increase of 6.56 percent change in the size of real per capita road maintenance spending.³ In a similar vein, the variable of expenditure decentralization displays a coefficient of 1.818 at the 1 percent significance level. This indicates that all else equal, a one-point increase in the share of expenditure implemented by the subnational level is associated with an increase of 9.22 percent

² The first stage results are provided in the Appendix Table 3.

³ Our dependent variable is in the log-transformation format. So, the calculation of 6.56 is based on $(\exp(1.582)-1) \times 100\%$. The calculation of 9.22 is based on $(\exp(1.818)-1) \times 100\%$

change in the size of real per capita road maintenance spending. These estimated effect sizes are economically significant.

A couple of our control variables are statistically significant in the models of road maintenance. Countries with a higher level of real GDP per capita and democratic regimes experience larger levels of road maintenance spending. At the same time, countries with democratic regimes and stronger institutional quality (voice and accountability index and political stability) are found to increase the size of road maintenance spending. By contrast, population density is found to reduce the share and level of road maintenance spending and higher population growth is associated with less road maintenance expenditures. This may be because higher population density and large population growth stimulate more demand for road capital spending with less focus on maintenance.

Table 2. Fiscal Decentralization and Road Maintenance Expenditures (Country Surface Land Area and GFI as IVs)

Variables	Model 1	Model 2	Model 3	Model 4
	Road Maintenance Spending Per Capita (2 nd Stage)	Road Maintenance Spending Share (%) (2 nd Stage)	Road Maintenance Spending Per Capita (2 nd Stage)	Road Maintenance Spending Share (%) (2 nd Stage)
Revenue Decentralization	1.582** (0.731)	0.091 (0.683)		
Expenditure Decentralization			1.818*** (0.710)	0.223 (0.545)
GDP Per Capita (Lagged)	1.159*** (0.225)	0.211 (0.198)	0.912*** (0.168)	0.001 (0.190)
Pop Density (Lagged)	-0.0016** (0.0006)	-0.001* (0.0005)	-0.002*** (0.0006)	-0.001** (0.0004)
Pop Growth (Lagged)	-0.210** (0.105)	-0.105 (0.092)	-0.248* (0.140)	-0.135 (0.099)
Urbanization (Lagged)	-0.007 (0.013)	0.0003 (0.007)	-0.002 (0.014)	0.003 (0.007)
Political Regime (Lagged)	0.082*** (0.031)	0.098** (0.038)	0.076** (0.033)	0.090** (0.037)
Political Ideology (Lagged)	0.017 (0.057)	0.042 (0.034)	-0.004 (0.064)	0.026 (0.034)

Voice & Accountability Index (Lagged)	-0.072 (0.358)	0.335 (0.315)	-0.564 (0.501)	0.261 (0.338)
Political Stability Index (Lagged)	0.287* (0.155)	0.121 (0.168)	0.325** (0.163)	0.097 (0.179)
Rule of Law Index (Lagged)	0.782* (0.405)	0.361 (0.423)	1.184*** (0.441)	0.769 (0.497)
Control of Corruption Index (Lagged)	0.013 (0.288)	-0.222 (0.218)	0.193 (0.431)	-0.432 (0.273)
Observations	945	941	945	941
N	42	42	42	42

Note: Country clustered standard errors are in parentheses, stars reflect the significant levels – ***p < 0.01, **p < 0.05, *p < 0.1. Year dummies are included.

We turn to our political decentralization measures. Table 3 provides the empirical results for the linkage between political decentralization and road maintenance activities. Recall that our political decentralization variable is measured as a dummy variable to capture whether countries hold independent local elections based on Hankla et al. (2019). In comparison with fiscal decentration, there is a less endogeneity concern for political decentralization. We use one-year lagged political decentralization variables in our model to address potential endogeneity between political decentralization and infrastructure maintenance. The use of lagged explanatory variables to mitigate the potential issue of simultaneity and reverse causation is a common practice in applied econometrics (e.g., Islam, 2018; Reed, 2015). Further, we utilize a Granger causality test to identify the direction of causality between political decentration and infrastructure maintenance. The results suggest causality runs one way from our political decentralization variable to infrastructure maintenance, but not the other way around.

It is interesting to note political decentralization variable shows a positive and statistically sign in both models. It means compared with democratically centralized countries, political decentralization is associated with increased sizes and shares of road maintenance expenditures.

Several control variables show a statistically coefficient. Countries with higher levels of real GDP per capita and voice and stability index are associated with larger levels of road maintenance spending. By contrast, economic development, population density, and growth are found to reduce the share and level of road maintenance spending.

**Table 3. Political Decentralization and Infrastructure Maintenance
(Panel Two-Way Fixed Effects)**

Variables	Model 1	Model 2
	Ln Road Maintenance Spending Per Capita	Ln Road Maintenance Spending Share
Political Decentralization Dummy (Lagged)	0.033** (0.148)	0.287** (0.078)
Ln GDP Per Capita (Lagged)	0.405** (0.179)	-1.555*** (0.156)
Pop Density (Lagged)	-0.002 (0.003)	-0.006** (0.003)
Pop Growth (Lagged)	-0.061 (0.045)	-0.136*** (0.023)
Urbanization (Lagged)	0.0005 (0.007)	0.008 (0.008)
Political Regime (Lagged)	-0.017 (0.017)	0.009 (0.022)
Political Ideology (Lagged)	0.067** (0.031)	0.073** (0.025)
Voice and Accountability Index (Lagged)	0.672*** (0.107)	0.532*** (0.085)
Political Stability Index (Lagged)	-0.091 (0.107)	-0.118 (0.076)
Rule of Law Index (Lagged)	0.085 (0.218)	-0.042 (0.171)
Control of Corruption Index (Lagged)	-0.054	-0.188*

	(0.145)	(0.096)
Observations	945	941
Number of groups	42	42
R-Squared	0.1605	0.2912

Note: Country clustered standard errors are in parentheses, stars reflect the significant levels – ***p < 0.01, **p < 0.05, *p < 0.1. Year dummies are included

Robustness Checks

We conducted a series of robustness checks for our main baseline results. First, while there is no evidence in the literature on the direct effect of the Geographic Fragmentation Index (GFI) on road infrastructure maintenance expenditures, GFI might have a direct effect on the cost of road maintenance activities and thus not meet the exclusion restriction condition. To address this potential concern, we dropped GFI and only used country surface area as the instrumental variable. The results in Table 4 are consistent with the main findings. Both revenue and expenditure decentralization variables display a positive and statistically significant sign in the models of the size of road infrastructure spending.

Table 4. Fiscal Decentralization and Road Maintenance Expenditures (Country Surface Land Area as IV)

Variables	Model 1	Model 2	Model 3	Model 4
	Road Maintenance Spending Per Capita (2 nd Stage)	Road Maintenance Spending Share (%) (2 nd Stage)	Road Maintenance Spending Per Capita (2 nd Stage)	Road Maintenance Spending Share (%) (2 nd Stage)
Revenue Decentralization	1.599** (0.663)	-0.039 (0.687)		
Expenditure Decentralization			1.929** (0.723)	0.255 (0.547)
GDP Per Capita (Lagged)	1.186*** (0.198)	0.247 (0.194)	1.039*** (0.190)	0.078 (0.196)
Pop Density (Lagged)	-0.0016** (0.0006)	-0.001* (0.0005)	-0.0019** (0.0006)	-0.001** (0.0004)
Pop Growth (Lagged)	-0.227** (0.106)	-0.117 (0.097)	-0.287** (0.143)	-0.157 (0.104)
Urbanization (Lagged)	-0.009 (0.013)	-0.001 (0.007)	-0.006 (0.014)	0.001 (0.007)

Political Regime (Lagged)	0.084*** (0.031)	0.100*** (0.038)	0.079** (0.034)	0.091*** (0.034)
Political Ideology (Lagged)	0.017 (0.057)	-0.005 (0.064)	0.040 (0.034)	0.025 (0.035)
Voice & Accountability Index (Lagged)	0.005 (0.362)	0.370 (0.321)	-0.399 (0.502)	0.358 (0.333)
Political Stability Index (Lagged)	0.281 (0.154)	0.117 (0.167)	0.331** (0.168)	0.094 (0.188)
Rule of Law Index (Lagged)	0.578 (0.417)	0.229 (0.405)	0.768 (0.529)	0.536 (0.467)
Control of Corruption Index (Lagged)	0.119 (0.302)	-0.153 (0.213)	0.412 (0.471)	-0.309 (0.289)
Observations	945	941	945	941
Number of Groups	42	42	42	42

Note: Country clustered standard errors are in parentheses, stars reflect the significant levels – ***p < 0.01, **p < 0.05, *p < 0.1.

Second, there are alternative ways to measure fiscal decentralization. Instead of using revenue and expenditure decentralization indicators, we use—the Regional Authority Index (RAI), which is an alternative measure commonly employed in the decentralization literature. Table 5 shows the empirical results using RAI as our alternative fiscal decentralization measure. It is interesting to note that the variable of RAI displays a positive and statistically significant coefficient sign in both Model 1 of road maintenance expenditure size (the coefficient is 0.015 at the 5 percent significance level) and Model 2 of road maintenance expenditure shares in total road spending (0.029 at the 5 percent significance level). In sum, the overall results for using RAI confirm that fiscal decentralization boosts government spending on road maintenance in both, size (real per capita) and shares (percentage in total road spending).

Table 5. Alternative Fiscal Decentralization Measure (Regional Authority Index) and Infrastructure Maintenance

Variables	Model 1	Model 2
	Road Maintenance Spending Per Capita	Road Maintenance Spending Share
Regional Authority Index (Lagged)	0.015** (0.007)	0.029** (0.012)
GDP Per Capita (Lagged)	1.168*** (0.220)	-1.279*** (0.104)
Pop Density (Lagged)	0.005* (0.002)	-0.0005 (0.001)
Pop Growth (Lagged)	-0.056 (0.058)	-0.113*** (0.026)
Urbanization (Lagged)	0.009 (0.006)	0.0144 (0.008)
Political Regime (Lagged)	0.012 (0.016)	0.019 (0.023)
Political Ideology (Lagged)	0.062* (0.036)	0.060** (0.026)
Voice and Accountability Index (Lagged)	0.405** (0.187)	0.421** (0.164)
Political Stability Index (Lagged)	-0.109 (0.133)	-0.089 (0.079)
Rule of Law Index (Lagged)	0.085 (0.299)	-0.060 (0.185)
Control of Corruption Index (Lagged)	0.034 (0.158)	0.178 (0.109)
Observations	945	941
Number of groups	42	42

Note: Country clustered standard errors are in parentheses, stars reflect the significant levels – ***p < 0.01, **p < 0.05, *p < 0.1.

Third, as an alternative to the instrumental variable method, we use system GMM for panel data.

Table 6 reports the estimation results using a dynamic panel model (system GMM). Across all four models, we find that the lagged (one period) infrastructure maintenance dependent variable is positive and statistically significant in each model. This suggests that current infrastructure maintenance expenditure is affected by last year's infrastructure maintenance spending. In comparison with the main specification, the variable of revenue decentralization displays a

consistently positive coefficient in the model of the size of road maintenance spending although the variable of expenditure decentralization loses its significance in Model 3. It is interesting to note that the positive coefficients of revenue decentralization and expenditure decentralization becomes statistically significant in the models of the share of road maintenance spending (Models 2 and 4).

Table 6. Fiscal Decentralization and Road Maintenance Expenditures (System GMM)

Variables	Model 1	Model 2	Model 3	Model 4
	Road Maintenance Spending Per Capita	Road Maintenance Spending Share (%)	Road Maintenance Spending Per Capita	Road Maintenance Spending Share (%)
Road Maintenance Per Capita One-Year Lag	0.738*** (0.049)	0.720*** (0.048)		
Road Maintenance Share One-Year Lag			0.737*** (0.050)	0.710*** (0.052)
Revenue Decentralization	0.450** (0.188)	0.933** (0.412)		
Expenditure Decentralization			0.054 (0.207)	0.633* (0.385)
GDP Per Capita (Lagged)	0.235** (0.106)	-0.181 (0.132)	0.187* (0.116)	-0.134 (0.121)
Pop Density (Lagged)	0.0001 (0.0005)	0.0002 (0.0004)	0.00003 (0.0003)	-0.0002 (0.0003)
Pop Growth (Lagged)	-0.071* (0.036)	-0.064** (0.027)	-0.096*** (0.032)	-0.050 (0.035)
Urbanization (Lagged)	-0.013** (0.005)	-0.002 (0.003)	-0.006 (0.004)	0.0015 (0.0035)
Political Regime (Lagged)	-0.0005 (0.013)	0.028** (0.012)	0.0003 (0.012)	0.029*** (0.010)
Political Ideology (Lagged)	0.004 (0.020)	0.028** (0.014)	0.014 (0.017)	0.032* (0.016)
Voice and Accountability Index (Lagged)	0.138 (0.074)	0.299* (0.158)	0.112 (0.089)	0.213 (0.171)
Political Stability Index (Lagged)	0.099 (0.050)	0.0123 (0.056)	0.138** (0.064)	0.0122 (0.065)
Rule of Law Index (Lagged)	-0.049 (0.088)	-0.051 (0.113)	-0.017 (0.098)	-0.005 (0.150)
Control of Corruption Index (Lagged)	-0.044 (0.082)	-0.083 (0.079)	0.074 (0.067)	-0.082 (0.086)
Observations	945	941	945	941
Number of Groups	42	42	42	42

Note: Country clustered standard errors are in parentheses, stars reflect the significant levels – ***p < 0.01, **p < 0.05, *p < 0.1

Fourth, we use alternative measures of political decentralization. Following, Shrestha, et al. (2023), we use local government index from the V-Dem dataset as an alternative political decentralization measure. The local government index captures the extent to which elected local governments can operate without political interference from upper-level governments. The lowest score of local government index means countries have no elected local governments. By contrast, a higher score of local government index indicates higher degree of autonomy in elected local governments. Table 7 presents the results of using alternative political decentralization measures. As expected, it is found that a higher value of local government index is consistently associated with a larger size and a higher share of maintenance in total road expenditures.

Table 7. Alternative Political Decentralization Measure and Infrastructure Maintenance

Variables	Model 1	Model 2
	Ln Road Maintenance Spending Per Capita	Ln Road Maintenance Spending Share
Local Government Index (Lagged)	0.540** (0.237)	0.368** (0.084)
Ln GDP Per Capita (Lagged)	0.661** (0.257)	-0.889*** (0.162)
Pop Density (Lagged)	-0.002 (0.002)	-0.003 (0.002)
Pop Growth (Lagged)	-0.056 (0.037)	-0.153*** (0.042)
Urbanization (Lagged)	0.010 (0.008)	0.0023** (0.010)
Political Regime (Lagged)	-0.019 (0.020)	-0.012 (0.022)
Political Ideology (Lagged)	0.067** (0.031)	0.075** (0.026)
Voice and Accountability Index (Lagged)	0.263 (0.210)	0.197 (0.185)
Political Stability Index (Lagged)	-0.077 (0.080)	-0.092 (0.080)

Rule of Law Index (Lagged)	0.245 (0.259)	0.020 (0.230)
Control of Corruption Index (Lagged)	0.006 (0.154)	-0.001 (0.101)
Observations	945	941
Number of groups	42	42
R-Squared	0.1856	0.1599

Note: Country clustered standard errors are in parentheses, stars reflect the significant levels – ***p < 0.01, **p < 0.05, *p < 0.1.

Conclusions and Policy Implications

Does decentralized governance increase public infrastructure maintenance spending? Extant literature has studied the association between fiscal decentralization and various public service outcomes, including the quantity and quality of public infrastructure. However, studies that link government decentralization and infrastructure maintenance are still rare. To fill this gap in the literature, in this research, we empirically test the impact of fiscal and political decenration on the level and share of road infrastructure maintenance across a large sample of developed and developing countries from 1995 to 2020. To address the endogeneity issue stemming from reverse causality and unobserved factors that have plagued numerous previous decentralization studies, in this paper we address the problem by using instrumental variable (IV) estimation, with country size and the GFI index as two instrumental variables for fiscal decentralization. Our main results confirm that revenue and expenditure decentralization strongly increase the levels of public spending on road maintenance. In addition, democratically decentralized countries are found to have larger shares and sizes of road maintenance spending. Our main findings are robust to alternative model specifications and different measures of fiscal and political decentralization.

Our research has important theoretical and policy implications. First, the last two decades have witnessed a burgeoning of the literature examining the impact of fiscal decentralization on a wider array of fiscal and economic issues. However, to the best of our knowledge, to date, no studies have investigated the relationship between decentralized governance and infrastructure maintenance; thus, our study expands the impact of government decentralization literature.

Second, compared with the abundant research on the determinants of infrastructure investment and quality, infrastructure maintenance has received less attention in the literature. This study provides empirical evidence that fiscal and political decentralizations matter for public spending on infrastructure maintenance and complements the literature on capital infrastructure and decentralized governance by examining the decentralization-infrastructure maintenance link.

Third, our findings consistently show decentralization plays a significant role in maintaining public infrastructure. To improve infrastructure maintenance, policymakers may consider the beneficial impact of increasing the fiscal and political autonomy of decentralized governments, granting more authority in self-rule and shared rule exercised by subnational governments within their countries.

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Appendix

Appendix Table 3. The First Stage Regression Results of Fiscal Decentralization and Road Maintenance Expenditures (Panel IV 2SLS Estimation)

Variables	Model 1	Model 2
	Revenue Decentralization	Expenditure Decentralization
Geographic Fragmentation Index	-0.002 (0.003)	-0.0001 (0.003)
Country Size (per 10,000 Square Miles)	0.0003*** (0.0001)	0.0003*** (0.0001)
GDP Per Capita	0.092* (0.056)	0.142*** (0.049)
Pop Density	-0.00005 (0.0001)	0.0002 (0.0002)
Pop Growth	-0.010 (0.023)	-0.025 (0.021)
Urbanization	0.0001 (0.002)	-0.003 (0.002)
Political Regime	0.007 (0.008)	0.004 (0.007)
Political Ideology	0.007 (0.009)	0.008 (0.011)
Voice and Accountability Index	-0.100 (0.072)	0.129* (0.069)
Political Stability Index	0.065* (0.035)	0.020 (0.044)
Rule of Law Index	-0.077 (0.083)	-0.216** (0.095)
Control of Corruption Index	0.058 (0.061)	0.028 (0.065)
Observations	945	941
Number of groups	42	42