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What determines urban resilience against COVID-19: City size or governance capacity?

Zhen Chu [a], Mingwang Cheng [a], Malin Song [b,*]

[a] School of Economics and Management, Tongji University, Shanghai 200092, China
[b] School of Statistics and Applied Mathematics, Anhui University of Finance and Economics, Bengbu, 233030, China

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ABSTRACT

This study analyzed the effects of urban governance and city size on COVID-19 prevention and control measures. Based on real-time data in 276 prefecture-level Chinese cities, we used the ordinary least squares plus robust standard error strategy. It was found that: (1) despite the non-significant effect of city size, urban governance capacity was an important factor affecting the prevention and control of the COVID-19 pandemic; urban governance capacity was particularly significant in the late control of the pandemic, but not significant in the early prevention; for every unit increase of urban governance capacity, the number of recovered COVID-19 cases per capita increased by 2.4%. Moreover, (2) the influence mechanism of anti-pandemic measures in cities could be divided into the workforce, financial, and material effects, and their contribution rates were 26.15%, 32.55%, and 37.20%, respectively; namely, the effective/timely assistance from Chinese central government regarding the workforce, financial, and material resources in key pandemic areas and nationwide played a major role in pandemic control. Additionally, (3) cities with a high level of smart city construction were more capable of enhancing the pandemic prevention and control effect, indicating that smart city construction is conducive to enhanced coping with public crises.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic is a major public health crisis that has had spillover effects on the economy and society and has attracted extensive international attention (Viezzer & Biondi, 2021). As of January 1, 2021, COVID-19 had been reported in 214 countries and territories, causing more than 83.47 million infections and more than 1.82 million deaths[1]. Owing to the high concentration of people and economic activity in cities, they are often the outbreak centers of pandemics. Therefore, more and more scholars have shown concern regarding the COVID-19 pandemic and anti-COVID-19 measures within urban areas (Mansour et al., 2021).

From the perspective of urban resilience, urban emergency governance facing infectious diseases such as COVID-19 has been proven to be incomplete (Acuto, 2020; Jie Chen et al., 2021). To recover the socioeconomic loss caused by the current pandemic and be better prepared for future public health issues, it is necessary to delve into the factors that affect urban resilience in terms of a public health emergency. Unlike natural disasters, which are usually not under human control, the impact of pandemic disasters varies greatly in scale due to different levels of urban preparedness and intervention measures (Hu et al., 2021; Lee et al., 2020). The differences can be attributed to two main factors including urban governance[2] and city size (Jie Chen et al., 2021; Lee et al., 2020). Therefore, an in-depth analysis of these factors could shed light on flaws in urban emergency governance, which further provides a vision for urban resilience improvement concerning

* Corresponding author.
E-mail addresses: 1810240@tongji.edu.cn (Z. Chu), walkercheng@163.com (M. Cheng), songmartin@163.com (M. Song).

1 Data source: https://ncov.dxy.cn/ncovh5/view/pneumonia?scene=1&clicktime=1579582559&enterid=1579582559&from=timeline&isappinstalled=0&entry=menu.

2 In order to seek the sustainable development of urban economy, society and ecology, it integrates the production factors such as capital, land, labor force, technology, information and knowledge in the city to realize the coordinated development of the whole region. In this study, integrated urban governance strategies that involve long-term visioning, pre-event planning, adequate investment in primary healthcare systems, early warning, and coordination of activities of different sectors and stakeholders are more conducive to timely and effective response mechanisms to pandemics and disease outbreaks in cities (Sharifi & Khavarian-Garmsir, 2020).

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pandemics (Scott, 2020; Wang, 2021a).

Given its significance, studies on the COVID-19 prevention and control have focused on both natural drivers (Li et al., 2021) coming from temperature (Liu et al., 2020), humidity (Xu et al., 2020), and wind speed (Coccia, 2020), as well as social drivers (Sannigrahi et al., 2020) such as urban governance and city size (Khavarian-Garmsir et al., 2021). However, these studies provide a series of competing interpretations for the COVID-19 prevention and control. While these factors account for a part of the COVID-19 prevention and control in China, they cannot explain the entire change. The closest papers in this regard are Khavarian-Garmsir et al. (2021) and (Chen et al., 2021), which document the importance of urban governance for timely crisis responses (Kim, 2021; Wang, 2021b) while urban density does not play a major role in the COVID-19 morbidity and mortality rates (Hamidi et al., 2020; J. Wang et al., 2021). Based on their seminal work, we further extend the research on the relationship between urban development and COVID-19 control by introducing a brand-new theoretical framework, expanding the scope of the analysis, and making substantial methodological improvements that allow for precise measurement. More specifically, this paper attempts to quantitatively investigate the impact of urban governance and city size on COVID-19 pandemic prevention and control based on the data set of Chinese cities. The main innovations and contributions of this paper are as follows: first, to more effectively reflect the actual situation of the pandemic in Chinese cities, we used what can be considered the most complete and comprehensive data set currently available in China on real-time pandemic data and regional characteristics. Our data also covers 276 prefecture-level Chinese cities, constituting a large cross-sectional sample that may yield findings with strong representativeness. Second, to innovatively analyze and compare the effects of urban governance and city size on the prevention and control of a pandemic, we applied the ordinary least squares (OLS) plus robust standard error strategy. Third, to compare the contribution rates and differences of urban governance systems, as well as the workforce, financial, and material effects of governance capacity, regarding the prevention and control of pandemics, we employed the mechanism decomposition method. This methodology allows for assessing the mechanisms by which urban governance affects pandemic prevention and control, providing knowledge that can be used by stakeholders to develop better-informed public crisis prevention and control systems. Fourth, considering that the Chinese government has been continuously promoting smart city[3] construction since 2012, we chose to innovatively introduce the regulatory index of smart city governance to assess the importance of urban governance on pandemic prevention and control.

The rest of this paper was structured as follows: the second section briefly reviews the COVID-19 pandemic in China, theoretically analyzes the mechanisms by which urban governance and city size affect prevention and control measures for COVID-19, and proposes hypotheses. The third section describes our research data, the econometric model, and the identification strategy for the empirical analysis. The fourth section provides an endogeneity discussion and describes the results of the robustness test. The fifth section tests the mechanisms by which the variables of interest affect urban prevention and control. The final section provides a study summary and comments.

2. Background and literature review

The COVID-19 pandemic is a typical major public crisis event, with its influence and destructive power having rapidly spread from the field of public health to political, diplomatic, economic, social, and other fields. According to the pandemic notification records provided by National Health Commission of the People's Republic of China, the provincial (municipal and district) health commissions, and following the law of crisis evolution and phased characteristics, the development stages of the COVID-19 pandemic were sorted based on the incubation, outbreak, and lasting periods, as shown in Table 1 (Ouyang et al., 2020). The COVID-19 pandemic hit hard mostly in large and medium-sized cities. Undoubtedly, the high concentration of activities and uncontrolled space in urban areas exposed the vulnerabilities these urban systems faced in a public health emergency; this led to lagged responses and the implementation of lockdown measures (Coşkun et al., 2021). However, under the strong leadership and careful deployment of Chinese central government and by relying on local governance capabilities, each province and city quickly controlled the pandemic and avoided potentially greater economic and social losses (Khavarian-Garmsir et al., 2021).

Since the reform and opening up, China has created an "urbanization miracle," which has attracted worldwide attention from both the perspectives of agricultural population migration and urban land expansion (Chu et al., 2021; Yigitcanlar & Kamruzzaman, 2018). However, there is still no consensus on the impact of city size on COVID-19. Small- and medium-sized city (i.e., with fewer than 500,000 people) advocates believe that pandemic costs in megacities are huge, as well as that prevention and control is certainly much easier to be conducted if the pandemic occurs in small- and medium-sized cities than in megacities (Coşkun et al., 2021). They also believe that locking down small- and medium-sized cities does not bring huge social costs and impede the pandemic's spread countrywide; accordingly, they believe that city size should be strictly controlled (Hua et al., 2021). Those who favor megacities consider that prevention and control of a pandemic have nothing to do with city size, instead of being dependent on city governance system and management; specifically, they emphasize that Chinese cities need to continue to scale up and take advantage of large-city governance (Hamidi et al., 2020; Khavarian-Garmsir et al., 2021).

An increasing number of scholars have described the decisive role of urban governance in tackling pandemics. Duggal (2020) pointed out that top-down and multilevel governance should be combined with strong, democratic, and integrated city-level governance to respond to urban pandemics effectively and flexibly. Additionally, measures advocated by countries such as China and Vietnam have been highly successful in practice (Earl, 2020). Contrastingly, Shammi et al. (2020) found that Bangladesh failed to actively analyze situations and assess risks related to COVID-19, hindering cities' capabilities to provide timely crisis responses. Moreover, Connolly et al. (2020) showed that, although Australian governments at all levels have taken positive actions to contain the virus' spread, their actions were not coordinated, their priorities were different, and this decentralized governance ultimately led to conflicts regarding the use of the country's limited resources (Steele, 2020). Therefore, the improvement of urban governance systems and capacity can be used to deal with public health crises effectively (Thoi, 2020).

To address the ongoing debate, we develop three hypotheses concerning whether cities with a larger scale, stronger governance capacity, and smarter construction would suffer positive or negative impacts on disease control (Table 2 and Fig. 1). Our three hypotheses are given below:

H1. The influence of city size on COVID-19 prevention and control is not significant.

During the rapid development stage of urbanization, it is common for many rural surplus labor forces to gather in urban areas. This explosive population growth hardly ever accompanies a similarly paced construction of existing urban housing and sanitation facilities, making highly concentrated urban activities an eventual security hazard (Chen et al., 2021; Song et al., 2021a). Accordingly, it is common for cities under rapid development to become overcrowded with an insufficient urban housing supply and low-quality housing. This situation also poses a severe challenge to urban health facilities, as underdeveloped health

[3] Taking advantage of information and communication technologies (ICT), a smart city refers to a city which has its critical infrastructures such as roads, bridges, tunnels upgraded to optimise resources allocation and maintenance activities (Chu et al., 2021).

Table 1
Development stages of the COVID-19 pandemic in China.

Crisis stage	Period	Description of the stages of the COVID-19 pandemic	Source
Incubation period	December 8, 2019 January 22, 2020	(1) The first case of viral pneumonia with an unknown cause in China was reported in Wuhan on December 8, 2019, and the number of cases had increased to 27 by December 31. On January 5, 2020, the Shanghai Public Health Clinical Center successfully detected the novel coronavirus and obtained the whole genome of the virus. Later, National Health Commission of the People's Republic of China confirmed that the "novel coronavirus" was the pathogen of the pandemic. (2) During the Spring Festival travel rush in the middle of January 2020, the COVID-19 pandemic gradually began to spread to other places in China. By January 22, the total number of patients in Wuhan had increased to 198. Further, cases or suspected cases of COVID-19 had been reported in Beijing, Guangdong, Zhejiang, Shanghai, Sichuan, Yunnan, Shandong, Guangxi, Hong Kong, Macao, other domestic areas, and overseas (e.g., Thailand, Japan, South Korea, and the USA). (3) At this stage, the COVID-19 pandemic was mainly prevalent in Hubei Province, especially Wuhan City, and showed a trend of spreading to other areas outside the province.	l Sina Finance: https://www.sohu.com/a/373647917_114988 l Central Committee of the Communist Youth League: https://baijiahao.baidu.com/s?id=1663302525416757757&wfr=spider&for=pc l Wuhan Municipal Health Commission: http://wjw.wuhan.gov.cn/ l National Health Commission of the People's Republic of China: http://www.nhc.gov.cn/wjw/index.shtml l (Ouyang et al., 2020)
Outbreak period	January 23, 2020 February 17, 2020	(1) On January 23, Wuhan, Huanggang, Ezhou, and many other places went into lockdown to curb the transmission of the pandemic. The number of infected people in Hubei increased to 444, and then Guangdong, Hunan, Zhejiang, Beijing, Hubei, Shanghai, Anhui, Chongqing, Tianjin, Sichuan, Yunnan, Guizhou, Shandong, Fujian launched a first-level response. (2) From late January to mid-February, there was an explosive growth of the pandemic. As of February 17, 2020, 72,436 people had been confirmed with and 1,868 died from COVID-19 in China, including 59,989 confirmed cases in Hubei (42,752 in Wuhan) and 1,789 died cases in Hubei (1,381 in Wuhan). In less than a month, the number of people confirmed with the infectious disease increased by 87 times, and the cumulative death toll increased 74-fold. (3) Hubei Province was in the outbreak period at this stage, with the number of confirmed cases and deaths increasing rapidly and the pandemic situation being very serious. Other regions were in the incubation period of the pandemic, and the growth rate of confirmed cases and deaths was relatively slow.	
Lasting period	February 18, 2020 Until now (2021)	(1) In late February 2020, the number of newly recovered people was higher than the number of newly confirmed people. The number of existing confirmed cases continued to decrease, going from 1,749 people on February 18 to 146 people on March 22. There was a "zero increase" in the number of newly confirmed people in many regions of the country. (2) At this stage, the pandemic in most areas was under effective control: the number of new and existing confirmed cases continued to decline, the number of recovered patients continued to increase, and production began to resume in some areas. However, the crisis has not been completely relieved.	

Table 2
Recent representative literature related to this article.

Factor	Source	Study area	Quantitative findings	Qualitative findings
City size	Coşkun et al. (2021)	Iran	Urban density does not play a major role in the COVID-19 morbidity and mortality rates.	
	Hua et al. (2021)	America	County density is not significantly related to the infection rate, possibly due to more adherence to social distancing guidelines.	
Urban governance	Earl (2020); Duggal (2020)	Vietnam		Top-down and multilevel governance should be combined with strong, democratic, and integrated city-level governance to respond to urban pandemics effectively and flexibly.
	Shammi et al. (2020)	Bangladesh	Bangladesh failed to actively analyze situations and assess risks related to COVID-19, hindering cities' capabilities to provide timely crisis responses.	
Smart city construction	James et al. (2020)	America		By fusing Internet of things sensors and machine learning technology, an urban platform can collect and store real-time data on various indicators, including vehicle, pedestrian flow, and air quality, helping local authorities conduct real-time monitoring, big data analysis of the pandemic, and make effective adaptive decisions.
	Datta (2020)	India.		Intelligent solutions can facilitate quarantine by effectively allowing avoidance of person-to-person contact, rapid detection of infected individuals, and the prediction of patterns of spread.

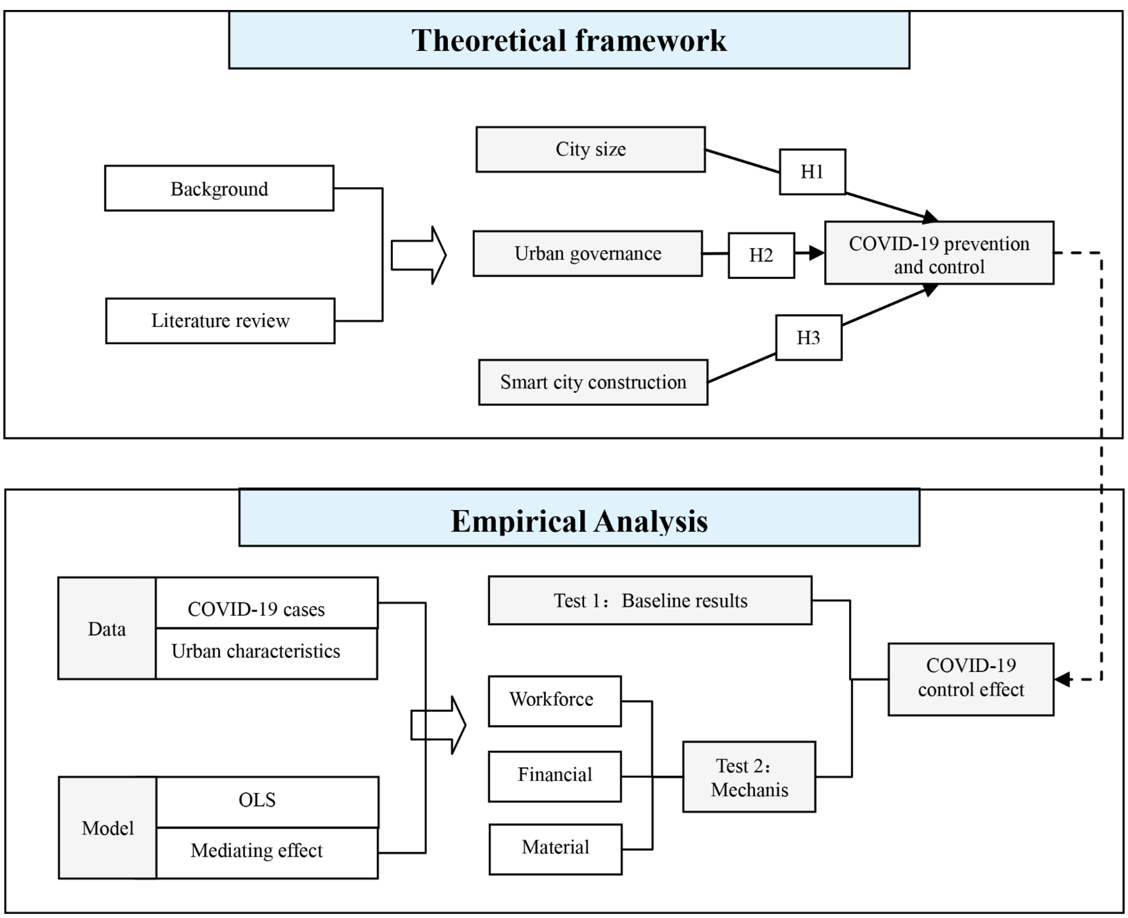

Fig. 1. The research framework in this study.

facilities can only support a relatively low urban population density. Therefore, in the case of imperfect infrastructure construction, cities, as the meeting points of various materials and population flows, objectively provide an optimal setting for the spread of an unexpected pandemic. Moreover, owing to having strong mobility and high density, the urban population also puts great pressure on stakeholders to control the pandemic's spread.

Meanwhile, larger cities tend to have a more developed social division of the labor system, allowing citizens to enjoy a lot of professional services without leaving their homes and to avoid the risk of face-to-face contact with others if faced with a pandemic. From the perspective of economies of scale, cities with high population density can also focus on providing more high-quality public resources for pandemic prevention and control; for example, more efficient detection of high-risk groups and admission of confirmed COVID-19 cases. Namely, city size presents advantages and disadvantages, and they offset one another to an extent.

H2. Urban governance has a positive impact on COVID-19 prevention and control.

Another important factor affecting the effectiveness of pandemic prevention and control is the improvement of the urban governance system and governance capacity (Song et al., 2021b; S. Wang et al., 2021b). Generally, a sound comprehensive urban management plan should fully invest in basic health facilities at an early stage and coordinate different departments and stakeholders in response to urban pandemics in a timely and effective manner (Duggal, 2020; Shammi et al., 2020; Thoi, 2020). With the progress of urbanization, the importance of urban governance in responding to public health crises has been increasingly recognized (Henkey, 2018; McGill, 2020). Some cities, based on rapid lockdown measures for pandemic areas, have prevented the virus' spread and reduced the socioeconomic impact of the pandemic by increasing detection efforts, improving surveillance technology, timely detection of infected people, and regulation of social distance (Duggal, 2020; Earl, 2020). In the process of handling the COVID-19 crisis, China coordinated different provinces and cities, carrying out community-based top-down anti-pandemic activities within cities. This approach of urban governance with state participation helped in taking timely actions to prevent the virus's spread (Hesse & Rafferty, 2020). However, there are two important prerequisites for its success: every side needs to trust the government and its actions to achieve expected targets (Earl, 2020; Thoi, 2020), and the relevant mechanisms need to be established for actively engaging citizens in these initiatives. Such an integrated approach can contribute to the formulation of appropriate long-term development and contingency plans, to avoid sectoral conflicts, and maximize stakeholder participation (Chakrabarty, 1998; Neutze, 1982). Namely, the top-down multi-level governance approach should be combined with strong, democratic, and integrated city-level governance to respond to various public emergencies effectively and flexibly.

H3. Smart city construction promotes the positive role of urban governance in pandemic prevention and control.

Smart cities use all types of embedded intelligent sensors to connect various kinds of public resources (e.g., grids, highways, and water supply systems), dynamically extract key information, analyze and coordinate city operation data to efficiently manage and allocate resources, and realize the sustainable development of cities (Amer et al., 2019; Yin et al., 2015). Since 2010, the Chinese government has issued a series of relevant policies (e.g., from top-level design to specific applications) to gradually guide and encourage the construction of smart cities in various regions (S. Wang et al., 2021a; Zhu et al., 2018). Intelligent solutions can facilitate quarantine by effectively allowing avoidance of person-to-person contact, rapid detection of infected individuals, and the prediction of patterns of spread (Datta, 2020). For example, drones can automatically deliver medical and commercial supplies during a lockdown, and healthcare workers can perform clinical care based on AI technology, which can both improve work efficiency and reduce human contact (Chen et al., 2020). These intelligent solutions can be widely used to identify infected people and deliver appropriate treatment (Chen et al., 2020; Cui et al., 2021; Song et al., 2020). By fusing Internet of things sensors and machine learning technology, an urban platform can collect and store real-time data on various indicators, including vehicle, pedestrian flow, and air quality, helping local authorities conduct real-time monitoring, big data analysis of the pandemic, and make effective adaptive decisions (James et al., 2020). For example, to further curb pandemic transmission, China developed a smartphone-based "health code" program to classify, identify, and guide residents' movements by tracking their health status and geographical locations (Ahmed et al., 2021; Yang & Chong, 2021; Zivkovic et al., 2021).

3. Model building and empirical analysis

3.1. Model establishment and variable setting

This study used the regression model to understand how city size and urban governance affect COVID-19 prevention and control. When there is excessively strong theoretical assumptions based on small samples and precise statistical distribution solutions in cross-sectional data model, the OLS estimator of a linear regression model does not become BLUE (Best Linear Unbiased Estimator). Thus, this study attempted to construct several data sets, covering 276 prefecture-level cities and using the large-sample asymptotic theory to avoid assumptions such as "strict exogeneity" and "normal random disturbance term" to make the model more applicable and robust. The model used in this study is as follows:

$$COVID_i = \beta_0 + \beta_1 Ucd_i + \beta_2 Usc_i + \sum_{j=3}^{m} \beta_j \boldsymbol{X}_i + \varepsilon_i \tag{3.1}$$

$COVID: \ n\times \ 1$ matrix of dependent variable, $Ucd: \ n\times \ 1$ matrix of independent variable, $Usc: \ n\times \ 1$ matrix of independent variable, $\boldsymbol{X}: \ n\times k$ matrix of independent variable, $\beta: \ (k+3)\times \ 1$ matrix of regression parameter, ε matrix of error term (Wooldridge, 2012).

More specifically, $COVID_i$ refers to the COVID-19 pandemic status of city *i* on February 18, 2020, including the regional differences regarding cumulative confirmed (*Cudia*), recovered (*Cure*), and dead (*Death*) COVID-19 cases. To ensure data comparability, we conducted further standardization based on the urban population. Confirmed COVID-19 cases were used to represent early pandemic prevention effects. Considering that Hubei Province is special compared with other provinces because it was the source and the pandemic outbreak center in China—while the confirmed cases in other regions were generally "imported"—only samples from Hubei Province were kept in the estimation process to avoid potential errors. Contrastingly, recovered and dead COVID-19 cases occurred in later pandemic stages, so they were used as proxy indices of pandemic control. However, considering that Wuhan City was assisted by the whole country in the control stage, we excluded its data from the regression samples.

By integrating the daily public information of the national and provincial health commissions, dxy.com provides a real-time data set of COVID-19 cases covering 31 provinces, municipalities, and autonomous regions in China. The sample date chosen was February 18, 2020, because of the sudden occurrence and persistence of the pandemic during the date and its representativeness, considering that it denotes a transitional period from the outbreak period to the last period.

The core explanatory variables, Ucd_i and Usc_i, represent the governance level and size of city *i*. Considering the lack of theoretic and quantitative research results in domestic urban governance research, we chose China's city comprehensive development index[4] as a substitute variable for the level of urban governance for the following reasons: First, based on Wang and Xia (2015), the city comprehensive development index can better evaluate and reflect the comprehensive governance capacity of a city based on environmental, social, and economic dimensions. Second, the index was compiled by official bodies, denoting that the data source related to this index and its calculation methods are credible; the data came from the China City Comprehensive Development Index 2018, jointly released by the Development Strategy and Planning Department of the National Development and Reform Commission and the Cloud River Urban Research Institute on December 2,

[4] "China's urban comprehensive development index 2018" consists of a total of 178 groups of indicators. Indicators comprehensively evaluate the development of Chinese cities from three dimensions (major items) of environment, society and economy. Data sources: https://baijiahao.baidu.com/s?id=1651957206379372362&wfr=spider&for=pc.

2019. It covers all 297 cities at and above the prefectural level in China.

City size was measured by the urbanization rate (*Urbar*) and the urban population (*Popul*), with the latter serving as a robustness test of the former. The urbanization rate reflects the agglomeration process in urban areas, specifically the migration from rural to urban locations. However, this method presented a hindrance, as the official statistical prefecture-level data do not include related urban and rural population variables; scholars also still debate this variable's data validity. Comparatively speaking, the urban population level variable, as defined from the perspective of land urbanization, has a high degree of recognition and is widely used by scholars. The data for these indexes were obtained from the China City Statistical Yearbook 2018.

If we look only at the fitting trend of urban governance and city size with the COVID-19 pandemic, as shown in Figs. 2, 3, and 4, we can observe that the COVID-19 pandemic was more serious in cities with larger population sizes or higher governance levels. However, both core explanatory variables are urban development factors, whereas the factors affecting COVID-19 are diverse and complex. Thus, a series of control variables, X_i, need to be set. To ensure the scientific validity of the control variables, they were mainly selected based on classical economic theories and the relevant literature.

Specifically, we used (1) the distance (Dista) from Wuhan and the migration scale index (Iss) while considering that the domestic pandemic began in Wuhan and spread outward from this single-center; hence, cities with closer geographical and economic links to the pandemic's center were more likely to be affected; to control for these two factors, we used the length of the distance in a straight line from a city to Wuhan to represent its geographical connection with the pandemic center, and the data for this variable were collected manually based on the ranging function in the Baidu Map Toolbox. We also chose to use the migration scale index from January 22, 2020, to represent the economic links between a city and the center of the pandemic because: first, this index reflects the number of people moving in and out of the region and can be compared horizontally between cities; and second, to prevent the pandemic's spread, lockdown measures started in Wuhan on January 23, 2020, denoting that the day before the "lockdown" could better reflect differences in the population flow related to the "Spring Festival travel rush" by region. Data for this index were collected manually based on the "Baidu Migration" big data visualization project.

We also controlled for (2) intra-city travel intensity; indeed, the population flow within a city is equally important to pandemic prevention and control as that outside a city; to concur with the pandemic investigation period, we assessed the exponential result of the ratio of people traveling toward a city to the resident population of that city on February 18, 2020. Finally, we controlled for (3) the economic development level (Pgdp), which is an important factor affecting pandemics in cities and can help to largely avoid possible missing data on macroeconomic characteristics. Please see Table 3 for further details.

Furthermore, by controlling the related potential influencing variables, we constructed the dummy variables of urban governance capacity and city size, with the average value of the urban comprehensive development index and urbanization rate in the sample period as the cut-off point. According to the offset correction matching findings (Table 4), cities with higher governance capacity on average not only significantly reduced COVID-19 deaths but also significantly improved COVID-19 patients' recovery levels. Meanwhile, city size exclusively negatively affected recovered COVID-19 cases, with no evidence of a significant relationship between city size and confirmed and dead COVID-19 cases. Nonetheless, as these are simply descriptive analyses, more rigorous conclusions depend on further testing.

3.2. Regression results and analysis

Since we considered the possibility of a heteroscedasticity problem in the cross-sectional data, we adopted the weighted least square method and variance inflation factor test—based on the baseline

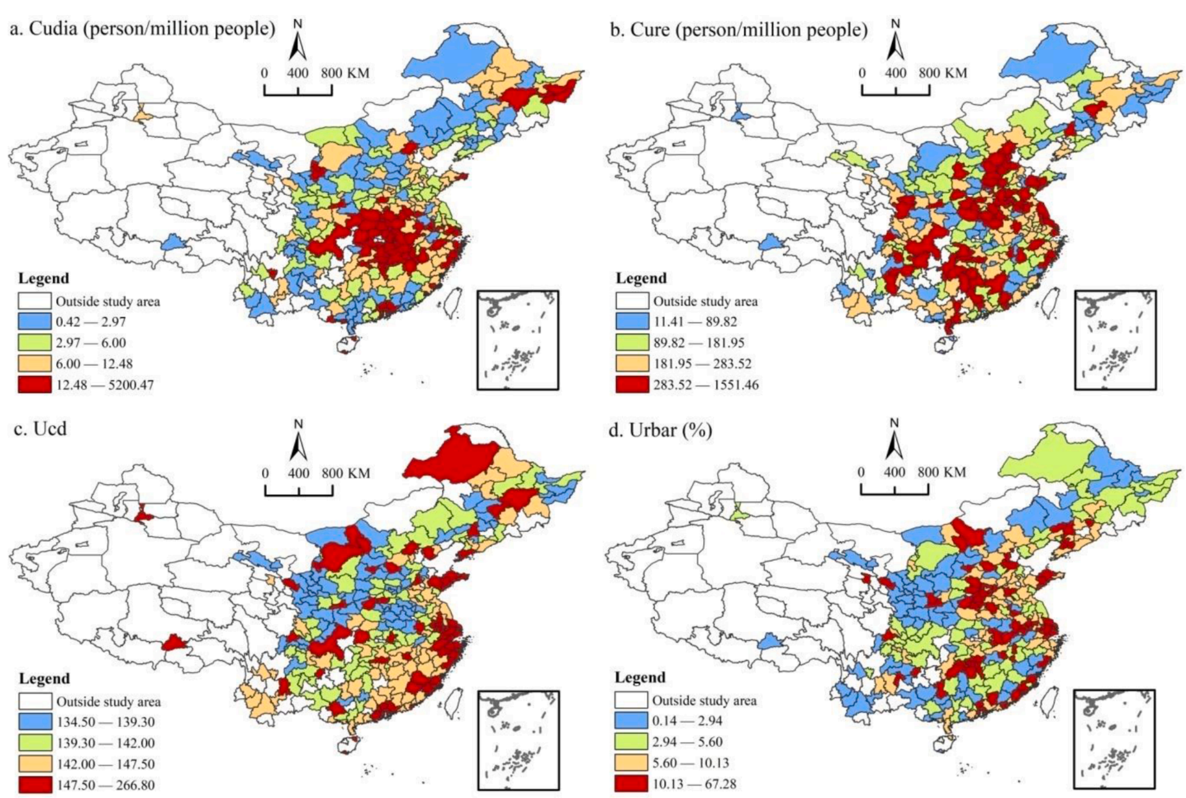

Fig. 2. Spatial distribution of Cudia, Cure, Ucd, and Urbar in China on February 18, 2020
Note: 297 prefectural-level cities in China are divided into quantiles based on the Cudia, Cure, Ucd, and Urbar. The two highest quantiles were defined as the high-value areas and the two lowest quantiles as the low-value areas.

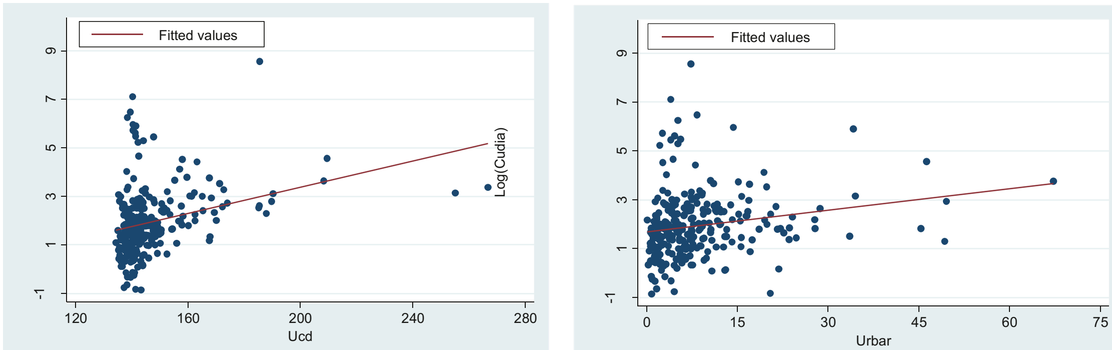

Fig. 3. Relationship between urban development and COVID-19 prevention effect.

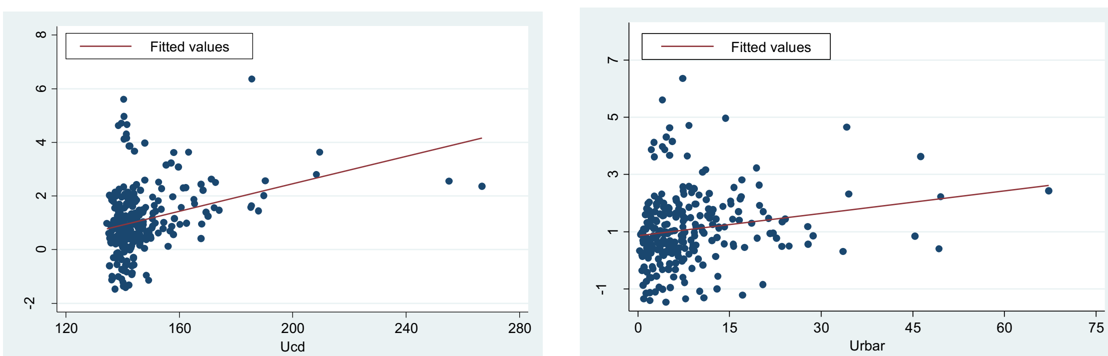

Fig. 4. Relationship between urban development and COVID-19 control effect.

regression—to gradually weaken the assumptions of the classical model and to eliminate potential estimation deviations. Meanwhile, to eliminate potential estimation deviations caused by data anomalies, the explained variables were estimated in their logarithmic form, unless otherwise specified.

Table 5 shows the regression results of the early prevention and late control stages of the pandemic. Judging from the R^2 and F values of the model, we assumed that the explanatory variables we selected had explanatory power over the explained variables, and the overall significance of the model was strong. Compared with column (1), the coefficients of the core explanatory variables in column (2) showed greater fluctuation, indicating the necessity of adding a series of control variables. Specifically, (1) the regression coefficient between city size and confirmed COVID-19 cases was not significant, same as that between governance capacity and confirmed COVID-19 cases. On the one hand, city size may not be a significant factor in a pandemic's spread, denoting that it yields no disadvantage during the spread; on the other hand, a pandemic is characterized by the suddenness and strong transmission of infectious disease, resulting in a major public health crisis, in the "failure" of urban governance or a slow response to the pandemic in

Table 3
Variable definition and statistical characteristics.

Variable type	Variable name	Symbol	Mean value	Standard error	Sample size	Descriptions
Explained variable	Recovered COVID-19 cases per capita	*Cure*	9.84	41.11	276	Ratio of recovered COVID-19 cases to the urban population (person/million people)
	Fatalities COVID-19 per capita	*Death*	1.10	10.84	276	Ratio of dead COVID-19 cases to the urban population (person/million people)
	Confirmed COVID-19 cases per capita	*Cudia*	44.63	326.65	276	Ratio of confirmed COVID-19 cases to the number of the urban population (person/million people)
Core explanatory variable	Governance level	*Ucd*	146.63	15.14	274	China City Comprehensive Development Index
	Urbanization rate	*Urbar*	8.27	8.82	276	Proportion of built-up area in the urban land area (%)
	Urban population	*Popul*	163.76	208.79	271	Total year-end population (10,000 persons)
Mechanism variable	Workforce	*Pdoc*	24.83	11.06	269	Ratio of number of doctors to the urban population (person/10,000 persons)
	Financial resources	*Pfin*	10.59	8.07	269	Ratio of general budgetary expenditure of local finance to the urban population (CNY 1,000/person)
	Material resources	*Pbed*	45.72	18.63	268	Ratio of hospital beds to the urban population (per 10,000 persons)
Control variable	Economic development level	*Pgdp*	92.84	382.67	276	Regional per Capita GDP (CNY 1,000/person)
	The distance from Wuhan	*Dista*	894.67	514.02	274	The distance in a straight-line from Wuhan (km)
	Migration scale index	*Iss*	1.95	1.25	276	The scale of urban migration
	Intra-city travel intensity	*Tie*	1.89	1.26	276	The exponential results of the ratio of people traveling to resident population in a city

Table 4
COVID-19 prevention and control based on offset correction matching estimators.

		Log (Cudia)		Log (Cure)		Death	
		(1)	(2)	(3)	(4)	(5)	(6)
Average treatment effect	dummy_Ucd	16.96***		0.401**		-0.851***	
		(1.066)		(0.158)		(0.0841)	
	dummy_Urbar		0.397		-0.268*		-0.027
			(0.855)		(0.162)		(0.292)
Control variable		Yes	Yes	Yes	Yes	Yes	Yes
N		12	12	259	259	271	271

Note: dummy_Ucd and dummy_Urbar, respectively, represent 0 or 1 based on the average value of urban governance and urbanization rate; namely, when the average value of a dummy variable was higher than the average value of its corresponding variable, it was 1; when the average value of the first was lower, it was 0. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; the values in brackets are standard errors, and all values were estimated using STATA 14.0.

Table 5
COVID-19 prevention and control: baseline regression results.

	Confirmed COVID-19 cases				Recovered COVID-19 cases		Dead COVID-19 cases	
	Cudia		Log (Cudia)		Log (Cure)		Death	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ucd	3.456	4.519	0.064	-0.006	0.025***	0.024***	-0.008**	-0.008*
	(3.706)	(4.241)	(0.048)	(0.028)	(0.004)	(0.005)	(0.004)	(0.004)
Urbar	-1.693	-3.788		-0.024**		0.002		-0.002
	(2.181)	(3.311)		(0.006)		(0.006)		(0.010)
Popul			-0.004		-0.77e-3**		-0.001**	
			(0.003)		(0.000)		(0.000)	
Cudia					0.002***	0.002***	0.006***	0.006***
					(0.000)	(0.000)	(0.001)	(0.001)
Pgdp		0.78e-5	0.12e-5	0.67e-5	3.07e-8	0.58e-9*	7.15e-8	0.99e-9
		(0.000)	(0.000)	(0.000)	(2.91e-8)	(0.000)	(5.59e-8)	(0.000)
Dista		-0.158*	-0.004**	-0.005***	-0.001***	-0.80e-3***	-0.20e-3	-0.24e-3
		(0.092)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Iss		-29.75	0.201	0.166	0.019	-0.155***	-0.138	-0.319*
		(20.01)	(0.296)	(0.277)	(0.080)	(0.044)	(0.149)	(0.166)
Tie		-30.63	-2.572	-1.848	-0.174***	-0.168***	-0.021	-0.021
		(20.55)	(1.667)	(1.055)	(0.040)	(0.041)	(0.039)	(0.049)
Constant term	-447.6	-330.6	0.946	9.513*	-1.474**	-1.327**	1.827***	1.940***
	(508.4)	(437.1)	(5.965)	(4.063)	(0.605)	(0.632)	(0.557)	(0.509)
N	272	272	12	12	259	259	271	271
R^2	0.023	0.080	0.914	0.931	0.534	0.523	0.580	0.578

Note: Columns (1)–(2) depict the results stemming from the whole sample; columns (3) and (4) show results pertaining only to data from Hubei Province; and columns (5)–(8) show the results excluding Wuhan City data. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; the values in brackets are standard errors, and all values were estimated using STATA 14.0.

its early stage, and in stakeholders missing the optimal timing for conducting early pandemic prevention measures.

Moreover, (2) the regression coefficient between urban governance capacity and recovered COVID-19 cases, and that between the former and dead COVID-19 cases showed a significance level of 1% and 5%, respectively. Namely, that urban governance capacity can significantly improve the recovery and reduce the risk of death of COVID-19 cases. However, the regression coefficient between city size and recovered COVID-19 cases, and that between the former and dead COVID-19 cases were both non-significant, indicating that there is no significant relationship between pandemic response capacity and city size. These results indicate that the advantages and disadvantages of city size often offset each other to a certain extent, hence not directly evoking differences in pandemic prevention and control among regions.

Concluding, Hypotheses 1 and 2 were confirmed; particularly, city size showed a non-significant effect, while urban governance capacity was an important factor affecting the prevention and control of COVID-19. Still, although governance capacity was significant in the late control of the pandemic, it failed to effectively prevent its early spread. Among the control variables, regardless of the period (i.e., at the early pandemic's spread or the late prevention and control measures period), the coefficient of intra-city travel intensity was significant; hence, city lockdown, short-term travel control, and isolation measures were scientifically validated and useful to some extent in dealing with the COVID-19 pandemic.

Furthermore, based on Eq. (3.1) and to investigate regional differences in the impact of urban governance capacity on the level of COVID-19 recovered cases, the cross term of urban governance capacity and region were added. The regression results are shown in the section of "Regional heterogeneity" in Table 5. Regarding urban governance capacity, compared with central China— where the pandemic has been more severe—the coefficients of the other two regions were all positive, with western cities showing significance at 1%. This indicates that there are significant regional differences in the impact of urban governance capacity on COVID-19; namely, for both recovered and dead COVID-19

Table 6
Urban governance and COVID-19 prevention and control: regional heterogeneity and contribution rates by region.

	Overall	Log (Cure)		
		Eastern region	Central region	Western region
Regional heterogeneity	0.029***	0.013	-0.011	0.077***
	(0.006)	(0.013)	(0.018)	(0.016)
Contribution rate	10.28%	14.95%	-0.80%	29.98%
Control variable	Yes	Yes	Yes	Yes
Sample size	253	89	93	71

Note: The spatial heterogeneity data in the table are the regression coefficients of urban governance capacity. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 7
Urban governance and COVID-19 prevention and control: robustness test.

	WLS: Log (Cure) Full sample		OLS: Log (Cure) Full sample		Smart	Traditional	Smart	Traditional
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ucd	0.023***	0.026***			0.026***	0.024	0.010**	0.026
	(0.004)	(0.005)						
Smart1			0.474***	0.440***				
			(0.061)	(0.052)				
Urbar	0.003		-0.008		0.006	-0.027	0.004	-0.002
	(0.007)		(0.005)		(0.005)	(0.018)	(0.006)	(0.012)
Popul		-0.30e-3		-0.001*				
		(0.000)		(0.000)				
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	259	253	257	257	132	125	130	122
R^2	0.524	0.527	0.553	0.557	0.480	0.597	0.528	0.624

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; the values in brackets are standard errors, and all values were estimated using STATA 14.0.

cases, urban governance capacity only showed a generally significant control effect in the non-hard-hit areas. Further, the aforementioned regression model showed only the marginal effect of urban governance capacity on pandemic control.

Moreover, by using the regression decomposition method, and based on the logarithmic COVID-19 equation and its regression results, we measured the contribution rate of urban governance capacity to COVID-19 control using a logarithmic variance. The decomposition results are shown in the section “Contribution rate” in Table 6. Results showed that the overall contribution rate of urban governance capacity to pandemic control was 10.28%; specifically, it went as low as -0.80% in the central region (i.e., severer pandemic), but also increased to 14.95%–29.98% in the eastern and western regions (i.e., farther away from the pandemic outbreak center). Therefore, first, urban governance capacity showed a high contribution rate to pandemic control, which is a key approach to pandemic prevention and control; therefore, it may be of great significance to improve the urban governance system and capacity for coping with major public crises. Second, the influencing factors of control of a pandemic were shown to be diverse and complex, as urban governance capacity was observed as not being fully responsible for the effect; accordingly, when faced with a major public crisis, it may not be enough to rely exclusively on the “all-out power” of the governance of a city or even a country; instead, they should also rely on external support. Indeed, during the pandemic, the severely afflicted areas received effective and timely assistance from Chinese central government and other parts of the country, which played a key role in the prevention and control of the pandemic in these regions.

Finally, based on the contribution rate and the regional heterogeneity analyses, urban governance capacity was shown to be vulnerable to and non-sufficient for tackling a pandemic during the period when it was concentrated in a region; practically, this denotes that the limited urban resources and governance capacity are likely to be overwhelmed by the outbreak of infectious disease and its concentration in a city or region, leading to a decline in the effectiveness of urban governance in pandemic prevention and control. Therefore, when envisioning a major public crisis, stakeholders should focus on promoting early warnings based on the notion of “early detection, early report, early prevention and control,” as this may help stifle the crisis at the initial or latent stage.

4. Endogeneity discussion and robustness test

The COVID-19 pandemic was a sudden and significant event with relevant spillover effects. Generally, exogenous variables can be treated without considering endogeneity. However, on the one hand, COVID-19 may impact cities according to size and urban governance even in the short term; examples are the impact of city lockdowns and travel restrictions on city size and leadership changes (e.g., which happened early on in Hubei Province, specifically in Wuhan) on city governance. On the other hand, the COVID-19 pandemic is a complex event and may have resulted from unobtainable factors, namely, that were beyond the ability of city governance. These two situations may lead to an endogeneity problem in the established model (Maiti et al., 2021). The former may be caused by the two-way interaction between explanatory variables and explained variables, while the latter may be caused by the omission of variables.

In the model and empirical analysis of this study, we focused on the impact that endogeneity may have on our empirical results. In cases where it is difficult to find a suitable instrumental variable for conducting two-stage least squares regression, other methods are adopted to minimize endogeneity’s effect. First, proxy variables were adopted (Kim, 2021). As shown in Table 3, to minimize the endogeneity caused by missing variables, some factors that were difficult to observe but may impact the COVID-19 pandemic (e.g., geographical, economic, and demographic factors) were included in the model with corresponding proxy variables. Of importance are the population movements before and after the outbreak period because they may be key factors for either the spread or the prevention of the pandemic; these data were not provided by the traditional data set we had access to. To better solve the endogenous problems caused by this omission of variables, by accessing Baidu Map Migration Big Data[5] and other websites, we manually collected data from 276 prefecture-level cities regarding the scale of urban migration, the intra-city travel intensity, and the distance between these cities and Wuhan.

Second, columns (1) and (2) in Table 7 report the weighted least square regression results. The results showed the coefficient of Ucd was not zero at the significance level of 1%, and there was an improvement from 0.024 (value acquired through OLS plus robust standard error) to 0.023; namely, the results remained robust even after considering the possible influence of heteroscedasticity, providing feasible evidence for the rationality of using the OLS plus robust standard error strategy in this study. Finally, we employed the predetermined variable method; to avoid the possible endogeneity issue between the aforementioned variables and the pandemic in the model, the data of core variables were all extracted from 2017 data sets, and we used three lagged phases compared with the pandemic outbreak.

Moreover, since there was no established data on the urban governance system and the governance capacity of Chinese cities, we used the China City Comprehensive Development Index as a proxy variable. As a new urban development model, smart city construction is rapidly rising worldwide, called “a new round of urban reform” by some scholars. The Chinese government attached great importance to smart city construction. Since the first national smart city pilot in 2012, more than 85% of cities have directly or indirectly participated in smart city construction,

[5] Data souce: http://qianxi.baidu.com/.

which plays a significant role in improving the urban governance system and capacity (Chu et al., 2021). Moreover, from the detection of the COVID-19 pandemic to the late prevention and control measures, every city has experienced a comprehensive impact on its governance system and been tested in its governance capacity from the beginning of this public health crisis. In the information age, local governments and related technology companies have used the Internet, big data, artificial intelligence, and other information technology tools to promote innovations in urban governance systems, models, methods, and ensure a scientific, refined, and intelligent urban management strategy to cope with the impact of the pandemic.

Accordingly, to conduct a robustness test, we used the city smartness index as a proxy variable of urban governance capacity. As for the measurement of the city smartness index, by referring to existing data and practices of (Shen et al., 2018)[6], we constructed a comprehensive evaluation index system based on six dimensions: smart economy, smart mobility, smart environment, smart people, smart life, and smart management. Then, the city smartness indexes (Smart1) of 276 prefecture-level cities in 2017 were calculated, using the multi-attribute decision-making method with combination weighting; this index served as a proxy variable for the level of smart city construction. As shown in columns (3) and (4) of Table 7, the results remained robust.

IESE Business School stresses that information communication technology (ICT) is a pillar for any society which desires to be called a smart society. Thus, based on prior research (Yigitcanlar & Kamruzzaman, 2018), we used the number of Internet users per 100 persons to represent a city's ICT popularization rate, serving as another variable for the city smartness index (Smart2). Furthermore, we divided cities into traditional cities (below the median) or smart cities (above the median) by referencing the sample median for the number of Internet users per 100 persons.

To investigate the heterogeneity of smart city construction on regional pandemic prevention and control, we performed grouped regression analysis using Eq. (3.1). The regression results are shown in columns (5)–(8) of Table 7, which indicated that, compared with traditional cities, the construction of smart cities more significantly promotes the urban governance's positive role in pandemic prevention and control, indirectly proving the advantages of smart city construction. The basic logic here is that, as cities begin to engage in smart construction, on the one hand, enterprises that constantly present new technologies and products will concomitantly accelerate their transformation to an intelligent management model; on the other hand, resource allocation within enterprises or among industries will become more efficient and reasonable, subsequently leading to improved science, technology, and efficiency within organizations. All such outcomes profoundly change the city's pandemic prevention and control capability.

5. Further discussion: internal mechanism and decomposition of pandemic prevention and control

Our statistical and econometric analyses indicated that urban governance capacity has a significant effect on pandemic control; prompting the question: by what mechanism does urban governance affect pandemic control? Generally, soon after the initial stage of a public health crisis, it passes on to the spread stage. To minimize loss caused by the crisis, stakeholders conducting pandemic management must make reasonable use of workforce, material, and financial resources and promote effective efforts to control the pandemic while constrained by the guaranteed resources at hand[7]. Based on the mediating effect analysis framework and mainly using the dimensions of the workforce, material, and financial resources of local governments and medical institutions, we established a corresponding mechanism model:

$$Chann_i^k(Pdoc_i, Pfin_i, Pbed_i) = \alpha_0 + \alpha_1^k Ucd_i + \sum_{j=2}^{n} \alpha_j \boldsymbol{X}_i + \varepsilon_i \tag{5.1}$$

$$COVID_i = \gamma_0 + \gamma_1 Ucd_i + \gamma_2^k Chann_i^k(Pdoc_i, Pfin_i, Pbed_i) + \sum_{j=3}^{n} \gamma_j \boldsymbol{X}_i + \varepsilon_i \tag{5.2}$$

Then, to analyze the credibility and explanatory power of these three dimensions/mechanisms, we adopted Gelbach's method (Gelbach, 2014):

$$COVID_i = \delta_0 + \delta_1 Ucd_i + \sum_{k=1}^{3} \delta_2^k Chann_i^k + \sum_{j=3}^{n} \delta_j \boldsymbol{X}_i + \theta_i \tag{5.3}$$

$$\widehat{\beta}_1 = \widehat{\delta}_1 + \sum_{k=1}^{3} \widehat{\alpha}_1^k \widehat{\delta}_2^k, \psi_k = \widehat{\alpha}_1^k \widehat{\delta}_2^k \Big/ \widehat{\beta}_1 \tag{5.4}$$

where $Chann_{i,t}^k$ represents the mechanism k of city i in year t, including the workforce, financial, and material effects; ψ_k is the proportion of the effect explained by the mechanism k. The regression and decomposition results are shown in Table 7.

The influence coefficients of urban governance capacity on per capita doctor retention, per capita financial expenditure, and per capita hospital beds were all significantly positive in the first stage of the regression (columns 2, 4, and 6, Table 8). That is to say that urban governance capacity has a direct role in enhancing the workforce effect and can significantly improve financial and material resources utilization. In the second regression stage, the results (column 1, Table 8) showed that the prevention and control system significantly improved the recovery of COVID-19 cases, supporting once more the supposition

[6] The index system includes six first-level indexes and twelve second-level indexes. Specifically, smart economy includes total year-end population and per capita gross domestic product; smart mobility includes the number of mobile phone users per 100 persons and the number of Internet users per 100 persons; smart people includes the total number of college students and the proportion of science and technology expenditure in fiscal expenditure; smart environment includes harmless disposal rate of domestic garbage and green coverage rate of built-up areas; smart life includes the number of hospital beds per 10,000 persons and the number of buses per 10,000 persons; and smart management includes the average wage of employees and the number of registered urban unemployed people per 100 persons.

[7] The involvement of Chinese central government in public crisis management played a key role in controlling the epidemic in the Hubei Province. Through Chinese central government, the whole country was quickly organized and mobilized to support the epidemic prevention and control efforts in Wuhan. On January 25, 2020, President Xi Jinping presided over a meeting of the Standing Committee of the Political Bureau of the CPC Central Committee to study the prevention and control measures for, and set up a central leading group to, the epidemic. On the next day, Premier Li Keqiang chaired a meeting of the leading group on COVID-19 to deploy COVID-19 prevention and control measures. On January 28, Vice Premier Sun Chunlan led a Central Steering Group to conduct guidance work in Wuhan, providing knowledge on the current progress of epidemic prevention and control efforts, the treatment of infected patients, the protection of medical workers, and other aspects. Then, more experts were sent to Hubei to ensure the production, deployment, and supply of epidemic prevention and control materials. On the same day, the CPC Central Committee issued the "Note on strengthening CPC's leadership and providing strong political guarantee to win the war against the COVID-19 epidemic," stressing that party committees, leaders, party organizations at all levels, and all party members should unite to unswervingly implement the decisions set forth by the CPC Central Committee and be determined to win the war against COVID-19. Besides, an inter-provincial matching mechanism was established to support COVID-19-related medical treatment in Hubei Province, with more than 40,000 medical personnel having been arranged, through successive batches, to support Hubei Province.

that the urban governance system and capacity building can help tackle the COVID-19 pandemic. In the third regression stage, the results (column 3, 5, and 7, Table 8) showed that the significance of urban governance capacity building in reducing the mortality risk of COVID-19 and the absolute value of its coefficients both decreased after the variables workforce, financial, and material resources were respectively included in the model (3.1). This result confirms the existence of these three dimensions' influence. This indicates that the prevention and control of COVID-19 requires a large amount of workforce, material resources, and financial resources, as well as the appropriate support of medical technology and effective control measures.

Moreover, to calculate the explanatory weight of each influencing mechanism, we decomposed each mediating effect using Eq. (5.3). Regarding recovered COVID-19 cases, the explanation proportion of the workforce was 26.15%, while financial and material resources were 32.55% and 37.20%, respectively, together accounting for 95.90% of the total effect. These results show that, first, urban governance—in its three dimensions—conducted by local governments and medical institutions as the main bodies explained most pandemic prevention and control efforts, with other mechanisms accounted for only 4%. Second, workforce, financial, and material resources were all key influencing factors of pandemic prevention and control, closely related to and jointly constituting the urban governance capacity (Earl, 2020).

6. Conclusions and comments

As the COVID-19 pandemic is a major public health crisis, research on the effects and mechanisms of its prevention and control at the city level can have profound political, economic, and social implications. Based on a brief review of how the COVID-19 pandemic developed in China, we conducted a theoretical analysis of the mechanism by which urban governance and city size affected COVID-19 prevention and control efforts. Based on the real-time data of the COVID-19 pandemic in 276 prefecture-level cities in China, an OLS plus robust standard error strategy was constructed to identify the causal effects between the interest variables.

Our major findings were: first, although the effect of city size was non-significant, urban governance capacity was an important factor affecting the prevention and control of COVID-19; specifically, governance capacity was particularly significant in the control of the pandemic at its later stages, but non-significant in early prevention efforts. Moreover, for every unit increase of urban governance capacity, the ratio of recovered COVID-19 cases per capita increased by 2.4%. Second, the mechanisms by which urban governance influenced COVID-19 prevention and control in cities can be divided into the workforce, financial, and material effects, and their contribution rates were 26.15%, 32.55%, and 37.20%, respectively; namely, urban governance conducted mainly by local governments and medical institutions explained most of the COVID-19 prevention and control efforts, while other mechanisms explained only 4% of such efforts. Therefore, effective and timely assistance from Chinese central government and other institutions and local governments throughout the country played a key role in controlling the pandemic within specific cities. Third, regardless of the pandemic stage (i.e., either in the early prevention or the late control stages), the coefficient of intra-city travel intensity was significant, indicating that city lockdown, short-term travel control, and isolation measures were scientifically valid and necessary for tackling the COVID-19 pandemic. Fourth, a high degree of smart city construction was conducive to enhancing pandemic prevention and control effect in a city, indicating that smart cities facilitate enhanced coping with public health crises.

This study has the following three policy implications: first, we showed that COVID-19's occurrence in cities and the effects of prevention and control efforts are not directly related to city size, but city governance capacity. Hence, we believe that China should combine its political characteristics and institutional advantages to find a suitable urban development model. Namely, the city size of Chinese urban areas should match their governance capacity, denoting that the development of Chinese cities requires not only an increasing population, number of buildings, and gross domestic product, but also a better governance capacity to prevent and control public health risks. Second, urban development endeavors should attach great importance to the occurrence and prevention of major public crises; thus, it seems necessary to perfect the urban governance system and capability. Particularly, we believe that certain workforce, material, and financial resources should be guaranteed and used more efficiently. Third, sustainable city development may depend on urban development model innovation, rather than in the pursuit of expanding or limiting city size. Hence, local governments implementing urbanization reforms should emphasize new and intelligent technology (e.g., Internet, big data, and artificial intelligence) to promote economic and social development, and ensure a scientifically based, refined, and intelligent governance that supports the construction of an innovative urban governance system and development model. From an empirical standpoint, we pay special attention to a context (i.e., China) that provides a limited ground for examining effects of both city size or governance capacity at work in other economies. Further analysis of urban resilience against COVID-19 that connects macro estimates offered by this paper to the data that characterize the processes in other countries remains an exciting area for future research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 8
Urban governance and COVID-19 prevention and control: mechanism testing and decomposition.

		Workforce		Financial		Material	
	Log (Cure)	Pdoc	Log (Cure)	Pfin	Log (Cure)	Pbed	Log (Cure)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ucd	0.024***	0.727***	0.010	0.511***	0.020***	0.978***	0.017**
	(0.005)	(0.045)	(0.007)	(0.114)	(0.006)	(0.085)	(0.007)
Pdoc			0.032***				
			(0.008)				
Pfin					0.026**		
					(0.013)		
Pbed							0.017***
							(0.005)
Urbar	0.002	0.268***	-0.010*	0.111	-0.005	0.484***	-0.010*
	(0.006)	(0.099)	(0.005)	(0.082)	(0.005)	(0.169)	(0.005)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	259	264	252	264	252	263	251
R^2	0.523	0.663	0.552	0.522	0.538	0.572	0.558

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