Measuring the differentiated contribution of foreign direct investment to regional GDP growth

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Abstract Foreign direct investment (FDI) plays an indispensable role in the socio-economic development of countries and plays a key role in promoting regional GDP growth. To investigate the differentiated impact of FDI on regional GDP growth in China, this paper proposes the Dagum Gini coefficient calculation method to compare whether FDI investment disparities across regions have contributed to economic gaps between coastal and inland regions. The OLS statistical regression method is employed as the empirical research method to determine the selection of dependent variables, control variables, and other variables. Using sample data from China spanning 2006 to 2023, empirical analysis is conducted. The analysis results indicate that the uneven distribution of FDI inevitably influences the economic disparities among China's eastern, central, and western regions. The Gini coefficient of FDI distribution differences generally moves in the same direction as the Gini coefficient of per capita GDP differences. Through full-sample benchmark, heterogeneity, and robustness tests, it is confirmed that improvements in FDI quality can significantly promote regional GDP growth.

Index Terms foreign direct investment, GDP, Gini coefficient, OLS statistical regression method

I. Introduction

Since the reform and opening-up, foreign direct investment has been one of the driving forces behind China's economic development [1]. By introducing and utilizing foreign capital, China has not only promoted its own rapid economic development but also contributed to global economic growth [2], [3].

The inflow of foreign direct investment has been an important driving force behind China's rapid economic development [4]. First, foreign capital has brought China a large amount of capital, technology, and management experience, promoting the upgrading and optimization of China's industrial structure [5], [6]. Second, foreign investment has created employment opportunities in China, alleviating employment pressure [7]. Additionally, through collaboration with Chinese domestic enterprises, foreign investment has provided more opportunities for Chinese companies, enhancing their competitiveness [8], [9].

However, foreign direct investment has also exacerbated regional disparities in GDP growth [10]. This is because the concentrated inflow of foreign investment has amplified the developmental advantages of affluent regions [11]. Foreign direct investment tends to favor regions with abundant resources, well-developed infrastructure, and large market sizes, thereby further expanding the advantages of these regions [12]-[14]. Conversely, relatively poorer regions, due to their lower attractiveness, struggle to attract sufficient foreign investment, leading to an increasingly widening GDP gap with wealthier regions [15], [16]. Additionally, foreign direct investment may exacerbate income inequality and contribute to social unfairness [17]. Foreign-invested enterprises often concentrate in industrial or high-value-added sectors, which typically have limited demand for low-skilled labor, potentially reducing employment opportunities for low-skilled workers and rural populations, thereby exacerbating income disparities [18]-[20]. To mitigate the expansion of regional GDP gaps caused by foreign direct investment, governments should implement proactive policy measures [21], [22]. First, governments can increase support for the development of underdeveloped regions by providing more investment and subsidies [23]. Additionally, by improving infrastructure, enhancing the investment environment, and improving service quality, the attractiveness of underdeveloped regions can be increased to attract more foreign investment [24], [25].

Literature [26] indicates that foreign direct investment (FDI) in each country is concentrated in a small number of regions. Based on data from Chinese cities, it points out that FDI is concentrated in China's coastal cities, and its "interregional spillover effects" have a positive impact on the growth of inland cities. Meanwhile, the industrial development of inland cities also affects their ability to absorb coastal FDI. Literature [27] uses panel data from

China's provinces, municipalities, and autonomous regions to explore the impact of inward foreign direct investment (IFDI) and outward foreign direct investment (OFDI) on regional innovation performance. The study shows that IFDI and OFDI have a positive impact on innovation performance, with IFDI having a greater impact on new product sales than OFDI. Literature [28] conducted an empirical analysis using panel least squares regression to examine the impact of FDI in the industrial sector on regional inequality in China's industrial value-added from 2003 to 2013. The results indicate that despite policy support for the economic development of inland regions, foreign companies still prefer to invest in coastal provinces. Literature [29] conducted a regression analysis of FDI and various economic growth indicators to examine the relationship between FDI and Australia's economic growth. The results indicate that FDI inflows contribute to economic growth, including GDP growth, export performance, and employment. Literature [30] examines the relationship between renewable energy consumption, FDI, and GDP across Chinese provinces, revealing that the relationship between per capita GDP, per capita FDI, and per capita renewable energy consumption is in a long-term stable equilibrium state. Literature [31] suggests that social capital can serve as one of the mediating factors determining the scale and direction of FDI's growth and productivity spillover effects at the regional level. To maximize FDI returns, it is necessary to consider the origin of foreign investors and the sectoral composition of FDI inflows. Literature [32] explores the impact of FDI inflows and institutional quality (IQ) on economic growth, revealing that FDI inflows and IQ are important factors for rapid economic growth, but FDI-driven economic growth is higher in Asian and Southern African countries. Literature [33] employs econometric and spatial analysis methods to examine the regional-specific determinants of FDI in China's eastern, central, and western regions. The findings suggest that governments seeking to attract FDI should not rely solely on it to promote local economic development but should instead focus on integrating local conditions with FDI to achieve economic growth. Literature [34] conducted a bibliometric study to measure FDI-EG research from various perspectives, revealing that current research on FDI firms primarily focuses on technology, firm performance, and theoretical exploration, while also tracing the evolution of FDI-EG research. Literature [35] assessed the impact of FDI on total factor productivity (TFP) across Russian regions and explored potential synergies between FDI and local R&D potential, aiming to validate the absorption capacity hypothesis. It revealed that FDI plays a significant role in regional economic development in Russia. Literature [36] analyzes the impact of FDI inflows on the development of Indian states, finding that, except for a few states, FDI inflows have made little contribution to the economic development of most Indian states. This is because FDI flows in the form of brownfield investments, and most regions lack the conditions to attract FDI.

FDI, as a form of international capital flow, is an important means of optimizing resource allocation and promoting productivity development on an international scale. In response to the differentiated impact of FDI on regional GDP growth in China, this paper proposes the Dagum Gini coefficient calculation method, defines the formula for the overall Dagum Gini coefficient, uses the Gini coefficient decomposition method to decompose overall differences, and decomposes regional gaps and their sources. An FDI analysis model is established, and a regional production function for Region $Cobb-Douglas$ is proposed. By taking the logarithm, the corresponding statistical regression calculation method is obtained. The GDP of each region is compared with the national average values of each variable to optimize the empirical model. Additionally, the OLS statistical regression method is employed, with a pooled data statistical approach for the research design. The Dagum Gini coefficient is used to measure the gaps in foreign investment and economic development between China's eastern, central, and western regions through dynamic comparison. The FDI analysis model and OLS statistical regression method are utilized to conduct an empirical analysis of the impact of FDI quality on regional GDP growth in China.

II. Study Design

Foreign direct investment (FDI) is a special form of transnational capital flow [37]. With economic development and the improvement of China's level of opening up, foreign capital has entered China in various forms, including human capital, technical capital, and so on. This paper conducts an in-depth study of the differentiated impact of FDI on regional GDP growth, conducts a quantitative analysis of the imbalance in FDI distribution and economic disparities in China, and examines the impact of FDI quality on regional GDP growth in China.

II. A.Research Sample and Data Sources
This paper uses data from 27 provinces in mainland China (including municipalities and autonomous regions, hereinafter referred to as provinces), excluding Tibet, Qinghai, and Hainan. Since Chongqing was established relatively recently, its data has been merged with that of Sichuan. Additionally, due to inconsistencies in the starting dates for the publication of FDI data across provinces, the time period selected to ensure the integrity of the sample data is 2006–2023. The data mainly comes from the National Bureau of Statistics of China, the China Statistical Yearbook, the statistical yearbooks of each province, the China Industrial Economy Statistical Yearbook, the China

Science and Technology Statistical Yearbook, the China Energy Statistical Yearbook, and the China Environment Yearbook.

II. B. Research Methods

II. B. 1) Dagum Gini coefficient calculation method

The Dagum Gini coefficient is an improved and revised version of the traditional Gini coefficient. Compared to the traditional Gini coefficient, the Dagum Gini coefficient introduces a parameter to adjust the calculation of the Gini coefficient, thereby more accurately reflecting the degree of income inequality [38]. It can further decompose the total income difference into intra-group differences, inter-group net differences, and hyper-variability density, fully considering the distribution of sub-samples, enabling a more detailed analysis of the intrinsic structure and relationships within the data. This addresses the issue of sample overlap that cannot be calculated using the traditional Gini coefficient and the Theil index, thereby improving the accuracy of measuring regional income differences.

In the Dagum Gini coefficient, inequality caused by inter-group overlap is referred to as excess variability. If there is overlap between sub-samples, meaning that some high-income regions have income levels lower than those of low-income regions, while some low-income regions have income levels higher than those of high-income regions. If the income of low-income groups in low-income regions is increased while maintaining the income of low-income groups in high-income regions, this may increase the intra-group Gini coefficient and exacerbate inequality in the overlapping regions, leading to an increase rather than a decrease in the Dagum Gini coefficient. Therefore, when there is a high degree of hyper-variability density between sub-samples, to reduce the Dagum Gini coefficient, it is necessary to consider both increasing the income of low-income groups in low-income regions and increasing the income of low-income groups in high-income regions. Generally speaking, the higher the Dagum Gini coefficient value, the greater the income disparity. The specific calculation method is as follows:

The overall Dagum Gini coefficient is defined as shown in Equation (1), where k denotes the number of regional divisions. China is primarily divided into three regions: the eastern region, the central region, and the western region; n denotes the number of households, $n_j(n_h)$ denotes the number of households in region $j(h)$, $y_{ji}(y_{hr})$ denotes the per capita net income of any household in region $j(h)$, and μ denotes the average per capita net income of all households:

$$G = \sum_{j=1}^{k}\sum_{n=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{nh}\frac{|y_{ji}-y_{hr}|}{2n^2\mu} \tag{1}$$

Before decomposing per capita net income, it is necessary to calculate the mean per capita net income for each region and rank them, i.e., $\mu_h \leq \cdots \leq \mu_j \leq \cdots \leq \mu_k$. Thus, the Dagum Gini coefficient G representing the overall per capita net income of households can be further decomposed into the intra-group Gini coefficient G_w, the inter-group net Gini coefficient G_b, and the hyper-variability density G_i, with the following relationships among the coefficients: $G = G_w + G_b + G_t$."

According to Dagum's decomposition method for the Gini coefficient, the overall difference can be further decomposed as follows. Equation (2) represents the Gini coefficient of per capita net income for households in region j, G_{jj} Equation (3) represents the contribution rate of intra-regional differences to the overall difference, G_w; Equation (4) represents the inter-group net Gini coefficient between region j and region h, G_{jh}; Equation (5) represents the contribution rate of the net inter-regional difference to the overall difference, G_{nb}; Equation (6) represents the contribution of the excess variation density, G_t;

$$G_j = \frac{\frac{1}{2\mu_j}\sum_{i=1}^{n_j}\sum_{r=1}^{n_j}|y_{ji}-y_{hr}|}{n_j^2} \tag{2}$$

$$G_w = \sum_{j=1}^{k}G_{jj}p_js_j \tag{3}$$

$$G_{jh} = \frac{\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}|y_{ji} - y_{hr}|}{n_j n_h (\mu_j + \mu_h)} \tag{4}$$

$$CF_{nb} = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}|p_j s_h + p_h s_j|D_{jh} \tag{5}$$

$$G_t = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j)(1 - D_{jh}) \tag{6}$$

Among these, $p_j = n_j\mu, s_j = n_j\mu_j/n\mu$. Additionally, D_{jh} represents the mutual influence between the indicators of regions j and h, while d_{jh} reflects the difference in per capita net income between these two regions, i.e., the expected value of the sum of all sample values that satisfy the condition $y_{jh} - y_{ji} > 0$ in these two regions. p_{jh} represents the expected value of the sum of all sample values in regions j and h that satisfy the condition $y_{hr} - y_{ji} > 0$. The definitions of D_{jh}, d_{jh}, p_{jh} are expressed by equations (7) to (9):

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \tag{7}$$

$$d_{jh} = \int_0^\infty dF_j(y)\int_0^y (y-x)dF_h(x) \tag{8}$$

$$p_{jh} = \int_0^\infty dF_h(y)\int_0^y (y-x)dF_j(x) \tag{9}$$

Among them, $(F_j)F_h$ is the cumulative distribution function of the $j(h)$ region. Therefore, $y_{ji}(y_{hr})$ can be used to represent the per capita net income of households, and the regional differences and sources can be decomposed.

II. B. 2) Construction of measurement models
1) Model Derivation

This paper primarily analyzes the substantive impact of FDI on regional GDP growth in China. Research on regional GDP growth differences should be based on long-term observations of regional GDP growth. Therefore, this paper adopts the analytical framework of development economics and assumes that regional GDP growth conforms to the Cobb-Douglas production function, where total output Y represents regional total output. Inputs include capital K and labor L, with capital inputs divided into domestic investment K_d and foreign direct investment K_f. The regional production function can be expressed as:

$$GDP = F(K_d, K_f, L) \tag{10}$$

The regional $Cobb-Douglas$ production function can be written as:

$$GDP = AK_d^a L^b K_f^c \tag{11}$$

To facilitate statistical analysis, the logarithm of formula (11) is taken to obtain the statistical regression formula (12):

$$In(GDP) = In(A) + aIn(K_d) + bIn(L) + cIn(K_f) + \varepsilon \tag{12}$$

where $In(A)$ is the intercept estimated by the equation, coefficients a, b, c are the estimated elasticities of explanatory variables K_d, L, K_f on regional economic growth, and ε is the statistical error. This paper examines the actual impact of FDI on GDP growth in China's eastern, central, and western regions. To compare whether differences in FDI investment across regions have led to economic disparities between the eastern, central, and western regions, the empirical design compares the GDP, K_d, L, K_f of each region with the national average values of each variable. The empirical model can be rewritten as follows:

$$\frac{In(GDP)}{\ln(gdp)} = In(A) + a\frac{In(K_d)}{\ln(k_d)} + b\frac{In(L)}{\ln(l)} + c\frac{In(K_f)}{\ln(k_f)} + \varepsilon \tag{13}$$

where gdp, k_d, l, k_f represent the national average values of GDP, K_d, L, K_f, respectively.

2) Empirical design

The empirical study uses the OLS statistical regression method and is conducted using the pooling data statistical method [39]. The data for the empirical study is mainly from the "China Statistical Yearbook," and the research area is divided into eastern, central, and western China.

II. C. Variable Selection
II. C. 1)   Dependent variables
This paper selects economic growth (GTFPit) as the dependent variable. Economic growth (GTFPit) is represented by the growth rate of total factor productivity.

II. C. 2)   Core explanatory variables
The core explanatory variable is FDI quality (QFDI). Based on the definition of FDI quality, this paper combines five indicators—profitability, technological level, management level, actual scale, and export capacity—into a comprehensive indicator to comprehensively characterize the quality of foreign direct investment.

II. C. 3)   Control variables
1) Environmental Regulation (ER): This study uses pollution control investment to measure environmental regulation.
    2) Trade Openness (OPEN): Measured by the ratio of total imports and exports to GDP.
    3) Human Capital (HP): This is represented by the ratio of the number of R&D personnel to the total number of employed individuals.
    4) Financial Development Level (JRFZ): This is measured by the ratio of the total loan balances of financial institutions in each province, municipality, and autonomous region to GDP.
    5) Fiscal Decentralization (FD): Fiscal autonomy is used as a proxy variable for fiscal decentralization.

II. C. 4)   Mediating variables
1) Industrial structure: Mainly divided into two indicators: industrial structure rationalization (SR) and industrial structure upgrading (SH).
    2) Innovation capacity (CXZS): Measured by R&D expenditure, R&D personnel investment, patent authorization volume, and other factors.

III. Measurement Analysis of Regional Imbalances in FDI and Economic Disparities in China
This chapter uses the Dagum Gini coefficient to measure the gap between foreign investment and the economy in China's three major regions—the east, central, and west—and conducts dynamic comparisons and empirical analyses based on this.

III. A. Analysis of regional economic disparity results
Calculate the Gini coefficient for China's three major regions—the eastern, central, and western regions—from 2006 to 2023, as shown in Table 1. First, from the Gini coefficient of regional disparities in per capita GDP, it can be seen that the internal disparities in the eastern region grew rapidly between 2006 and 2014, remained in a state of slight fluctuation between 2015 and 2023, but were significantly higher than those in the central and western regions, indicating that the internal differences in per capita GDP in this region are relatively large. In the central region, the internal Gini coefficient decreased by an average of 3% annually between 2006 and 2011, but entered an adjustment phase in the following four years, with regional disparities stabilizing around 0.016. After 2016, there was a slight upward trend. Compared to other years, the western region showed a more pronounced downward trend in the first three years, followed by fluctuations around 0.045 thereafter. Overall, compared to 2006, the internal GDP per capita gaps in the central and western regions have decreased to varying degrees by 2023, while the internal Gini coefficient in the eastern region has increased.

Table 1: China 's regional economic Gini coefficient from 2006 to 2023

Year	Total Gini coefficient	Intra-region difference			
		Eastern region	Central region	Western region	Intra-regional gap contribution
2006	0.308	0.056	0.038	0.061	0.018
2007	0.311	0.047	0.023	0.054	0.018
2008	0.311	0.063	0.019	0.048	0.018
2009	0.312	0.057	0.02	0.045	0.018
2010	0.315	0.049	0.033	0.05	0.018
2011	0.318	0.068	0.02	0.048	0.018
2012	0.318	0.055	0.016	0.046	0.019
2013	0.341	0.068	0.016	0.046	0.021
2014	0.343	0.071	0.018	0.041	0.021
2015	0.355	0.068	0.016	0.041	0.022
2016	0.332	0.065	0.016	0.045	0.022
2017	0.324	0.064	0.017	0.043	0.022
2018	0.324	0.069	0.017	0.044	0.022
2019	0.308	0.065	0.017	0.045	0.021
2020	0.306	0.064	0.018	0.042	0.021
2021	0.298	0.069	0.021	0.044	0.022
2022	0.299	0.067	0.022	0.044	0.022
2023	0.296	0.069	0.022	0.045	0.022

III. B. Analysis of the results of regional differences in FDI distribution

The distribution differences of FDI across the three major regions are analyzed, with the results shown in Table 2. Regarding the regional distribution gaps of FDI, compared to 2006, the Gini coefficients within each region have all decreased, with the eastern, central, and western regions decreasing by 13.43%, 59.2%, and 25.54%, respectively. This indicates that FDI in the central region not only has the smallest distribution gap but also the most significant decrease. Overall, the regional distribution disparity of FDI decreased from 0.075 in 2006 to 0.056 in 2023, a reduction of 25.33%. The distribution disparity of FDI between regions also decreased, with the eastern-central, eastern-western, and central-western regions decreasing by 9.25%, 15.97%, and 1.38%, respectively. This indicates that although the eastern and western regions have the largest distribution gap in FDI, their decline has been the most significant since 2006. Overall, the regional distribution disparity of FDI decreased from 0.451 in 2006 to 0.406 in 2023, a decrease of 9.98%.

Table 2: Gini coefficient of regional distribution difference of FDI in China

Year	Total Gini coefficient	Intra-region difference				Inter-provincial differences			
		Eastern region	Central region	Western region	Intra-regional gap contribution	Eastern-Central	East-West	Central-West	Contribution of inter-regional gap
2006	0.526	0.201	0.174	0.184	0.075	0.638	0.808	0.508	0.451
2007	0.507	0.17	0.176	0.144	0.055	0.617	0.805	0.508	0.452
2008	0.511	0.168	0.19	0.156	0.066	0.66	0.774	0.486	0.445
2009	0.529	0.18	0.202	0.226	0.07	0.69	0.806	0.486	0.459
2010	0.54	0.202	0.08	0.23	0.074	0.733	0.785	0.484	0.466
2011	0.534	0.193	0.063	0.232	0.069	0.699	0.804	0.485	0.465
2012	0.539	0.213	0.037	0.204	0.069	0.672	0.844	0.493	0.47
2013	0.525	0.203	0.092	0.167	0.07	0.628	0.815	0.509	0.455
2014	0.511	0.204	0.097	0.18	0.067	0.591	0.786	0.529	0.444
2015	0.516	0.207	0.139	0.166	0.068	0.576	0.802	0.545	0.448
2016	0.508	0.194	0.159	0.147	0.062	0.559	0.785	0.564	0.446
2017	0.486	0.177	0.163	0.16	0.057	0.565	0.746	0.537	0.429
2018	0.475	0.175	0.111	0.154	0.059	0.539	0.728	0.535	0.416
2019	0.469	0.164	0.07	0.128	0.055	0.562	0.704	0.522	0.414
2020	0.456	0.165	0.066	0.13	0.051	0.549	0.685	0.503	0.405
2021	0.456	0.168	0.071	0.137	0.052	0.562	0.675	0.505	0.404

2022	0.457	0.17	0.07	0.136	0.057	0.578	0.659	0.498	0.4
2023	0.462	0.174	0.071	0.137	0.056	0.579	0.679	0.501	0.406

The changes in the regional distribution of FDI in China from 2006 to 2023 are shown in Figure 1. The total Gini coefficient for regional distribution of FDI decreased from 2006 to 2008, rose slowly from 2009 to 2012, and continued to decline in subsequent years, consistent with previous analyses of FDI distribution. Overall, the imbalance in FDI regional distribution has decreased, from 0.526 in 2006 to 0.462 in 2023, representing a reduction of 12.17%. As shown in the figure, the Gini coefficient for FDI distribution differences between regions accounts for 87.88% of the overall Gini coefficient, indicating that the overall FDI distribution differences are primarily driven by regional FDI distribution patterns.
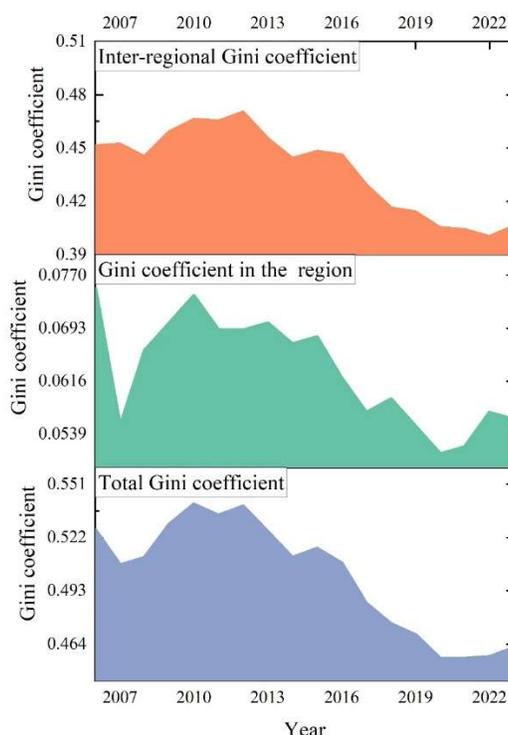

Figure 1: The change of regional distribution difference of FDI in China

III. C. Comparative Analysis of Regional Economic Disparities and Imbalances in FDI Distribution

The Gini coefficient for the distribution of per capita GDP and FDI across Chinese regions is shown in Table 3. As can be seen from the table, between 2006 and 2023, the Gini coefficient for per capita GDP across Chinese regions showed a fluctuating trend and ultimately reflected a narrowing of economic disparities. Meanwhile, the distribution differences in FDI across the three major regions showed a fluctuating decrease, with the trend particularly pronounced between 2015 and 2020. The trends in these two indicators overlapped to some extent.

Table 3: China 's inter-regional per capita GDP and FDI from 2006 to 2023

Year	Eastern-Central		East-West		Central-West	
	Per capita GDP	FDI	Per capita GDP	FDI	Per capita GDP	FDI
2006	0.38	0.638	0.57	0.808	0.244	0.508
2007	0.391	0.617	0.573	0.805	0.236	0.508
2008	0.395	0.66	0.572	0.774	0.228	0.486
2009	0.398	0.69	0.571	0.806	0.22	0.486
2010	0.4	0.733	0.58	0.785	0.23	0.484
2011	0.4	0.699	0.587	0.804	0.234	0.485
2012	0.414	0.672	0.601	0.844	0.231	0.493
2013	0.43	0.628	0.63	0.815	0.236	0.509
2014	0.43	0.591	0.64	0.786	0.238	0.529

2015	0.434	0.576	0.663	0.802	0.248	0.545
2016	0.411	0.559	0.633	0.785	0.255	0.564
2017	0.396	0.565	0.614	0.746	0.261	0.537
2018	0.383	0.539	0.596	0.728	0.263	0.535
2019	0.374	0.562	0.576	0.704	0.25	0.522
2020	0.368	0.549	0.559	0.685	0.248	0.503
2021	0.363	0.562	0.544	0.675	0.242	0.505
2022	0.361	0.578	0.54	0.659	0.241	0.498
2023	0.362	0.579	0.533	0.679	0.24	0.501

To better observe the relationship between per capita GDP and FDI distribution differences from 2006 to 2023, a comparative chart is presented in Figure 2. As shown in the figure, the dynamic trends of the Gini coefficient for per capita GDP and FDI changes are generally consistent, both experiencing an initial rise followed by a decline. However, changes in per capita GDP lag behind those in FDI, and the magnitude of changes in the FDI Gini coefficient is significantly greater than that of per capita GDP. In summary, the distribution differences in FDI and the Gini coefficients of per capita GDP differences among China's three major regions—the eastern, central, and western regions—generally move in the same direction, but there are certain differences in the magnitude of these changes.
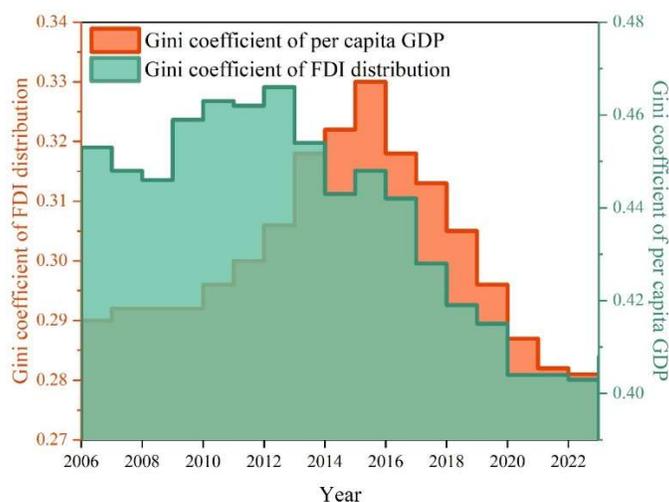

Figure 2: Differences in the distribution of per capita GDP and FDI between regions

IV. Empirical Analysis of the Impact of FDI on Regional GDP Growth in China

This chapter will use the FDI analysis model and OLS statistical regression method to conduct an empirical analysis of the impact of FDI on regional GDP growth in China.

IV. A. Full sample benchmark testing

To examine the average impact of FDI quality on regional GDP growth in China, this paper first tests the basic relationship between the two using the full sample. The test results are detailed in Table 4. Columns (2) to (6) represent the stepwise addition of control variables. According to the regression results in the table, when all control variables are added, the quality of FDI has a positive impact on regional GDP growth in China, and this positive effect is significant at the 1% level, meaning that as the quality of FDI continues to improve, it promotes regional GDP growth.

Table 4: Full sample benchmark regression results

-	(1)	(2)	(3)	(4)	(5)	(6)
	GTFP	GTFP	GTFP	GTFP	GTFP	GTFP
QFDI	0.234***	0.238***	0.226***	0.233***	0.226***	0.235***
	(0.078)	(0.075)	(0.076)	(0.078)	(0.077)	(0.082)
HP	-	3.686***	3.445***	3.863***	3.628***	3.422***

	-	(1.042)	(1.067)	(1.012)	(1.035)	(1.045)
OPEN	-	-	0.086**	0.075**	0.077**	0.084**
	-	-	(0.034)	(0.034)	(0.031)	(0.038)
ER	-	-	-	-0.015*	-0.015*	-0.018*
	-	-	-	(0.007)	(0.008)	(0.008)
JRFZ	-	-	-	-	-0.038	-0.043
	-	-	-	-	(0.033)	(0.033)
FD	-	-	-	-	-	-0.289
	-	-	-	-	-	(0.187)
Time fixed	YES	YES	YES	YES	YES	YES
Individual fixation	YES	YES	YES	YES	YES	YES
_Cons	1.060***	0.934***	0.922***	1.106***	1.147***	1.274***
	(0.018)	(0.046	(0.052)	(0.118)	(0.124)	(0.185)
R^2	0.16	0.153	0.155	0.181	0.175	0.176

IV. B. Heterogeneity test

1) Testing by different geographical regions

Based on the division of China into eastern, central, and western regions, heterogeneity tests were conducted. Considering that panel data may change from short panel to long panel, panel-corrected standard errors (PCSE) were used, and explanatory variables were standardized to make the regression results more robust. The results of the regional heterogeneity tests are shown in Table 5. Models (1) and (3) present the regression results of FDI quality on GDP growth in the eastern and central-western regions, respectively, without controlling for variables. Models (2) and (4) present the regression results of FDI quality on GDP growth in the eastern and central-western regions, respectively, after controlling for variables. The regression results show that FDI quality significantly promotes regional GDP growth in both the eastern and central-western regions. A comparison reveals that the impact of FDI quality on GDP growth passed the 5% significance level test in the eastern region, but only reached significance at the 10% level in the central-western region. This indicates that compared to the central-western region, improvements in FDI quality have a stronger promotional effect on GDP growth in the eastern region. A possible reason is that the infrastructure in the central and western regions is relatively underdeveloped, unable to match the high-quality FDI absorbed, thus failing to generate effective technology spillover effects and consequently unable to exert a stronger promotional effect on GDP growth.

Table 5: Results of regional heterogeneity test

	(1)	(2)	(3)	(4)
	GTFP	GTFP	GTFP	GTFP
QFDI	0.444	0.668**	0.211**	0.152*
	(0.288)	(0.283)	(0.085)	(0.076)
HP	-	3.736**	-	1.550
	-	(1.331)	-	(1.523)
OPEN	-	0.242***	-	0.168*
	-	(0.058)	-	(0.095)
ER	-	-0.046**	-	-0.005
	-	(0.021)	-	(0.007)
JRFZ	-	-0.105	-	-0.024
	-	(0.082)	-	(0.026)
FD	-	-0.355	-	-0.118
	-	(0.368)	-	(0.141)
Time fixed	YES	YES	YES	YES
Individual fixation	YES	YES	YES	YES
_Cons	1.006***	1.524**	1.068***	1.112***
	(0.094)	(0.488)	(0.018)	(0.105)
R^2	0.251	0.316	0.214	0.214

2) Testing based on the varying levels of development of the tertiary sector

Considering that there may be differences in the levels of development of the three sectors among different provinces, this could lead to variations in the impact of FDI quality on regional GDP growth in China. The results of the regional tests based on the level of development of the tertiary sector are shown in Table 6. The models (1) and (3) in the table perform regression analyses separately for regions with a developed tertiary sector and regions with an underdeveloped tertiary sector without including control variables. Models (2) and (4) include control variables and separately examine the impact of FDI quality on regional GDP growth in regions with a developed tertiary sector and regions with an underdeveloped tertiary sector. According to the regression results, FDI quality has a significant positive promotional effect on regional GDP growth, regardless of whether the region has a developed or underdeveloped tertiary sector. Further comparison reveals that the significance is stronger in provinces with a developed tertiary sector than in regions with an underdeveloped tertiary sector. This may be because regions with a relatively developed tertiary sector have a more highly specialized industrial structure, with industries concentrated in labor- and capital-intensive sectors that consume fewer resources, enabling efficient resource allocation, reduced energy consumption, and weaker environmental pollution, thereby significantly promoting regional GDP growth.

Table 6: According to the test of different levels of development of the tertiary industry

-	(1)	(2)	(3)	(4)
	GTFP	GTFP	GTFP	GTFP
QFDI	0.267**	0.208**	0.168*	0.156*
	(0.112)	(0.094)	(0.105)	(0.096)
Control variables	-	YES	-	YES
Time fixed	YES	YES	YES	YES
Provincial fixed	YES	YES	YES	YES
_Cons	1.061***	1.358***	1.048***	1.235***
	(0.026)	(0.215)	(0.0245)	(0.325)
R^2	0.155	0.188	0.214	0.222

IV. C. Robustness testing

1) Endogeneity issues

The findings of this study may be affected by endogeneity issues: on the one hand, there may be a reverse causal relationship between FDI quality and GDP growth, leading to endogeneity issues. FDI quality can promote GDP growth, but GDP growth can also affect FDI quality. On the other hand, although this study has controlled for other factors affecting GDP growth, there may still be omitted variables that cause the model to be incorrect. Additionally, there may be some errors in the measurement of FDI quality indicators during the research process.

To ensure that the regression results are more scientific and reliable, this paper will address the endogeneity issue. The results of the endogeneity treatment are shown in Table 7. Columns (1) and (2) in the table use lagged FDI quality and FDI quality growth rate as instrumental variables, respectively, and re-estimate regional GDP growth using two-stage least squares (2SLS) to reduce potential regression bias caused by endogeneity issues. To test the validity of the instrumental variables, this paper employs multiple statistical tests: the Kleibergen-Paap LM test and the Kleibergen-Paap Wald F test. The results of these statistical tests all reject the null hypothesis, passing the tests for unidentifiability and weak instrumental variables, further indicating a strong correlation between the instrumental variables and the endogenous variables. Finally, the probabilities from the Hansen test are 0.4755 and 0.2637, which fail to reject the null hypothesis of overidentification at the 10% significance level, indicating that the instrumental variables are exogenous and thus valid. From the regression results, it can be seen that after endogeneity treatment, the regression results of FDI quality on regional GDP growth remain significantly positive, indicating that improvements in FDI quality can significantly promote regional GDP growth, further validating the correctness of the theoretical analysis.

Table 7: Endogenous treatment results

-	(1)	(2)
QFDI	0.223**	0.224*
	(0.102)	(0.128)
Control variables	YES	YES
Time fixed	YES	YES
Provincial fixed	YES	YES
Kleibergen-Paap rk LM statistic	65.68	123.35

	[0.0000]	[0.0000]
Kleibergen-Paap rk Wald F statistic	95.58	134.126
	{19.93}	{19.93}
Hansen	[0.4755]	[0.2637]
R^2	0.068	0.071

2) Substitute indicator test

To enhance the robustness of the empirical results and make the research conclusions more scientific and credible, this paper conducted two types of robustness tests: first, replacing the explanatory variable, using the FDI performance index as a substitute indicator for FDI quality; Second, combining the GML productivity index with a non-radial, non-angular DEA-SBM model, the growth rates of total factor productivity for each province from 2006 to 2023 were calculated as a robustness indicator for GDP growth. The results of the robustness tests are shown in Table 8. The empirical results indicate that FDI quality has a positive and significant promotional effect on regional GDP growth in China, consistent with the previous estimation results. This suggests that the empirical results are robust.

Table 8: Robustness test results

-	(1)	(2)
	Replace explanatory variables	Replace the explained variable
QFDI	-	0.145*
	-	(0.076)
FDI performance	0.865*	-
	(0.515)	-
Control variables	YES	YES
Time fixed	YES	YES
Provincial fixed	YES	YES
_Cons	0.191	1.566***
	(0.278)	(0.414)
R^2	0.435	0.158

V. Conclusion

This paper first uses the Dagum Gini coefficient to measure the gaps in foreign investment and economic development among China's three major regions—the east, central, and west—and conducts dynamic comparisons and empirical analyses. Calculating the Gini coefficients for China's three major regions—the east, central, and west—from 2006 to 2023, the internal disparities in the eastern region are significantly higher than those in the central and western regions. Compared to 2006, the per capita GDP disparities within the central and western regions have decreased to varying degrees by 2023, while the Gini coefficient within the eastern region has increased. The Gini coefficients for FDI distribution differences in the three regions decreased by 13.43%, 59.2%, and 25.54%, respectively, compared to 2006. The distribution differences in the central region were the smallest, and the decrease was the most significant. The Gini coefficient for FDI distribution differences between regions decreased from 0.451 in 2006 to 0.406, representing a decrease of 9.98%. Additionally, the Gini coefficient for regional distribution differences accounted for 87.88% of the overall Gini coefficient, indicating that the overall distribution differences in FDI are primarily driven by regional distribution disparities. When comparing the economic disparities between the eastern, central, and western regions with the imbalance in FDI distribution, the Gini coefficient for per capita GDP across regions in China exhibits a fluctuating trend and ultimately decreases due to narrowing economic disparities. Meanwhile, the disparity in FDI distribution across regions shows a fluctuating decrease, with the two trends overlapping to some extent but differing in magnitude.

Using OLS statistical regression methods, an empirical analysis was conducted on the impact of FDI on regional GDP growth in China. In the full-sample benchmark test, FDI was found to have a positive impact on regional GDP growth in China, and this effect was significant at the 1% level. The continuous improvement in FDI quality can promote regional GDP growth in China. In the heterogeneity test, when examining different geographical regions, it was found that the quality of FDI in China's eastern, central, and western regions all significantly promote regional GDP growth. Additionally, through tests based on the different levels of development of the tertiary industry, it was confirmed that regardless of whether the region is developed or underdeveloped in terms of the tertiary industry, the quality of FDI exhibits a significant positive promotional effect on regional GDP growth. Finally, the analysis results were subjected to robustness tests, including endogeneity treatment and alternative indicator tests. In terms

of endogeneity treatment, the probability of the Hansen test was 0.4755 and 0.2637, respectively, failing to reject the null hypothesis of overidentification at the 10% significance level, confirming the validity of the instrumental variables. Furthermore, the regression results of FDI quality on regional GDP growth remained significantly positive after endogeneity treatment, validating the correctness of the analysis in this paper. In the replacement indicator test, both the explanatory variables and the dependent variables were replaced, yet the positive and significant promotional effect of FDI quality on China's regional GDP growth was still demonstrated, further indicating the robustness of the empirical results in this study.

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Express one's thanks

Declarations
The authors declare no conflict of interest concerning the results and content.

Data availability
The data is available on request.

Conflict of interest declaration
The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

Author contributions
The first and third authors were responsible for the research design, data collection, and data analysis. The first and second authors contributed to the manuscript writing and revision. All authors have read and agreed to the published version of the manuscript.

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