SPATIO-TEMPORAL DISPARITY IN THE INEQUALITY AND DETERMINANTS OF DISABILITY-RELATED MULTIPLE DEPRIVATION BETWEEN 2010 AND 2020 IN TIANJIN MUNICIPALITY, CHINA

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ABSTRACT

Inclusive development in the Global South encounters challenges from a growing disability and development gap amid increasing education, employment and social participation, accompanied by higher expectations and resource consumption. This study aims to analyse the spatio-temporal disparity of the Index of Disability-Related Multiple Deprivation (IDMD) across 313 sub-districts in Tianjin Municipality from 2010 to 2020 and identify the socioeconomic factors and their heterogeneous effects. Results show persistent urban–rural disparities but decreasing intra-municipality disparities. Deprivation inequality varies across regions – decreasing in urban fringe and rural areas but increasing in the urban centre. Economic growth initially reduces IDMD until a certain point, beyond which it increases. The growth of migrant and elderly populations decreases IDMD. Urbanization's impact is limited, mainly affecting middle quantiles. Considering rapid economic development, urbanization and ageing, prioritizing disability-inclusive development is imperative. Further research should focus on health equality, particularly addressing rural individuals with disabilities, informal employment and ageing effects.

Key words: Index of Disability-Related Multiple Deprivation; disability-inclusive development; intra-municipality disparity; rural left-behind persons with disabilities; informal employment; ageing disability

INTRODUCTION

Supporting the social development of impoverished or low-income households and vulnerable groups, and addressing social inequality are fundamental objectives of inclusive development (Rauniyar & Kanbur 2010; Ebuenyi *et al.* 2021). Within this context, persons with disabilities – defined as those who have long-term physical, mental, intellectual or sensory impairments which, in interaction with various barriers, may hinder their full and effective participation in society on an equal basis with others – have been recognized as a vulnerable group by the United Nations' 2030 Agenda for Sustainable Development, with a focus on poverty reduction (UNDP 2015). To promote disability-inclusive international cooperation,

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Catalina Devandas-Aguilar, the United Nations Special Rapporteur on the rights of persons with disabilities, published a report providing guidance to states and international actors on achieving disability inclusivity in line with the Convention on the Rights of Persons with Disabilities (CRPD) (United Nations 2020).

Deprivation refers to a state where individuals lack regular access to essential resources and services, such as income, employment, education and healthcare, which are necessary for their well-being (Townsend 1987; Nolan & Whelan 1996). For persons with disabilities, this deprivation is compounded by additional challenges, termed disability-related deprivation, where physical, social and institutional barriers further limit access to these essential resources, deepening their marginalization in already deprived contexts (Qiu *et al.* 2022). In countries of the Global South with low- and medium-average incomes, the prevalence of disability is notably high and persons with disabilities are more susceptible to poverty compared to their non-disabled counterparts (Mitra *et al.* 2013). This disparity highlights the social and economic exclusion they face, as they are often 'left behind' in the developmental progress benefiting others, including advances in education, employment and social participation. Research suggests that in emerging middle-income countries, this disability–development gap will widen as rising education, employment and social participation are matched by increasing expectations and resource consumption, while persons with disabilities continue to have fewer or no access to these resources (Groce & Kett 2013; Chung *et al.* 2020). Evidence from countries like South Africa, Brazil, India and China indicates that persons with disabilities are not benefiting equally from socioeconomic advancements, leaving them further behind (Hashemi Nazari *et al.* 2013; Mizunoya & Mitra 2013; Trani *et al.* 2020).

Previous studies have examined the socioeconomic deprivation and inequality faced by persons with disabilities and demonstrated the need for universal disability-related policies and benefits (Qiu *et al.* 2022). These studies rely on cross-sectional data and typically examine the spatial distribution of deprivation at a certain point in time, but do not account for spatio-temporal disparity. Longitudinal studies have demonstrated the growing socioeconomic status gap between persons with disabilities and wider society (Zhang *et al.* 2022). For instance, Brock's analysis of the national trends in the educational placement of students with an intellectual disability in the United States over the past 40 years found that progress had stalled in recent years and most students were educated in segregated settings (Brock 2018). Similarly, Garberoglio *et al.* (2019) and found it did not decrease between 2008 and 2017. Moreover, discrimination has been shown to negatively impact the salaries of employees with disabilities (Kruse *et al.* 2018). In terms of health, the strong association between disability and premature mortality continued from 1800 to 2000, with the disability–survival gap increasing (Junkka *et al.* 2022). However, most of these studies have focused on a specific dimension, and no measurement instrument has yet been developed with the capacity to measure changes in multiple disability-related deprivation associated with socioeconomic development, in accordance with contemporary disability paradigms.

Existing studies on the spatial patterns of deprivation and poverty have struggled to disentangle the interplay and significance of its varied drivers (Chen *et al.* 2019). Prior research has suggested that changes in housing discrimination and residential segregation, local policymaking and inequalities of economic and employment opportunities may be associated with spatial–temporal patterns of deprivation (Thompson & Dahling 2019). The drivers of deprivation vary across different levels of deprived areas, such as urban and rural regions within a municipality. For instance, Séguin *et al.* (2012) highlighted globalization, economic restructuring and government policy changes as significant factors shaping poverty patterns in metropolitan areas. Yuan *et al.* (2018) identified market-oriented urban regeneration, economic development and urbanization rates (URBs) as primary drivers of deprivation in urban and urban–rural mixed areas, while economic restructuring, housing reform and the urban–rural dichotomy influenced deprivation in rural areas of Chinese cities. In rural areas, the expansion of the non-farming sector, agricultural productivity,

availability of land and consumption levels in proximate urban areas were key drivers of reductions in rural poverty in developing countries (Lanjouw & Murgai 2009). Other studies found that the increase in the ageing population and inadequate provision of public services were key determinants of high levels of poverty in rural areas (Chen *et al.* 2016). Some studies have found that disability-related deprivation is consistent with general area-level deprivation and that the determinants may vary at different spatial scales (Bella & Dartanto 2018). However, understanding the dynamics and drivers of disability-related deprivation remains limited, especially concerning ageing, migration, rapid urbanization and economic growth in fast-growing developing countries.

The dynamic socioeconomic landscape of the past decade has notably impacted populations worldwide, with particularly pronounced effects in rapidly developing countries like China. In the past decade (2010–2020), China has experienced socioeconomic development and demographic change, with the Industrialisation Composite Index rising from 66 to 93 (100 indicates full industrialisation), the URB increased from 34.17% to 60.34% and the ageing population rate increased from 13.26% to 18.70% (Zheng 2021; Ma *et al.* 2023). This has led to a rise in industrial injuries, traffic accidents and age-related illnesses, which has contributed to the increase in the proportion of the population with a disability (Kämpfen *et al.* 2018). Consequently, this period holds significant importance in comprehending the growth of the disabled population in China. Tianjin is chosen for this study as it exemplifies the rapid urbanization and socioeconomic transformations seen across many cities in China, but with unique regional characteristics such as its economic structure and demographic composition that make it a pertinent case for exploring urban–rural disparities in disability-related deprivation. Anti-poverty policies and targeted initiatives, while implemented nationwide, have specifically addressed obstacles faced by individuals with disabilities and are particularly emphasized in rural areas, where their effects are more pronounced than in urban areas due to the lower baseline of social services and infrastructure (Chao *et al.* 2019). In these areas, enhancements in accessibility and healthcare can significantly transform daily life. This marked disparity underscores the need for a detailed study of rural–urban differences to fully understand and enhance the effectiveness of these interventions.

This study presents a spatio-temporal analysis of the changes in disability-related deprivation within a Chinese city from 2010 to 2020. The research focuses on examining the dynamics of the longstanding urban–rural deprivation gap and the heterogeneous effects of socioeconomic development and population structure on disability-related deprivation. The study aims to address three key research questions: (1) did disability-related deprivation change over time between sub-district units across municipality? (2) what is the impact of socioeconomic development and population structure on disability-related deprivation? and (3) did these factors have heterogeneous effects on different levels of deprived areas? This paper serves as the first empirical study in China to examine the dynamics of disability-related deprivation in representative mega city of Tianjin, reflecting the unique challenges and transformations seen in emerging upper-middle-income countries of the Global South. Tianjin's rapid urbanization and demographic shifts make it an ideal case for exploring the nuanced impacts of socioeconomic changes on disability-related deprivation at the municipality scale, thereby contributing unique insights into urban–rural disparities within the broader context of the Global South. The findings are expected to enhance our understanding of the significant variations in disability-related deprivation across different areas and demographics. Furthermore, by focusing on the Global South, this study addresses a significant gap in existing literature that often overlooks or underestimates the complexities and specific challenges faced by this region in the context of urbanization and ageing. Anticipated to inform the creation of tailored anti-deprivation policies, these results will guide adaptations to both temporal and spatial shifts in deprivation, address changes in socioeconomic and demographic contexts and implement differentiated strategies across areas with varying levels of deprivation. This is particularly crucial in the

Global South, where rapid urbanization and population ageing pose additional challenges. Ultimately, this approach aims to provide more effective and equitable support for individuals with disabilities and to ensure that the benefits of urban and demographic transitions are inclusively shared among all societal segments.

DATA AND METHODS

Study area – Tianjin, a mega industrial municipality southeast of Beijing, was selected as the study area. It is divided into 313 sub-districts, each averaging about 38.09 square kilometres in area and roughly 36,800 people in population. All sub-districts were allocated to one of three regions, following the 2021–2035 Tianjin Master Plan: the urban centre (total inner circles); the urban fringe (between urban and rural areas around the central urban area); and rural areas (outer city sub-districts and predominantly rural areas).

These regions vary not only in geographical characteristics but also in population dynamics. Between 2010 and 2020, the disabled population in Tianjin increased from 150,000 to 350,000. On average, each sub-district has a disabled population of 1134, representing 2.5% of its total population. Specifically, in the three types of regions, the average disabled populations are as follows: 2483 (3.6%) in urban centres, 1004 (2%) in the urban fringe and 646 (2.4%) in rural areas. During this period, the Tianjin Municipal Government initiated multiple policies and projects to improve disability-related services and access to built environments (Figure 1).

Data collection – This study used four primary data sources. Firstly, the social and health attributes of certified persons with disabilities (gender, age, disability type, disability level, household registration, current residential address, workplace, education level and marital status) in 2010 and 2020 were extracted from the Database of Persons with Disabilities in Tianjin. Secondly, the location and descriptors (type, year of construction, area and numbers of medical and nursing personnel) of disability-related services and facilities (schools, daycare centres, rehabilitation centres and employment services) were extracted from the Database of Disabled Facilities in Tianjin. The number and size of existing facilities in 2010 and 2020 were calculated based on the year of construction, taking into account the expansion and capacity of the facility. Both databases were supplied by the Tianjin Disabled Persons' Federation (TDPD)[1]. Details of the data processing methods have been described elsewhere (Qiu *et al.* 2022). Thirdly, location data of basic public service facilities (commercial, health, education, culture and sports) were extracted from Gaode Map POI data. Fourthly, elderly and migrant population data at sub-district level were drawn from the Sixth Census in 2010 and Seventh Census in 2020. GDP and URBs were extracted from the Tianjin district-level statistical yearbooks from 2011 to 2021.

Since administrative boundaries were adjusted during this decade, this study uses the administrative boundaries in 2020 as the reference for comparison. Two methods were used to facilitate spatial and temporal comparisons between unmatched and incomparable geographical units between 2010 and 2020. Several sub-districts in 2010 were merged based on 2020 boundaries, and the average values across these sub-districts were used. By contrast, some sub-districts in 2010 were split into small polygons and merged into different sub-districts in 2020. Values

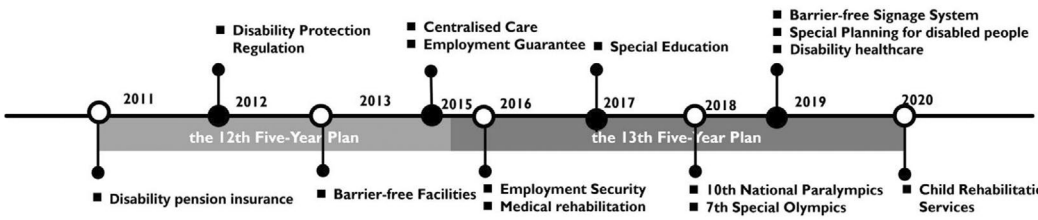

Figure 1. *Disability-related regulations, policies and projects introduced in Tianjin Municipality between 2010 and 2020.*

Table 1. *The domains and indicators of the IDMD.*

Domain	Domain weight (%)	Indicators	Indicator weight (%)
Employment	25	% persons with disabilities who are either unemployed (aged 18 to 60) or receive zero pension (age over 60)	10
		% industrial workers with disabilities	7.5
		% unskilled service sector workers with disabilities	7.5
Marital status	15	% persons with disabilities (aged >20) who have never been married	7.5
		% divorced persons with disabilities	7.5
Education	20	% persons with disabilities without a diploma	10
		% persons with disabilities (over15 years old) with low educational attainment (under junior high school)	10
Health	10	% persons with disabilities with the most severe level[a] of disability	15
Services	20	∑ of the closest distances of each type of disability service and facility to the sub-district population-weighted centroid	10
		∑ of the closest distances of each type of basic public service and facility to the sub-district population-weighted centroid	10
Barrier-free environment	10	The total number of barrier-free facilities	10

[a]*Each type of disability is divided into 4 levels depending on their severity, according to the "Practical Assessment Standards for People with Disabilities in China". The most severe level (level 1), indicates very serious barriers to participation in a social life, irrespective of the disability type.*

in these new sub-districts were recalculated using weightings based on area adjustments (Yuan *et al.* 2018). These weightings were derived to account for population distribution within the changing boundaries, ensuring that the recalculated values reflect the demographic realities of both time periods. This approach was crucial for mitigating potential distortions in the analysis caused by administrative changes.

Analysis and modelling – *Analysing the spatio-temporal disparity of* IDMD – Six domains of deprivation proposed by Qiu *et al.* (2022) were included in this study: employment status, marital status, education level, severity of disability, distance to basic public services and Barrier-free environment. To provide a more comprehensive picture of the employment situation of persons with disabilities, two indicators were added in the employment domain: the proportion of industrial workers with disabilities and the proportion of unskilled service-sector employees with disabilities (Table 1). These additions were deemed crucial for providing a more accurate representation of employment deprivation among the disabled.

Each domain and indicator were given a weighting value (Table 1). The same weightings were applied in 2010 and 2020 to aid comparability. Weightings were derived using the analytic hierarchy process (AHP), involving pairwise comparisons to evaluate each indicator's relative importance based on literature and expert consensus. This method was chosen to ensure a rigorous empirical basis, integrating methodologies from existing deprivation indices such as the English and European Indices of Deprivation (McLennan *et al.* 2019; Fabrizi *et al.* 2023) and adapting them to the context of disability, as detailed in studies from similar contexts in Chinese cities (Yuan *et al.* 2018) and specifics related to disability (Qiu *et al.* 2022). The specific

steps of the AHP method used are detailed in the Tables S1–S5. This approach ensures that the weightings accurately reflect the unique challenges faced by persons with disabilities, providing a robust framework for our analysis. The IDMD was calculated using Equation (1):

$$IDMD_i = \sum_{i=1}^{n} E_i \times \left(\sum_{j=1}^{k} L_{j=1} \times x_j \right) \quad (1)$$

where E_i is the weighting value i; L_j is the loading score for indicator j; and x_j is the standardized value of indicator j. All indicators were in the same direction. In each spatial unit (sub-district), the weight of each domain was multiplied by each indicator, and the IDMD value was calculated by adding all the products together. A higher IDMD score suggests a higher degree of deprivation. Changes in the value of the IDMD between 2010 and 2020 were calculated at sub-district level to illustrate the spatio-temporal disparity of IDMD.

Analysing the intra-municipality inequality of IDMD – The Theil Index was used to measure the inequality of IDMD across the municipality. Changes in the value of the Theil Index between 2010 and 2020 reflected the disparity of IDMD inequality. The Theil Index is the same as redundancy in information theory and reflects the maximum possible entropy of the data minus the observed entropy (Theil 1967). This index is widely used to measure relative economic development because it can differentiate between within-group inequality and between-group inequality. The Theil Index of IDMD inequality was calculated using Equation (2).

$$T = T_{BR} + T_{WR} = \sum_{i=1}^{3} y_i \times \log\left(\frac{y_i}{p_i}\right) + \sum_{i=1}^{3} y_i \times \left[\sum_{j} y_{ij} \log\left(\frac{y_{ij}}{p_{ij}}\right) \right] \quad (2)$$

where T is the inequality of IDMD across the whole municipality, T_{BR} is the between-group inequality of IDMD, that is, the inequality between different region types, and T_{WR} is the within-group inequality of IDMD, that is, the inequality between sub-districts in the same region type. i is the region type (i=1,2,3 corresponds to the urban centre, urban fringe and rural regions, respectively). y_i is the IDMD in i region as a percentage of total IDMD, and p_i is the number of persons with disabilities in i region as a percentage of the total number of persons with disabilities. j is the sub-unit of i, the sub-district. y_{ij} is the IDMD in j sub-district as a percentage of IDMD in i region, and p_{ij} is the number of persons with disabilities in j sub-district as a percentage of that in i region. The larger the T value, the greater the spatial inequality in disability-related deprivation in the municipality.

The contributions of between-group (inter-regional) (W_{BR}) and within-group (intra-regional) (W_{WR}) IDMD inequality were calculated using Equations (3 and 4).

$$WBR = TBR / T \quad (3)$$

$$WWR = TWR / T \quad (4)$$

Identifying regional or local clusters of inequality is a key element to understanding spatial inequality. Spatial inequality studies aim to understand whether these clusters are close or adjacent to each other or if they centre on the potential source of the inequality (Porter & Howell 2012).

This study used a LISA cluster transitions method to identify and visualize spatial clusters of inequality. In our LISA cluster transitions analysis, we utilized a Queen contiguity spatial weight matrix to define neighbourhood relationships among sub-districts. This matrix considers sub-districts sharing a boundary or a vertex as neighbours, which is appropriate for our analysis of spatial clusters of inequality at administrative level represented as polygon. This choice ensures that the spatial dependency is realistically represented, particularly useful for visualizing and analysing the transitions in IDMD values from 2010 to 2020. Each sub-district's interaction with its neighbours was assessed to track changes and persistencies in spatial clusters over the study period. A LISA cluster transition map was also produced to analyse

changes in spatial clusters of inequality over time. This method groups areas (in this case, sub-districts) by the changes in univariate LISA values over time (Martin *et al.* 2017). LISA cluster transitions provides a visual representation of a transition matrix. A sub-district with a high value of IDMD that is surrounded by other high-value sub-districts in 2010 and 2020 was given the value 11 (alternatively high–high and high–high). A sub-district that had a low IDMD value and was surrounded by other low IDMD value sub-districts in both years was given the value 22 (low–low and low–low), and a sub-district that changed from a not significant IDMD value in 2010 to a high value of IDMD surrounded by other high-value sub-districts was given the value 01 (or not significant, high–high). Overall, the transitions among high–high, low–low and not significant enable an understanding of the regional changes in IDMD at sub-district level.

Modelling the socioeconomic determinants of IDMD – Quantile regression (QR) was used to model the socioeconomic determinants of IDMD. This method was chosen over OLS regression as it does not assume explanatory variables have a particular distribution or the same distribution, which is often the case for socioeconomic variables, nor does it assume the presence of a moment function. QR also provides accurate and robust findings in the presence of outliers and heavily tailed distributions (Bera *et al.* 2016). Thus, this model could reveal whether the determinants had heterogeneous effects on different levels of IDMD. The quantile estimator is obtained by solving the following optimization problem, Equation (5):

$$min_{\beta\in R^k}\left[\sum_{i\in\{i:y_i\geq x_i'\beta\}}\theta|y_i-x_i'\beta|+\sum_{i\in\{i:y_i\geq x_i'\beta\}}(1-\theta)|y_i-x_i'\beta|\right] \quad (5)$$

For the θth quantile $(0<\theta<1)$, where y_i is the dependent variable and x_i is a k by 1 vector of the explanatory variables.

Reducing disability-related deprivation requires a clear understanding of its determinants. Drawing on existing studies on the dynamics of poverty and deprivation (Chen *et al.* 2016; Thompson & Dahling 2019), the explanatory variables used in this study included dummy variables which indicated the year in which a sub-district fell (Year 2010 and Year 2020), as well as per capita GDP (PGDP), URB, elderly population rate (EP) and migrant population rate (MP) (Table 2). The square of PGDP was also included to verify whether IDMD and PGDP met the Kuznets hypothesis. The year's dummy variables were used to compare differences between years. A log transformation was applied to IDMD, PGDP, URB and MP variables to make their distributions more symmetric and mitigate against potential heteroscedasticity.

RESULTS

Spatio-temporal disparity of IDMD – The box plot in Figure 2 shows the distribution of IDMD values in 2010 and 2020. The range of IDMD values decreased from 0.181–1.204 in 2010 to 0.020–1.010 in 2020. However, the median value increased slightly from 0.548 to 0.586 and the interquartile range was smaller, indicative of an increase and convergence of deprivation levels in areas with moderate levels of disability-related deprivation.

Figure 3A,B display IDMD values for 2010 and 2020, respectively, with values and colours segmented by quantiles. The overall spatial distribution trend of IDMD remained consistent, forming an increasing circle from the lowest values in the central city and the eastern urban fringe area to the highest in the northern rural area. Figure 4 shows the change in IDMD value in each sub-district between 2010 and 2020. IDMD values increased in most sub-districts in the urban centre and urban fringe, particularly in the eastern area of the urban fringe. By contrast, IDMD values decreased in the vast majority of rural area sub-districts. The biggest decrease in disability-related deprivation occurred in rural town centres and their surrounding sub-districts, with smaller to no increases in rural area outer suburbs. These results are partly consistent with the study by Yuan *et al.* in which the deprivation in Guangzhou city increased in the urban centre

Table 2. *Description of the explanatory variables of IDMD.*

Variable	Abbreviation	Description	Obs.	Mean	Std. Dev.	Min	Max
IDMD	IDMD	The scores of IDMD	626	0.509	0.188	0.020	1.204
Per capita GDP	PGDP	Measured by the growth rate of per capita GDP	626	7.114	12.053	0.126	61.690
Urbanization	URB	Measured by rate of urbanization	626	0.710	0.420	0.021	1
Elderly population	EP	Measured by the percentage of population aged 65 and above	626	0.078	0.036	0	0.178
Migrant population	MP	Measured by percentage of non-household registration population	626	0.392	0.288	0.015	1

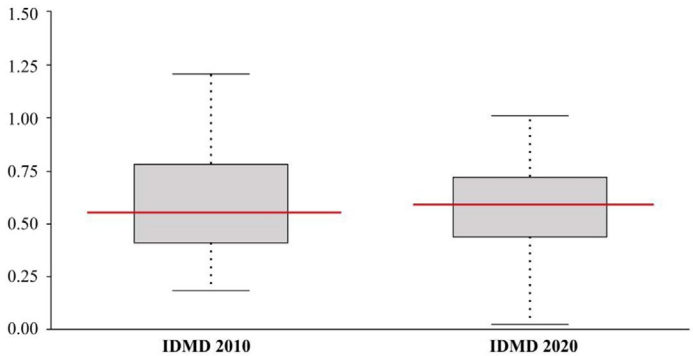

Figure 2. *Box plot showing the difference in IDMD 2010 and 2020 (the red horizontal line represents the median, and the box represents the 25th to 75th percentiles).*

but decreased in the urban fringe between 2000 and 2010 (Yuan *et al.* 2018).

Spatial–temporal disparity of IDMD inequality – The spatial inequalities of IDMD across the whole municipality and within each region (urban centre, urban fringe and rural areas), as measured by the Theil Index, are shown in Table 3. The relative contributions of within-region and between-region inequalities to total inequality are also given. The overall disparity in disability-related deprivation between urban and rural areas declined between 2010 and 2020, as evidenced by the decrease in the Theil Index from 0.7667 to 0.6001. Deprivation inequality decreased in the urban fringe (from 0.3831 to 0.2367) and in rural areas (from 0.1807 to 0.1157) but increased markedly in the urban centre (from 0.0997 to 0.1358). This suggests higher intra-regional deprivation inequality in developed areas but lower intra-regional deprivation inequality in less-developed areas.

The results from LISA cluster transition matrix (Figure 5) show that the majority of sub-districts had a similar level of deprivation in 2010 and 2020. A total of 55 sub-districts had consistently high levels of deprivation and 33 had consistently low levels, which are mainly located in rural and urban centres, respectively. Sub-districts with high–high clusters in 2010 and 2020 were located predominantly in rural regions and those with persistent low–low clusters were located predominantly in the urban centre. The remaining sub-districts changed from an insignificant level of clustering to either a high–high or low–low cluster pattern or vice versa, indicating where significant changes occurred between 2010 and

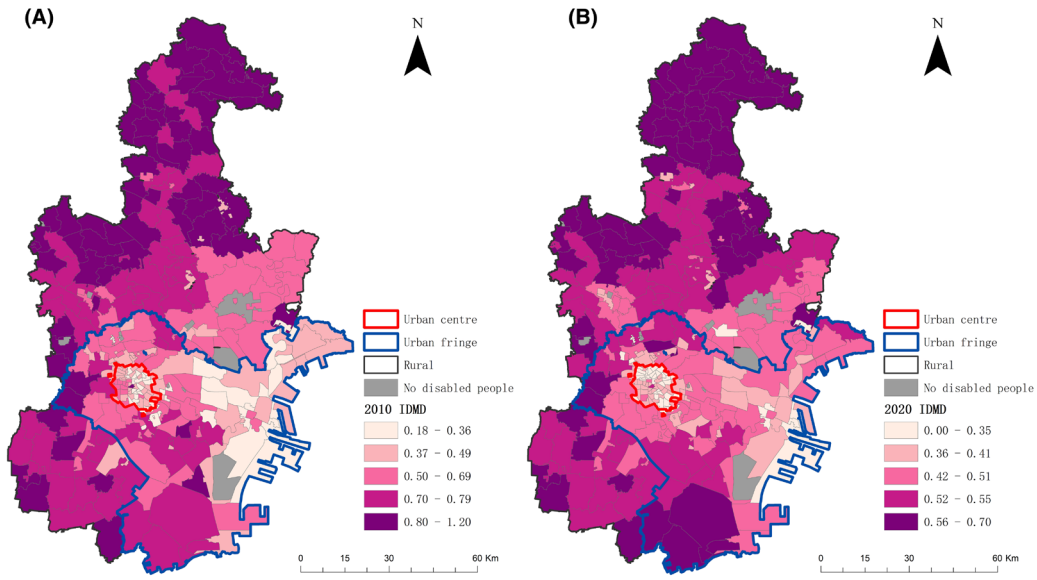

Figure 3. *Trends and Changes in IDMD Values in Tianjin (2010–2020): (A) 2010 and (B) 2020. 'No disabled people' indicates areas with zero registered disabled residents.*

2020. IDMD increased in many sub-districts in rural areas but decreased in some sub-districts scattered throughout the urban centre and urban fringe. Many sub-districts in the new industry development zone in the urban fringe changed from low–low to not significant, indicating an emerging agglomeration pattern.

Socioeconomic determinants of IDMD – A QR regression analysis was carried out to identify whether year, PGDP, URB, EP or MP were significant determinants of IDMD. The results in Table 4 and Figure 6 show the 10th, 20th, 30th, 40th, 40th, 50th, 60th, 70th, 80th and 90th percentiles of *ln*(IDMD). The OLS results showed that ln(PGDP) was positive determinant of IDMD with statistical significance at 5%. Year 2020, $\ln(\text{PGDP})^2$, ln(MP) and ln(EP) were negative predictors of IDMD, while ln(URB) was not significant predictor of IDMD.

Year dummy variables are used to compare the IDMD between two sampling periods, namely, 2010 and 2020. The coefficient of Year 2020 was found to be statistically significant and negative at the 1% significance level, indicating a reduction in IDMD in 2020 when compared to 2010. Notably, the coefficients of Year 2020 exhibited a significant declining trend across various quantiles, with values ranging from −0.041 in the 30th quantile to −0.152 in the 90th quantile.

Economic development, represented by *ln*(PGDP) and $ln(\text{PGDP})^2$ variables, had a nonlinear relationship with IDMD. The coefficients of *ln*(PGDP) and $ln(\text{PGDP})^2$ were significant in the 30th–90th, indicating the critical point at which the impact of economic development stops reducing IDMD and starts increasing it. The OLS results of *ln*(URB) were not significant; however, the quantile coefficients were negative and significant in the 50th–70th quantiles.

The OLS regression results showed that increases in the migrant and elderly populations significantly reduced IDMD. The *ln*(MP) coefficient remained relatively stable across all quantiles, whereas the *ln*(EP) coefficient showed a decreasing trend. The *ln*(MP) had the most significant effect on IDMD of all the variables, with a decreasing trend from −0.366 in the 10th quantile to −0.443 in the 50th quantile, followed by an increase to −0.342 in the 90th quantile. The coefficient of *ln*(EP) decreased from −0.203 in the 10th quantile to −0.389 in the 90th quantile.

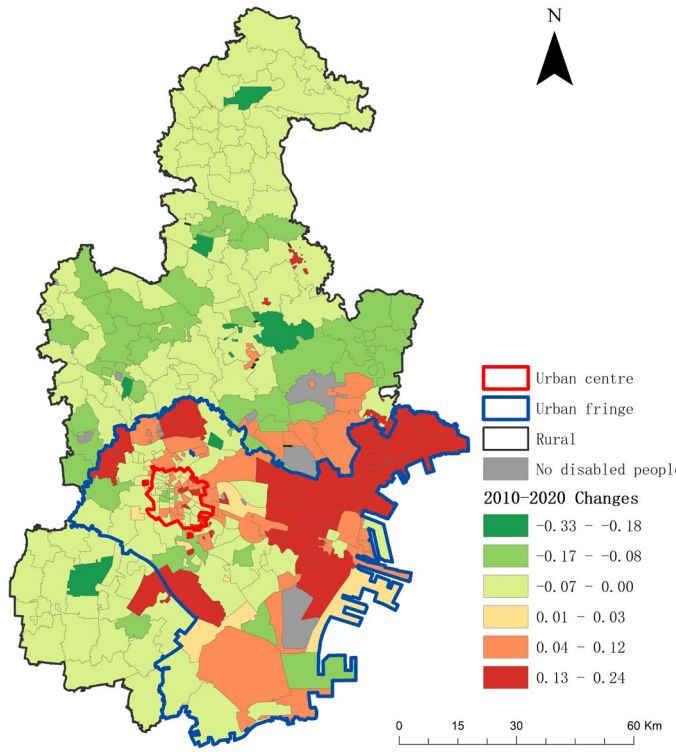

Figure 4. *Changes in IDMD Values in Tianjin (2010–2020). 'No disabled people' indicates areas with zero registered disabled residents.*

Table 3. *Theil Index of IDMD.*

	Theil Index							
Year	Total	Urban centre	Urban fringes	Rural	Between-group	Within-group	Between-group contribution (%)	Within-group contribution (%)
2010	0.7667	0.0997	0.3831	0.1807	0.1032	0.6635	13.46	86.54
2020	0.6001	0.1358	0.2367	0.1157	0.1118	0.4883	18.63	81.37

DISCUSSION

Shrinking urban–rural inequalities of IDMD – The observed changes in IDMD values between 2010 and 2020 signify the persistent presence of urban–rural inequality in disability-related deprivation throughout the study period. Notably, a larger proportion of highly deprived sub-districts were located in rural areas, aligning with general findings from urban deprivation and poverty studies (Yuan *et al.* 2018). Persons with disabilities residing in rural areas continued to face significant levels of deprivation in 2020, referred to as the 'left-behind persons with disabilities' resulting from rapid urbanization (Qiu *et al.* 2022). However, while the IDMD values have decreased in rural areas – signalling improvements there – an increase observed in the urban centre and urban fringe suggests a relative worsening of conditions for persons with disabilities in these areas compared to rural regions. This shift indicates a decline in the relative advantages that urban areas pre-

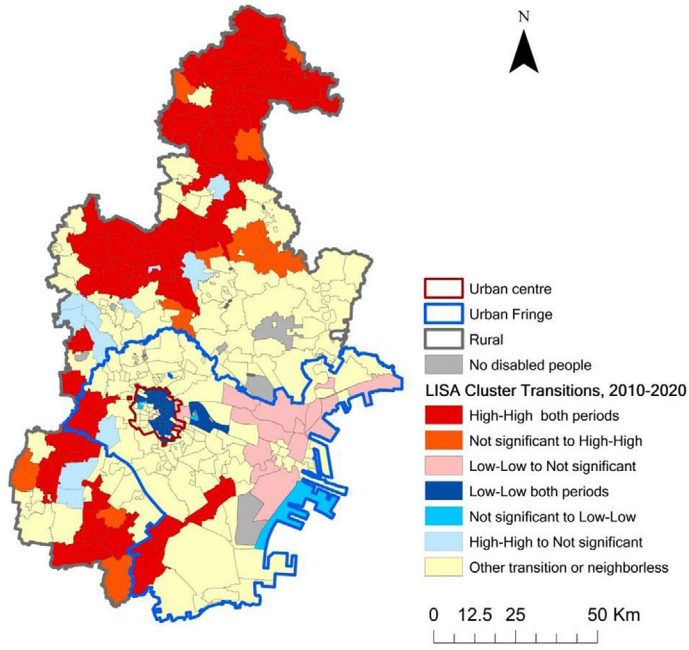

Figure 5. *Spatio-temporal clusters of IDMD values between 2010 and 2020.*

viously held over rural areas for persons with disabilities, marking a significant change in the urban–rural disparity regarding accessibility and quality of life for this demographic. Furthermore, the decrease in the Theil Index between 2010 and 2020 provided confirmation of the narrowing urban–rural gap.

The observed decline in IDMD inequality can be attributed to policies and projects implemented by the Tianjin Municipal Government aimed at improving education, employment and rehabilitation opportunities for persons with disabilities over the study period (Figure 1). These policies align with efforts for coordinated urban–rural development, including initiatives such as new-type urbanization, rural revitalization and anti-poverty strategies. Notably, sub-districts in the urban centre exhibited minor changes in IDMD, suggesting that rural areas experienced more responsive policies and significant impact. However, the overall effect of disability-related policies remained relatively limited. While these policies successfully lifted persons with disabilities out of absolute poverty, improvements for those who were already less deprived were constrained. Therefore, there is a need to enhance the provision of basic public services for marginalized and disadvantaged persons with disabilities, particularly in rural areas (Zhou *et al.* 2020). By effectively addressing deprivation and reducing the urban–rural gap, policymakers can enhance the well-being of persons with disabilities. Considering the marginal effects of disability-related policies, careful resource allocation targeting is necessary to maximize benefits.

Rising socioeconomic inequality for persons with disabilities – The results showed that economic growth increased disability-related deprivation, which contradicts the commonsense view that economic growth reduces poverty. This finding highlights the dilemma between promoting socioeconomic development and tackling poverty (Roemer & Gugerty 1997). It also provides evidence for the phenomenon of what appears to be a lack of inclusive growth in developing countries. This is the so-called 'Disability and Development Gap' phenomenon, in which persons with disabilities are left behind by public policies in developed regions and

Table 4. *Results of the quantile regression analysis.*

		Quantile levels								
Variables	OLS	q10	q20	q30	q40	q50	q60	q70	q80	q90
Year dummy (ref: Year 2010)										
Year 2020	−0.090*** (0.0090)	0.012	−0.013	−0.041***	−0.079***	−0.100***	−0.119***	−0.124***	−0.131***	−0.152***
		(0.0246)	(0.0127)	(0.0158)	(0.0167)	(0.0095)	(0.0061)	(0.0064)	(0.0075)	(0.0071)
ln(PGDP)	0.037** (0.015)	0.018	0.025	0.037*	0.036*	0.044**	0.035**	0.029**	0.030**	0.024*
		(0.0327)	(0.0208)	(0.0208)	(0.0201)	(0.0188)	(0.0153)	(0.0124)	(0.0125)	(0.0146)
$ln(\text{PGDP})^2$	−0.008** (0.0038)	−0.003	−0.005	−0.010**	−0.009*	−0.010**	−0.008**	−0.006*	−0.007**	−0.006*
		(0.0076)	(0.0044)	(0.0046)	(0.0050)	(0.0047)	(0.0040)	(0.0037)	(0.0037)	(0.0037)
ln(URB)	−0.010 (0.0150)	−0.022	−0.028	−0.018	−0.018	−0.025**	−0.027***	−0.024**	−0.019	−0.003
		(0.0320)	(0.0181)	(0.0142)	(0.0115)	(0.0103)	(0.00917)	(0.0123)	(0.0125)	(0.0115)
ln(MP)	−0.410*** (0.0312)	−0.366***	−0.396***	−0.407***	−0.442***	−0.443***	−0.417***	−0.413***	−0.383***	−0.342***
		(0.0838)	(0.0343)	(0.0290)	(0.0264)	(0.0202)	(0.0207)	(0.0247)	(0.0260)	(0.0215)
ln(EP)	−0.308*** (0.0380)	−0.203***	−0.222***	−0.317***	−0.344***	−0.349***	−0.346***	−0.349***	−0.351***	−0.389***
		(0.0720)	(0.0446)	(0.0437)	(0.0325)	(0.0291)	(0.0286)	(0.0390)	(0.0330)	(0.0331)
Constant	0.652*** (0.0266)	0.472***	0.534***	0.609***	0.671***	0.702***	0.727***	0.740***	0.756***	0.798***
		(0.0563)	(0.0320)	(0.0341)	(0.0281)	(0.0259)	(0.0228)	(0.0212)	(0.0186)	(0.0201)
Observations	626	626	626	626	626	626	626	626	626	626
R-squared	0.397	0.099	0.203	0.298	0.362	0.4	0.421	0.455	0.5	0.462

Standard errors in parentheses.
****p < 0.01; **p < 0.05; *p < 0.1.*

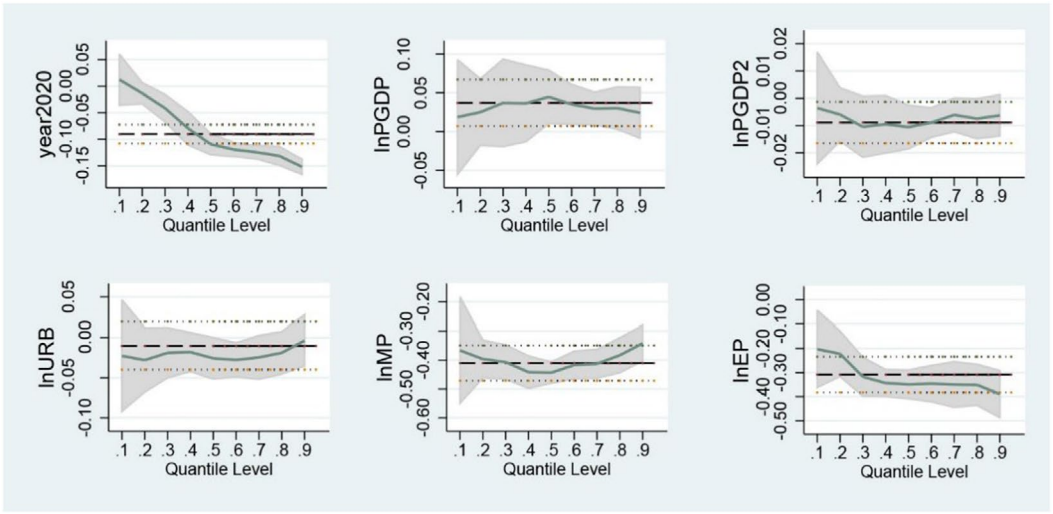

Figure 6. *Changes in quantile regressions coefficients.*

countries (Pinilla-Roncancio *et al.* 2020). The U-curve relationship between economic development and IDMD indicated that improvements in social equity, including for vulnerable groups such as persons with disabilities, are likely to stall after economic development passes the first inflexion point (Chatterjee & Sheoran 2007).

The heterogeneous impact of PGDP on disability-related deprivation, particularly in the urban fringe, sheds light on the limitations of China's disability policies and the challenges faced by persons with disabilities in a fully fledged market economy. In this study, the fastest economic growth in 2010–2020 was observed in this area, particularly in the eastern industrial areas. This study observed the fastest economic growth during the period of 2010–2020, particularly in the eastern industrial areas, where inflation and rising living costs, coupled with low-income growth, further exacerbated the poverty experienced by persons with disabilities (Shang 2000). This finding could be used to expand the theory of relative deprivation of persons with disabilities, insofar as rapid socioeconomic development is likely to create greater deprivation for persons with disabilities than their reference group (Pineda & Corburn 2020). Persons with disabilities in urban fringe are likely to be vulnerable since faced with livelihood transmutation and are unable to afford the soaring costs of living and urban commercial housing here, which then delays their marriage and education prospects (Méndez-Lemus & Vieyra 2014). To address these issues, China's future economic development should prioritize inclusive growth to reduce inequality among different groups.

Double-edged sword of informal employment – All the regression coefficients of ln(MP) consistently indicated that an increase in the migrant population led to a decrease in IDMD. The influx of population brings vitality to China's economy and society. In China, most interprovincial migrant workers tend to have lower levels of education, are middle-aged, have middle- or low-income levels and job oriented. Regions with larger migrant populations often offer informal, low-skilled and low-paying jobs in industries such as construction, transportation and manual labour. Numerous studies have criticized informal employment due to its association with higher rates of injuries, job instability and physical and mental disabilities without adequate compensation (Sangaramoorthy 2019). Moreover, informal workers face difficulties in terms of social integration, including job insecurity, income instability, social marginalization resulting from population registration restrictions, limited

access to public services and heightened vulnerability during crises.

However, it is crucial to acknowledge that the informal employment sector has been recognized as an 'easy-entry sector' where individuals can earn some income, which is preferable to having no income at all (Geyer Jr. 2023). The accessibility of the informal employment sector often allows individuals with disabilities to enter the labour market more readily compared to the formal labour markets. Moreover, the migrant population was found to have a greater likelihood of reducing IDMD in areas with moderate IDMD values, which corresponded to significant quantiles of urbanization. This finding partially validates the influence of rapid urbanization on population mobility and the prevalence of informal employment, providing job opportunities for rural migrants who face challenges in securing formal employment in cities, thereby contributing to the alleviation of employment and poverty issues (Chen *et al.* 2021). However, it should be noted that rapid urbanization may also lead to discrimination against rural migrants and social segregation in urban areas. Therefore, an inclusive model of development is needed to ensure that the benefits of urbanization are shared among vulnerable groups, including persons with disabilities.

Disability-related deprivation diminishes with age – 'Elderly-disability' is a common phenomenon where older adults are more susceptible to various types of disabilities due to the natural decline in physiological and cognitive functions with age (Wang *et al.* 2020). For instance, some physical disabilities in the elderly arise from the degeneration of bones and muscles over time (Heath & Fentem 1997), common vision problems like cataracts and macular degeneration leading to visual impairment (Swenor & Ehrlich 2021), prevalent hearing loss particularly sensorineural deafness (Yévenes-Briones *et al.* 2021) and cognitive disabilities triggered by Alzheimer's disease and other forms of dementia (Lisko *et al.* 2021). According to the Tianjin Disability Database in 2020, approximately 60% of individuals with disabilities were elderly, highlighting the prevalence of disability within this age group. Common sense suggests that elderly persons with disabilities and their families face a higher risk of poverty due to increased healthcare costs and reduced work capacity, leading to heightened economic vulnerability and health-related impoverishment (Levchenko 2021).

Although it has become common sense that elderly individuals with disabilities are more deprived compared to healthy elderly individuals, it is worth noting that this relative poverty is specifically in comparison to healthy elderly. There is scant research comparing the poverty levels of disabled elderly individuals against younger individuals with disabilities. In this study, all regression coefficients of ln(EP) consistently indicated that an increase in the EP led to a decrease in IDMD. This result might initially appear to contradict common sense, but it is actually reasonable. This phenomenon can be explained by the fact that persons with disabilities generally have a shorter life expectancy, and according to the Tianjin Disability Database, 75% of elderly individuals with disabilities acquire their disability after the age of 60, a pattern known as 'disability-aging' (O'Brien 2009). This implies that the majority of elderly persons with disabilities were not disabled during their working years, which means that their opportunities for education, training, employment and wealth accumulation were not influenced by their disability. Additionally, they often receive family support in their old age (Mont & Nguyen 2018). The findings of this study align with previous research highlighting age-related disparities in disability patterns, demonstrating that a higher EP is associated with lower levels of deprivation among persons with disabilities (Qiu *et al.* 2022). Therefore, it is the inequality in disability-related deprivation that diminishes with age, rather than the prevalence of disability itself.

The study sheds light on the 'disability-aging' and 'elderly-disability' (Wang *et al.* 2020), revealing the relationship between disability and population aging. This highlights the importance of recognizing the distinct needs of older individuals with disabilities. To effectively address the challenges at the intersection of ageing and disability, health departments and policymakers should prioritize age-inclusive health policies and

services. It is crucial for health departments to acknowledge and prioritize age-inclusive health policies and services in their agendas to ensure the well-being and support of older persons with disabilities.

Policy implications – The findings of this study have relevance to disability-inclusive development and have implications for urban planners and policymakers who seek to create healthy cities and sustainable development in the Global South. In light of the significant reduction in IDMD from 2010 to 2020, it is important to consider the specific policy interventions during this period. For instance, the enhancement of the National Disability Insurance Scheme under the 12th Five-Year Plan (2011~2015), which included improved coverage for assistive technologies and rehabilitation services, likely contributed to these positive outcomes. Firstly, increasing the supply of basic public services for disabled people, especially for those left behind in rural areas, can effectively reduce deprivation and decrease the urban–rural gap (You *et al.* 2020). Considering the marginal effects disability-related policies have, policymakers should target the allocation of resources carefully to maximize benefits (Onukwugha *et al.* 2015). Furthermore, the employment guarantee policy, strengthened during the 13th Five-Year Plan (2016~2020), provided more stable employment opportunities for people with disabilities, particularly in urban fringe, thereby potentially reducing disability-related deprivation. China's future economic development should focus on inclusive growth to reduce inequality among different groups. Moreover, rapid urbanization has brought both opportunities and challenges; while it offers informal employment opportunities for disabled people, it also results in discrimination against rural migrants and social segregation in cities (Bechange *et al.* 2021). An inclusive model of development that ensures the benefits of urbanization are shared among vulnerable groups, such as disabled people, is needed (Wei & Wahnschafft 2015). Fourthly, the phenomena of 'disability-aging' (O'Brien 2009) and 'elderly-disability' (Velayutham *et al.* 2016) which were demonstrated in this study provide a new perspective from which to re-examine the relationship between disability and population aging. Health departments should consider wider issues of psychosocial intervention and life planning for the elderly disabled population.

CONCLUSIONS

This study used data from the Tianjin Disability Database in 2010 and 2020 to explore the dynamics of the Index of Disability-Related Multiple Deprivation (IDMD) and the heterogeneous effects of socioeconomic development and population structure on IDMD levels. The major findings from the Theil Index, LISA and QR analyses can be summarized as follows. Firstly, the longitudinal analysis revealed that although deprivation inequality decreased across the whole municipality, the urban–rural gap in deprivation still existed in 2020 and IDMD increased markedly in the urban fringe. This evidence has contributed to the expansion of the current literature on the dichotomy between urban and rural settlement types (Vliet *et al.* 2020). Secondly, Social, environmental and physical barriers may hinder the full implementation of policies advocating for the rights of persons with disabilities in rural settings. Against the backdrop of rapid economic development, urbanization and ageing in the Global South, it was observed that increases in economic growth were associated with an increase in IDMD. This finding contributes to our understanding of the 'Disability and Development Gap' and sheds light on the relative deprivation experienced by individuals with disabilities (Parey 2020). Thirdly, the analysis demonstrated that the growth of migrants and EPs decreased IDMD through the provision of informal employment opportunities and a reduced impact of deprivation on elderly persons with disabilities. This highlights the dichotomy of informal employment (González *et al.* 2021) and the threshold and contextual factors affecting the employment of individuals with disabilities (Agovino & Rapposelli 2016). Furthermore, deprivation decreases with age, allowing for a comprehensive investigation into the multiple deprivations faced by people with disabilities over their lifetimes.

Several limitations of this study are noted. Firstly, the 10-year timeframe for this study is still relatively short. It was not possible to provide a complete picture of disability-related deprivation in Chinese cities during other critical periods of social change, such as China's Reform and Opening Period (1980s) and the period of economic restrictions of state-owned and collective enterprises (1990s) as suitable data were not available. Secondly, it is likely that disability-related deprivation varies considerably depending on the type of disability. Future studies could disaggregate deprivation by disability type to identify more targeted disability-related policies.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest and do not have any possible conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are not publicly available due to privacy and ethical restrictions.

Endnote

[1]The Disabled Persons' Federation is a public institution that participates in the administration of civil servants and is an organization that represents and addresses persons with disabilities's issues in China.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web site:

Appendix S1.