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Changes in Family Structure during Shantytown Redevelopment and Their Correlation with the Living Space

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Abstract: Amid rapid urbanization, shantytown redevelopment profoundly transforms urban environments and catalyzes substantial changes in social, economic, and family structures. Yet, most previous studies have focused narrowly on the outcomes of single residential mobility events, overlooking the complex dynamics that unfold across the pre-redevelopment, during-redevelopment, and post-redevelopment phases. This study investigates changes in family structure and their correlation with living space throughout all three phases of shantytown redevelopment in Heze City, Shandong Province, China, from 2016 to 2023. Collecting data through a community survey, we gathered 1035 valid responses to analyze family structure and residential characteristics. Our analysis, which included Sankey diagrams and cross-lagged panel models (CLPM), revealed a predominant trend of large families fragmenting into smaller nuclear units and demonstrated a significant positive correlation between family structure complexity (FSC) and living space. Notably, the FSC from a previous phase had a significant influence on the living space of the following phase, indicating lagged effects where housing choices are influenced by prior family structure. Further comparisons across different housing types and tenures during the temporary phase highlighted diverse structural changes among families. These insights are crucial for policymakers to refine urban redevelopment strategies, better meet residents' needs, and enhance the efficacy of policies.

Keywords: urban redevelopment; family structure; living space; cross-lagged panel model; shantytown redevelopment

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1. Introduction

In the context of rapid urbanization, shantytown redevelopment has become a crucial strategy for many cities to improve residents' quality of life and enhance their urban built environment [1]. However, this process entails more than just changes in physical space, as it also serves as a catalyst for profound social, economic, and family structural changes [2,3]. Understanding these changes is essential to ensure that urban redevelopment initiatives are inclusive and will not harm the well-being of residents being affected. Among the potential changes resulting from shantytown redevelopment, changes in family structure are particularly important because they directly influence the social cohesion, economic stability, and overall well-being of individuals and communities.

Previous studies have explored the change in family structure from the perspective of family life cycle. As the family life cycle progresses, some 'big events' might result in a change in family structure [4,5]. Examples include young couples getting married, children being born and growing up, children becoming independent and living separately from parents, etc. [6]. As the family structure changes, the family's demand for the function of site and house also changes, often leading to residential mobility and to houses that better suit the current life stage of the family [7,8], and potentially resulting in changes

to living space. For example, a family might move from a smaller unit to a larger one to accommodate newborns, or a young adult might move from a large unit that he/she used to live in together with his/her parents and instead reside in a smaller unit by himself/herself.

Forced residential mobility (FRM) is another 'big event' that might significantly impact family structure and the family life cycle [9]. Different from voluntary residential mobility resulting from families' proactive choices, FRM is driven by policy, such as shantytown redevelopment policies that compel residents to move from their original homes to government-designated resettlement houses [10]. As a result, residents are forced to leave familiar environments and move to new residences, which might change not only various aspects of their daily lives, but also the living space of their residential units [11,12].

Changes in living space may lead to the dispersion of family members or unite a large family, in other words, the change of family structures [2]. Studies have shown that in some cases, during demolition and resettlement, some families might downsize from one large unit into two or three smaller units. As a result, the large family originally living together has to disperse into different units, forming smaller families [13]. Different from urban renewal in many other countries, in the Chinese practice of shantytown redevelopment, residents often go through a temporary residence phase while waiting for resettlement houses to be built. The living space might also change during this period and influence the family structure.

Therefore, the family structure change during the shantytown redevelopment process is actually a three-phase change [14]. The three phases include the pre-redevelopment phase (Phase 1), where residents live in their original residences; the during-redevelopment phase (Phase 2), a temporary residence phase where residents temporarily live elsewhere while waiting for the construction of resettlement housing; and the post-redevelopment phase (Phase 3), where residents move back to the new resettlement housing at their original location [14]. Normally, each household will be offered the resettlement house(s) with the same living space as their original residence. Previous studies have often focused only on the outcomes of family structure and living space changes resulting from the mobility of a single residence [15], while seldom examining the changes during all three phases.

This study takes Heze City, Shandong Province, China, which underwent large-scale shantytown redevelopment from 2016 to 2023, as an example. It examines the dynamics of family structure changes at each phase of shantytown redevelopment and their relationship with the living space. Specifically, the study answers three research questions: (1) How does the family structure change during shantytown redevelopment? (2) What is the correlation between the family structure change and living space change? (3) Is there any difference between this correlation and the types of residential units regarding the changes in family structure? Answers to these questions will provide new insights and references for family life cycle theory and urban redevelopment practices.

2. Data and Methods

2.1. Study Area and Background

This study explored changes in family structure in Heze City of Shandong Province, China. Heze is the least developed city in Shandong Province. In 2015, Heze's per capita GDP ranked last in the province (17/17), with over 70% of its main urban area covered by shantytowns. In June 2015, the Chinese central government put forward a policy to encourage larger-scale shantytown redevelopment [16,17]. Under this policy background, Heze launched a larger-scale shantytown redevelopment plan starting in 2016. From 2016 to 2018, Heze ranked first among all prefecture-level cities in China for three consecutive years in terms of shantytown redevelopment volume, with a total of over 371,000 units renovated over three years, affecting the lives of more than 1.2 million residents in shantytown areas [18].

The demolition and resettlement brought by the shantytown redevelopment led to large-scale residential mobility within the city. During this process, factors such as the family life cycle and living space changed, leading to significant changes in family structure. By

the second half of 2023, most of the shantytown redevelopment projects initiated between 2016 and 2018 had completed resettlement, providing an excellent research opportunity to study a series of social issues, including changes in family structure triggered by the large-scale shantytown redevelopment from 2016 to 2018.

Since Heze's shantytown redevelopment projects were mainly concentrated in the main urban area of Mudan District, this study was conducted within the urban area of Mudan District (Figure 1). A series of community surveys, including questionnaires and interviews, were conducted in the five Subdistricts under the actual jurisdiction of Mudan District.

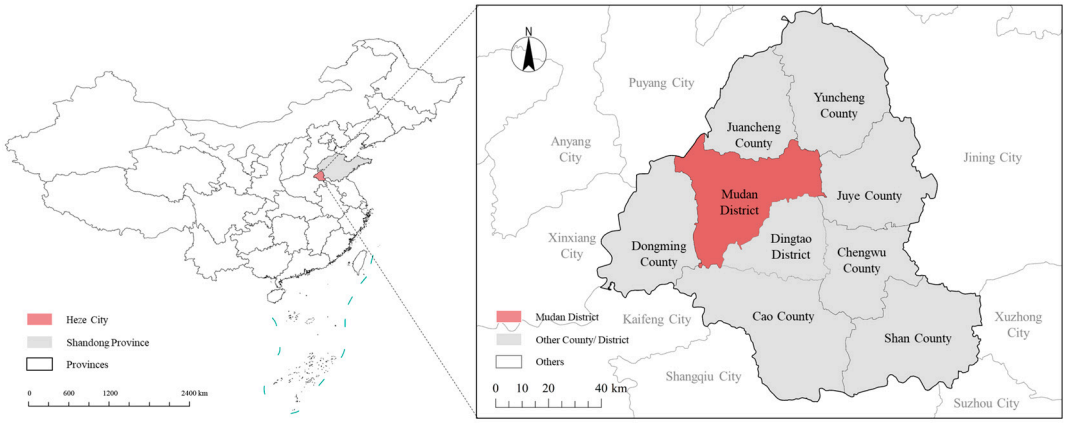


Figure 1. Heze City and study area.

2.2. Data Collection

2.2.1. Community Survey

The five Subdistricts under the actual jurisdiction of Mudan District in the urban area are Dongcheng Subdistrict, Xicheng Subdistrict, Beicheng Subdistrict, Nancheng Subdistrict, and Helou Subdistrict. The questionnaire survey for this study was conducted in these five Subdistricts. From one to four resettlement communities were selected for each Subdistrict, depending on whether the shantytown redevelopment of the community began during the large-scale redevelopment period of 2016–2018 and whether most of the resettlement work had been completed by July 2023. After consulting with the government and ensuring that the total number of samples between Subdistricts was similar, we finally identified between one and two resettlement communities as survey communities in each Subdistrict, resulting in a total of seven resettlement communities as our sample communities (as shown in Table 1). Among them, Zhongda-heyuan community resettled families from several demolished communities, primarily including Huangchao Community and the West area of early Heze City. The actual demolition of the West area of early Heze City took place in early 2019, which does not fall within the selected range of 2016–2018. However, since it still belonged within the planned project of 2018, we considered it a valid sample community. Unlike the off-site resettlement that is universal in other large cities in China, Heze, as a medium-sized city, generally adopted on-site resettlement, which means the resettlement residences were constructed in the same locations as the original residences.

In the survey of target communities, this study employed random sampling, with an overall sampling rate of 20.5% and individual community sampling rates ranging from 8.5% to 42.7%. Some communities had higher sampling rates to ensure that the sample size differences between communities were not too large. To ensure the validity of the survey, the research team trained local university students as surveyors. The surveyors visited the respondents in the target communities and conducted structured face-to-face interviews. This method effectively avoided potential misunderstandings of survey questions by respondents and significantly increased the proportion of valid questionnaires. The study considered as valid questionnaires from families that continuously resided in Mudan

District throughout the entire redevelopment process and had complete and logically consistent data. Ultimately, the survey collected a total of 1035 valid questionnaires.

Table 1. Sample Community.

	Original Residence	Subdistrict	Resettlement Residence	Resettlement Model	Number of Samples
1	Dongan community	Dongcheng Subdistrict	Zhongbei-xinduxin	In situ	189
2	Baiyuan community	Xicheng Subdistrict	Liucaiyuan-jiayuan	In situ	90
3	Huangchao community	Xicheng Subdistrict	Zhongda-heyuan	In situ	157
4	West area of early Heze City	Xicheng Subdistrict	Zhongda-heyuan	Nearby (about 800 m)	76
5	Zhongyue community	Nancheng Subdistrict	jiahheyiyuan	In situ	94
6	Zhanglou community	Nancheng Subdistrict	Tietou-ronghuafu	In situ	124
7	Yimin community	Beicheng Subdistrict	Kaixingtianxia	In situ	87
8	Yueguang community	Helou Subdistrict	Wanfujiayuan	In situ	218

The survey was conducted at the household level, collecting socioeconomic status and residential information for all three phases of shantytown redevelopment. Since some families relocated more than once during the temporary residence phase (Phase 2), the characteristics of Phase 2 referred to in this study pertain to the location where these families lived the longest during Phase 2.

For ease of subsequent analysis, the study divided the entire sample based on housing type and housing tenure during the temporary residence phase. Based on housing type, there were 638 families living in apartment buildings (ABs) and 397 families living in detached houses (DHs, shantytowns or villages) during Phase 2. Typically, ABs have areas ranging from 90 to 150 m^2, while DHs are mostly above 200 m^2. Based on housing ownership, there were 201 families living in self-owned housing (SOH), 807 families living in rental housing (RH), and an additional 27 families living in temporary government-provided housing during Phase 2.

2.2.2. Family Structure and Living Space

This study classified family structures into five categories: Extended Family (EF), Stem Family (SF), Nuclear Family (NF), Single-Parent Family (SPF) and Other Family (OF). The classifications of EF, SF and NF are commonly used in the field of sociology [19,20], with the main criteria being "generation" and "core number". "Generation" refers to the number of generations included among family members, while "core number" refers to the number of married couples within the family.

An EF includes two or more generations and at least three cores. An SF includes two or three generations and two cores. An NF includes one or two generations and one core. An SPF includes two generations with no core. OF in this study mainly refers to elderly single-person households. In families with more than three generations, if one spouse of the middle-aged or older couple has passed away, the family is still considered to have one core to distinguish between EF, SF and SPF in special cases. The specific descriptive statistics of each type of family structure across the three phases are shown in the Table 2.

Table 2. Descriptive Statistics of Family Structure Types.

Sample	EF	SF	NF	SPF	OF	Total
ALL-1	115 (11.1%)	383 (37.0%)	493 (47.6%)	16 (1.5%)	28 (2.7%)	1035 (100.0%)
AB-1	62 (9.7%)	259 (40.6%)	297 (46.6%)	4 (0.6%)	16 (2.5%)	638 (100.0%)
DH-1	53 (13.4%)	124 (31.2%)	196 (49.4%)	12 (3.0%)	12 (3.0%)	397 (100.0%)
SOH-1	23 (11.4%)	72 (35.8%)	92 (45.8%)	5 (2.5%)	9 (4.5%)	201 (100.0%)
RH-1	91 (11.3%)	309 (38.3%)	390 (48.3%)	9 (1.1%)	8 (1.0%)	807 (100.0%)
ALL-2	55 (5.3%)	397 (38.3%)	543 (52.5%)	13 (1.3%)	27 (2.6%)	1035 (100.0%)
AB-2	16 (2.5%)	268 (42.0%)	336 (52.6%)	3 (0.5%)	15 (2.4%)	638 (100.0%)
DH-2	39 (9.8%)	129 (32.5%)	207 (52.1%)	10 (2.5%)	12 (3.0%)	397 (100.0%)
SOH-2	12 (6.0%)	81 (40.3%)	100 (50.0%)	1 (0.4%)	7 (3.5%)	201 (100.0%)
RH-2	43 (5.3%)	314 (38.9%)	432 (53.5%)	10 (1.2%)	8 (1.0%)	807 (100.0%)
ALL-3	11 (1.1%)	217 (21.0%)	754 (72.8%)	13 (1.3%)	40 (3.8%)	1035 (100.0%)
AB-3	4 (0.6%)	145 (22.7%)	461 (72.3%)	3 (0.5%)	25 (3.9%)	638 (100.0%)
DH-3	7 (1.8%)	72 (18.1%)	293 (73.8%)	10 (2.5%)	15 (3.8%)	397 (100.0%)
SOH-3	1 (0.4%)	31 (15.4%)	152 (75.6%)	4 (2.0%)	13 (6.5%)	201 (100.0%)
RH-3	10 (1.2%)	184 (22.8%)	592 (73.4%)	7 (0.9%)	14 (1.7%)	807 (100.0%)

Note: α-1 represents the sample situation in Phase 1 for group α; similarly, α-2 and α-3 represent the sample situations for group α in Phase 2 and Phase 3, respectively. EF, SF, NF, SPF and OF refer to Extended Family, Stem Family, Nuclear Family, Single-Parent Family, and Other Family, respectively. ALL, AB, DH, SOH and RH refer to the full sample; sample of families living in Apartment Buildings; sample of families living in Detached Houses; sample of families living in Self-Owned Housing; and sample of families living in Rental Housing, respectively.

To facilitate model analysis, this study used principal component analysis (PCA) based on three indicators: core number, number of family members, and number of school-age children, to generate a normalized indicator—family structure complexity (FSC). The core number was specifically defined by family structure type, as explained in the preceding paragraph, with the number of family members and the number of school-aged children being directly obtained from the questionnaire survey. Prior to conducting PCA, we first performed the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity on the data. The KMO value (0.683) was greater than 0.600, indicating moderate collinearity among the variables, which is suitable for PCA. The *p*-value of Bartlett's test (0.000) was significantly less than 0.05, demonstrating significant correlations among the variables, rejecting the hypothesis of variable independence, and further supporting the use of PCA. After standardizing the data, the PCA results revealed that the first principal component explained 68.3% of the variance, while the first two components together accounted for 86.6% of the variance. Considering the rate of variance explained and model complexity, we selected the first two principal components to construct the FSC index. The final FSC index was obtained by calculating the weighted average of the scores of these two principal components.

The living space data were obtained from questionnaire responses by the respondents. The descriptive statistics for FSC and the independent variable, residential area, are shown in the Table 3.

Table 3. Descriptive Statistics of Family Structure Complexity and Residential Area.

Sample	Variable	Mean	Std	Min	Max
ALL	X1	280.060	121.534	28.000	1000.000
	X2	148.522	73.218	20.000	600.000
	X3	127.748	25.431	85.000	366.000
	Y1	0.000	1.016	−2.045	3.474
	Y2	0.000	0.997	−2.072	3.808
	Y3	0.000	0.948	−1.862	4.651

Table 3. *Cont.*

Sample	Variable	Mean	Std	Min	Max
AB	X1	267.726	106.526	28.000	1000.000
	X2	116.085	35.362	20.000	400.000
	X3	130.543	27.520	85.000	366.000
	Y1	−0.005	0.958	−2.045	3.474
	Y2	−0.048	0.866	−2.072	3.808
	Y3	0.020	0.909	−1.862	4.403
DH	X1	299.881	140.266	30.000	935.160
	X2	200.650	86.988	25.000	600.000
	X3	123.256	20.918	86.000	247.000
	Y1	0.008	1.104	−2.045	3.474
	Y2	0.077	1.175	−2.072	3.808
	Y3	−0.032	1.009	−1.862	4.651
SOH	X1	285.059	135.249	30.000	935.160
	X2	154.945	85.878	25.000	600.000
	X3	124.652	20.709	86.000	247.000
	Y1	−0.033	1.126	−2.045	3.474
	Y2	0.126	1.208	−2.072	3.808
	Y3	−0.204	0.976	−1.862	3.251
RH	X1	280.181	117.691	28.000	1000.000
	X2	150.113	68.223	25.000	600.000
	X3	128.938	26.596	85.000	366.000
	Y1	0.050	0.966	−2.045	3.474
	Y2	0.016	0.909	−2.072	3.808
	Y3	0.092	0.913	−1.862	4.651

Note: X refers to living space, with X1, X2, and X3 representing the residential area in Phase 1, Phase 2 and Phase 3, respectively; the unit for X is m^2. Y refers to family structure complexity, with Y1, Y2, and Y3 representing the family structure complexity in Phase 1, Phase 2 and Phase 3, respectively. ALL, AB, DH, SOH and RH refer to full sample, sample of families living in Apartment Buildings, sample of families living in Detached Houses, sample of families living in Self-Owned Housing, and sample of families living in Rental Housing, respectively.

2.3. Cross-Lagged Panel Model

In this study, a three-wave cross-lagged panel model (CLPM) was employed to analyze the time-lagged effects between variables. This model is widely used in behavioral sciences to explore causal relationships between variables [21,22]. The CLPM model examines the lagged effects of variables by setting a lagged term $t-1$, and it can account for the cross-lagged and autocorrelated effects between variables. The general expression for a three-wave CLPM model is as follows:

$$Y_t = a + b_1 Y_{t-1} + b_2 X_{t-1} + e_t$$
$$X_t = c + d_1 X_{t-1} + d_2 Y_{t-1} + f_t$$

where Y represents family structure complexity, X represents residential area, and t represents the Phase. a and c are intercepts, b_1, b_2, d_1 and d_2 are model parameters, and e_t and f_t are error terms.

The path diagram for the three-wave CLPM is illustrated in Figure 2. X refers to living space, with X1, X2, and X3 representing the living space in Phase 1, Phase 2 and Phase 3, respectively; the unit for X is m^2. Y refers to family structure complexity, with Y1, Y2, and Y3 representing the family structure complexity in Phase 1, Phase 2 and Phase 3, respectively.

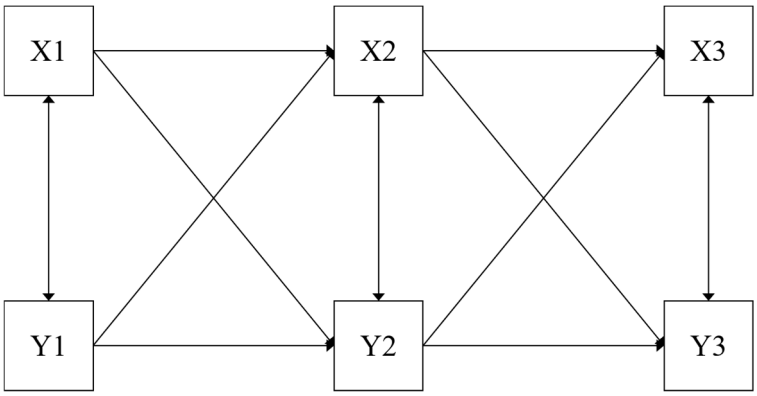


Figure 2. Path diagram for the CLPM. Note: X refers to living space, with X1, X2, and X3 representing the residential area in Phase 1, Phase 2 and Phase 3, respectively; the unit for X is m^2. Y refers to family structure complexity, with Y1, Y2, and Y3 representing the family structure complexity in Phase 1, Phase 2 and Phase 3, respectively.

The cross-lagged panel model (CLPM) includes three types of paths: autoregressive paths, mutual influence paths, and cross-lagged paths. Autoregressive paths examine the impact of previous data on living space/FSC on the subsequent phases (i.e., X1 → X2 → X3, Y1 → Y2 → Y3). Mutual influence paths test the mutual influences between living space and FSC in the same phases (i.e., X1 ↔ Y1, X2 ↔ Y2, X3 ↔ Y3). Cross-lagged paths investigate the impact of the previous phase's living space/FSC on the subsequent phase's FSC/living space, respectively, to observe if there is any cross-lagged effect (i.e., X1 → Y2, Y1 → X2, X2 → Y3, Y2 → X3).

3. Results and Discussion

3.1. Family Structure Changes during Shantytown Redevelopment

To explore the change in family structure between the three phases of shantytown redevelopment, we plotted a Sankey diagram of the five categories of family structure (Figure 3).

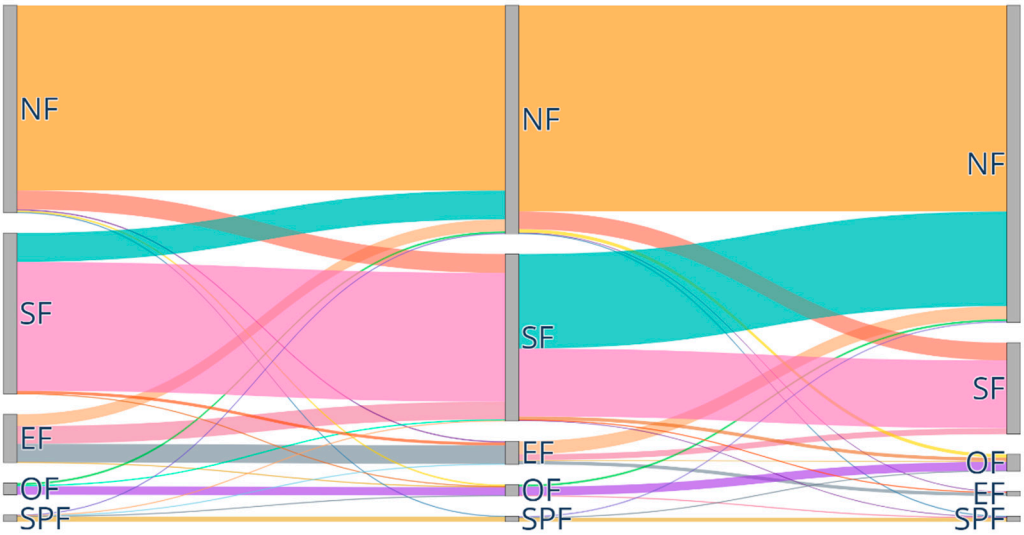


Figure 3. Family Structure Changes across Three Phases. Note: EF, SF, NF, SPF and OF refer to Extended Family, Stem Family, Nuclear Family, Single-Parent Family, and Other Family, respectively.

The overall trend in family structure change is the fragmentation of large families (stem families and extended families) into smaller families (nuclear families). This trend is more pronounced when transitioning from Phase 2 to Phase 3 compared to the transition

from Phase 1 to Phase 2. This could possibly be attributed to two reasons. First, the temporary nature of residences in Phase 2 meant that most families did not undergo significant changes. Second, the certainty of residential changes in Phase 3, which saw families moving from large detached houses (DHs) to smaller apartment buildings (ABs) and from single to multiple residences, significantly impacted the family life cycle. For instance, the acquisition of new homes facilitates marriage among young adults [23].

"Nuclear Families (NF)" exhibited two main trends from Phase 1 to Phase 2: the majority of NFs were maintained as the same category, while a small portion of NFs turned into SFs. In Phase 3, families that remained as NFs consistently maintained this structure, showing great stability. In contrast, families that became SFs in Phase 2 returned to NFs after resettlement (Phase 3), indicating that the change in Phase 2 was only a temporary cohabitation. Interviews revealed two main scenarios for NFs transforming into SFs during Phase 2. The first scenario involves some NFs temporarily moving into the homes of their children or parents. The second scenario occurs when both the family's and their parents' or children's homes are affected by shantytown redevelopment, and they choose to rent one house and live together during the temporary phase to save housing costs or due to housing supply constraints during the demolition. After resettlement, families typically receive multiple resettlement houses, allowing for separation and ultimately reverting to NFs.

"Stem Families (SF)" showed a trend of gradual dissolution throughout the shantytown redevelopment process, with a more pronounced dissolution after resettlement. Some NFs flowed into SFs in the post-redevelopment phase (Phase 3), but these families were originally SFs or EFs at the beginning of the shantytown redevelopment (Phase 1). Interviews revealed several scenarios for this "Reverse Trend" movement. The first scenario is temporary separation during Phase 2, where some families rented smaller apartments to accommodate children's schooling and parents' commuting needs, while the older generation temporarily returned to their rural "old home". After resettlement, they moved back together. The second scenario is the normal life cycle progression, where young adults get married without separating. This "Reverse Trend" cohabitation after resettlement is also related to the resettlement process, as some resettlement communities had not fully completed the handover of resettlement houses. Some families only received one resettlement house and, due to nostalgia for their old location and the cost of renting, moved in quickly. For multiple families that separated during the temporary phase, cohabitation occurred post-resettlement due to the limited number of houses received. This post-resettlement cohabitation is temporary, and most will revert to NFs once all resettlement houses are delivered.

The trend of the gradual dissolution of "Extended Families (EF)" is also very evident. As the shantytown redevelopment progresses, EFs continuously transform into SFs and NFs, except for a portion (those that shifted to NFs in Phase 1) that exhibit the previously mentioned "Reverse Trend" movement. Families that transformed from EFs to SFs in the first phase mostly remained stable and continued to be stable after resettlement. However, there is still a trend of shifting to NFs as resettlement housing is delivered. This trend is also related to the number of resettlement houses. When EFs transform into SFs, they essentially split into two or more families, at least one SF and one NF. After resettlement, if there are only two resettlement houses, the situation from Phase 2, with one SF and one NF, remains. Only with three or more resettlement houses can the trend towards an NF be ensured.

For the remaining two special types of families, "Single-Parent Families (SPF)" exhibit high stability. Most SPFs maintain their original structure throughout the shantytown redevelopment. However, "Other Families (OF)" show a significant increase after resettlement. In this study, OFs mainly refer to elderly single-person households. The increase in their number is due to many elderly people living separately from their children after moving from one shantytown house to multiple resettlement houses. However, these families differ fundamentally from traditionally defined elderly people living alone. In these cases, the

children usually live in another house within the same resettlement community, ensuring that the elderly do not significantly lack care.

3.2. The Correlation between Family Structure and Living Space

The three-wave cross-lagged panel model (CLPM) was then applied to explore the correlation between family structure and living space during the shantytown redevelopment, and the modeling result is represented in Figure 4. The paths in the CLPM can be divided into autoregressive paths, mutual influence paths, and cross-lagged paths.

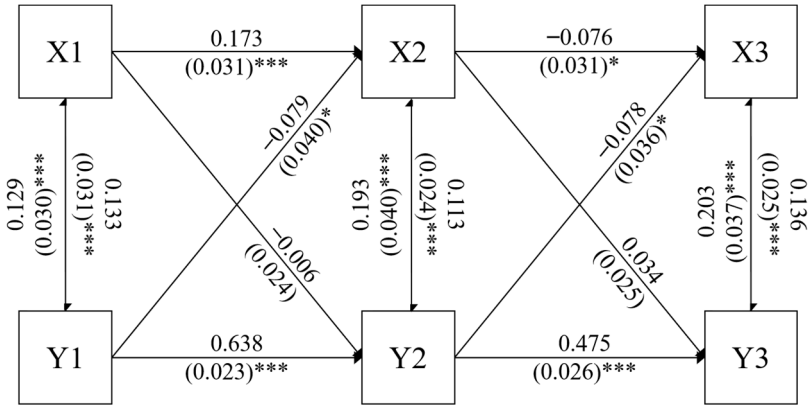


Figure 4. Cross-Lagged Regression Results. Note: The path coefficients are standardized coefficients; Significance levels: *** = 0.001; ** = 0.01; * = 0.05; · = 0.1. X refers to living space, with X1, X2, and X3 representing the residential area in Phase 1, Phase 2 and Phase 3, respectively; the unit for X is m^2. Y refers to family structure complexity, with Y1, Y2, and Y3 representing the family structure complexity in Phase 1, Phase 2 and Phase 3, respectively.

The autoregressive paths depict the influences of the previous phases of the same variable. In this study, we examined the autoregressive paths for both living space and family structure complexity (FSC).

Firstly, regarding the autoregressive paths for living spaces (X1 → X2 → X3), regression results show that Xt−1 consistently has a significant impact on Xt, indicating that the living space is associated with that of the previous phase. However, the coefficient is positive for the X1 → X2 path while negative for the X2 → X3 path, indicating different directions of the potential influence. The positive coefficient of the X1 → X2 path may be due to the fact that families living in large houses in Phase 1 generally accommodate more family members, which requires a higher X2, while families living in small houses in Phase 1 might be more sensitive to housing prices, thus might choose to rent an even smaller unit to save housing costs. The government subsidy also exaggerates this trend. During Phase 2, the government provides certain renting subsidies to help residents through the temporary housing phase. The subsidy is calculated based on the housing area of the original residence, so families with smaller original living spaces often receive relatively less transition subsidy.

However, by Phase 3, the X2 → X3 path is significantly negative. By further delving into the data, we found that most of this trend comes from the change from large living space to smaller living space. This is because more complex families, such as "Extended Families (EF)", need to choose a larger number of resettlement houses to achieve the goal of separating households. The total area of resettlement housing is generally calculated based on the area of the original house being demolished during shantytown redevelopment. Given that the living areas of original residences are similar in size, the area of each individual unit will be smaller for more complex families. Families with higher FSC tend to have larger living spaces; this reveals why there is a significant negative correlation between Y2 → X3 and X2 → X3.

Regarding the autoregressive paths for family structure complexity (Y1 → Y2 → Y3), results show that Yt−1 consistently has a positive and significant association with Yt. This

indicates that complex family structures tend to maintain their complexity throughout the shantytown redevelopment process, while simple family structures also remain simple. This finding suggests a relative stability of family structure during the shantytown redevelopment, suggesting that the fragmentation or combination of families is not immediate and often requires a long period to change traditional living habits and family concepts.

Then, we explored the mutual influence paths of all three phases (X1 ↔ Y1, X2 ↔ Y2, X3 ↔ Y3) to examine the correlation between living space and FSC. Results show that all three of these mutual paths exhibit significant positive correlations, indicating a reciprocal relationship between living space and family structure. In other words, living space and family structure mutually influence each other, with complex families tending to live in larger units and simple families tending to live in smaller units. In terms of path coefficient values, we found that the coefficients of X1 → Y2 (0.133) and Y1 → X2 (0.129) are similar in Phase 1, while in Phase 2 and Phase 3, X2 → Y2 (0.113) and X3 → Y3 (0.136) are smaller than Y2 → X2 (0.193) and Y3 → X3 (0.203). This finding indicates that, in the temporary residence and resettlement phases, the influence of family structure complexity on living space is greater than the effect vice versa. Therefore, during the shantytown redevelopment process, families dynamically adjust their family structure and living space, primarily considering choosing living spaces that suit the family life cycle, even though this process may take into account the size of the dwelling.

Lastly, we examined the cross-lagged effects (X1 → Y2, X2 → Y3, Y1 → X2, Y2 → X3) to explore how the living space/FSC is associated with the FSC/living space in the previous phase, respectively. Results show that the coefficients of X1 → Y2 and X2 → Y3 are both insignificant, indicating that the living space in the previous phase does not significantly affect FSC in the subsequent phase (X1 → Y2, X2 → Y3). However, the FSC in the previous phase has a significantly negative impact on the living space in the subsequent phase (Y1 → X2, Y2 → X3). This indicates the existence of lagged effects of FSC on living space. Therefore, when families are making residential choices, their decisions might still be influenced by the family structure of the previous phase. For Y1 → X2, from previous trends, it can be seen that the more complex the family, the more likely it is to disintegrate. Under the condition that all families receive similar transitional housing subsidies, the average subsidy received by multiple families after the disintegration of complex families is relatively lower, resulting in them only being able to rent smaller living spaces. For the negative correlation from Y2 → X3, which indicates that the higher FSC in phase 2 is associated with the smaller living space in phase 3, the reason might be the fragmentation of larger families into smaller ones when resettling, resulting in smaller living space.

3.3. Comparison between Types of Residential Units

3.3.1. Comparison of Family Structure Changes

When families from the shantytown areas leave their original residence and choose temporary housing, they have two main options for housing types: apartment buildings (ABs) or detached Houses (DHs). Due to the fact that families all lived in DHs (normally a single building with several floors and large area) before shantytown redevelopment, families who chose to temporarily reside in ABs experienced a significant reduction in living space when transitioning from Phase 1 to Phase 2, which might probably lead to a change in family structure, whereas those who chose to temporarily reside in DHs did not experience a significant change in living space. Therefore, we compared the change in family structure between families living in ABs and DHs in Phase 2.

The finding is consistent with our hypothesis, that families living in ABs in Phase 2 exhibited more significant structural change (Figure 5a), while families living in DHs in Phase 2 remained stable regarding their family structure (Figure 5b). The category of families that had the greatest change during the transition from Phase 1 to Phase 2 was the extended family (EF). As can be seen from Figure 5a, the number of EFs among those temporarily residing in ABs decreased sharply. This indicates that the change in residential area from DH to AB mainly affected large-scale family structures, particularly

EFs, prompting them to transition to NFs or SFs. The stability of SFs, which are relatively large-scale family structures, suggests that cohabitation involving two generations and two married couples can adapt to significant changes in living area. In contrast, EFs, involving cohabitation of two generations and more than three married couples, are more sensitive to the transition from DHs to ABs, possibly due to the challenges of sister-in-law or brother-in-law relationships brought about by the change in living space [24].

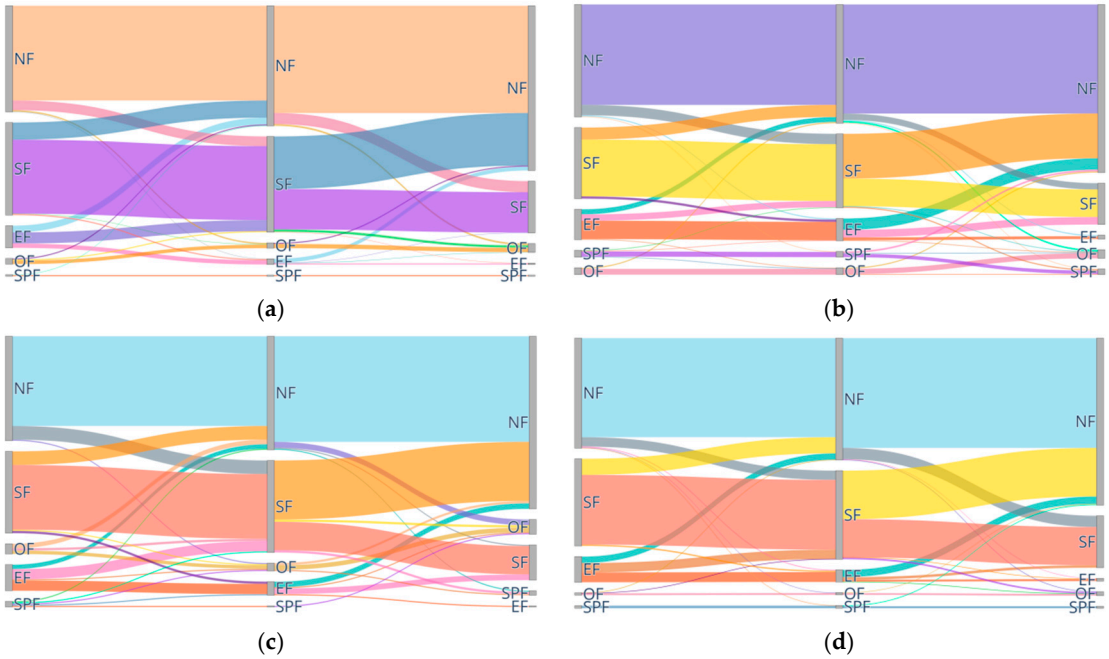


Figure 5. Family Structure Changes by Groups. (**a**) Apartment Building (AB); (**b**) Detached House (DH); (**c**) Self-Own Housing (SOH); (**d**) Rental Housing (RH). Note: EF, SF, NF, SPF and OF refer to Extended Family, Stem Family, Nuclear Family, Single-Parent Family, and Other Family, respectively.

We then compared the change in family structure between families with different types of housing tenure in the temporary residential phase. Families undergoing shantytown redevelopment mainly have two choices in Phase 2: for families who own another house, they may choose to live in their self-owned housing (SOH) during the temporary residence phase, while families without other houses opt for rental housing (RH).

Comparing Figure 5c,d, there was no significant difference in housing tenure during the transition from Phase 1 to Phase 2. However, during the transition from Phase 2 to Phase 3, the proportion of SFs transitioning to NFs was slightly higher among families with SOH than among those with RH. This is because, once the construction of resettlement housing was completed, some generations within SFs that owned other residences may have chosen to continue living in their own housing from the temporary phase. This led to the splitting of SFs into two families, each residing in different houses.

3.3.2. Comparison of Correlations

Comparing the differences between apartment buildings (ABs) and detached Houses (DHs) regarding the correlation between FSC and living space (Figure 6a,b), there were three main paths that showed different effects: X1 $\rightarrow$ X2, X1 $\leftrightarrow$ Y1, and X2 $\rightarrow$ Y3. For X1 $\rightarrow$ X2, we found that the living space of the original residence did not significantly influence that of the temporary living for families living in ABs in Phase 2, while this impact was significant for those living in DHs. The reason may be because the difference in the living spaces of available ABs in the market was not obvious; thus, families did not have many different choices. However, DHs, being unplanned and of disorderly construction, are often significantly different in terms of living space, providing families with choices to reside in DHs with areas similar to those of their original residential units. Therefore,

the X1 → X2 path had a significantly positive coefficient for the DH samples. For X1 ↔ Y1, there was no significant association between FSC and living areas for the DH samples, while the AB samples showed significantly positive correlations. This is likely due to the relatively higher ownership ratio for DHs compared to ABs. For X2 → Y3, the DH sample showed that the living in the temporary residence phase (Phase 2) affected the FSC in the next phase, which was a phenomenon not observed in the full sample or other subsamples. This suggests a unique role played by the large area of DHs, which might provide more residential flexibility and transitional possibility during the temporary phase, and is worth further investigation in future research.

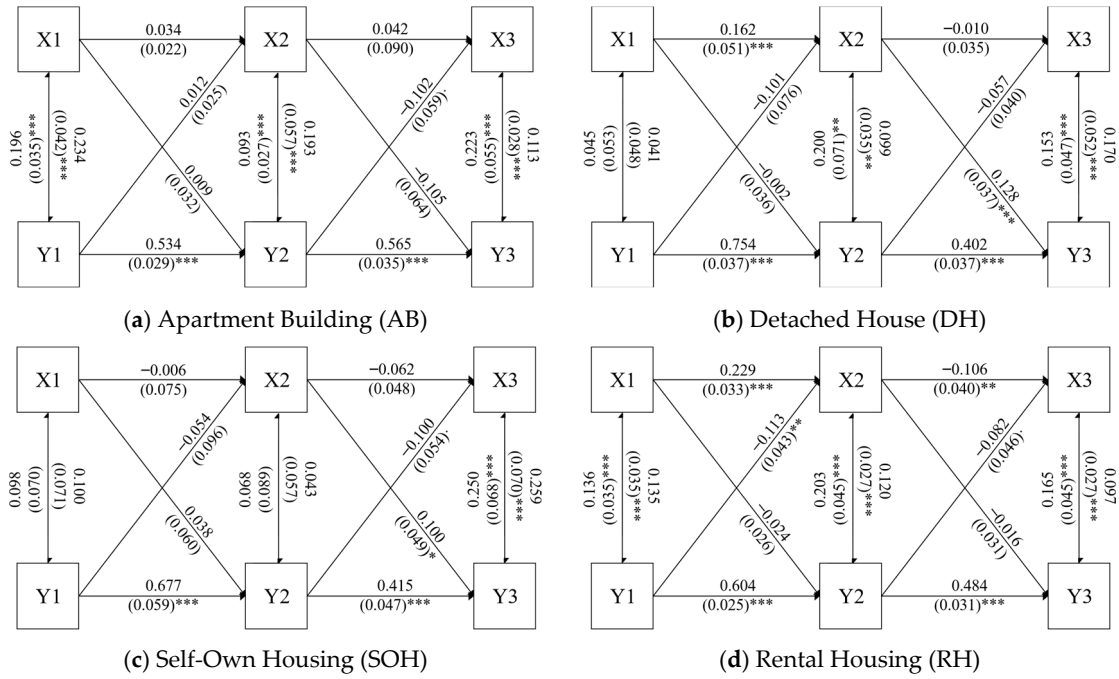


Figure 6. Cross-Lagged Regression Results by Groups. Note: The path coefficients are standardized coefficients; significance levels: *** = 0.001; ** = 0.01; * = 0.05; · = 0.1. X refers to living space, with X1, X2, and X3 representing the residential area in Phase 1, Phase 2 and Phase 3, respectively; the unit for X is m^2. Y refers to family structure complexity, with Y1, Y2, and Y3 representing the family structure complexity in Phase 1, Phase 2 and Phase 3, respectively.

Differences between self-owned housing (SOH) and rental housing (RH) groups were even more pronounced (Figure 6c,d). Results show that the X1 → X2 → X3, Y1 → X2, X2 → Y3, X1 ↔ Y1 and X2 ↔ Y2 paths all exhibited different effects. For the autoregressive path of SOH (X1 → X2 → X3), the SOH samples did not show significant correlation. The reason may be because families temporarily residing in SOH have multiple properties; thus, the living spaces in different phases are not correlated. Additionally, such families just lived in the properties they owned at each phase, instead of choosing the residential units based on their current family structure. As a result, both the X1 ↔ Y1 and X2 ↔ Y2 paths were insignificant for the SOH samples. Conversely, the X1 → X2 → X3, X1 ↔ Y1 and X2 ↔ Y2 paths were all significant for the RH samples, indicating that the living space in each phase might be influenced by that of the previous phase, and has a significant and positive correlation with FSC. Another path that exhibited a difference between the SOH and RH samples was the Y1 → X2 → Y3 path. As can be seen from Figure 6c,d, the correlation between Y1 and X2 was insignificant for SOH but significant for RH, while the correlation between X2 and Y3 was significant for SOH but insignificant for RH. This is because families in SOH generally obtain temporary housing before the shantytown redevelopment and then move into SOH during the temporary phase. The family structure at the time of shantytown redevelopment could not be considered when obtaining this

house. For families in RH, the rented housing was generally chosen after the shantytown redevelopment occurred, so the family structure during the redevelopment was taken into account. In addition, the living space in Phase 2 significantly influenced the FSC in Phase 3 for the SOH samples, while the effect was insignificant for the RH samples. This may be because the families living in SOH in Phase 2 had to adjust their family structure to utilize the resettlement units in Phase 3 provided by the government, while the families living in RH in Phase 2 had already changed their family structure when temporarily renting a house, so did not need to adjust further during the resettlement phase.

4. Conclusions

This study, through a survey of 1035 families involved in the shantytown redevelopment projects in Mudan District, Heze City, Shandong Province from 2016 to 2023, explored the changes in family structure in different phases of the shantytown redevelopment and their relationship with living space. The study found that during the shantytown redevelopment process, family structures shifted from large families to small families, with extended families and stem families gradually dissolving, and nuclear families increasing. Additionally, there was a phenomenon of "Reverse Trend" movement due to temporary cohabitation during the temporary residence phase and the initial resettlement phase.

The results from the cross-lagged panel model revealed several key insights. First, the mutual influences between living space and family structure complexity (FSC) were observed within the same period, with the impact of FSC being predominant. This indicates that even in the context of temporary living and forced residential mobility, proactive family choices remained dominant. Second, both living space and FSC influenced the subsequent phase's living space and FSC, highlighting the incremental changes in living space and family structure during the shantytown redevelopment process. Additionally, in the cross-lagged effect analysis, the family structure from the previous phase significantly influenced the living space in the next phase, further demonstrating that residential choices under this scenario are primarily proactive adaptations by families to their life cycle stages.

In the subgroup tests, both groups exhibited significant differences. Firstly, concerning changes in family structure, the distinction between temporary residences in apartment buildings (ABs) and detached houses (DHs) lies in the primary timing of large family disintegration, which is a result of the differences in living space between ABs and DHs. For self-owned housing (SOH) and rental housing (RH), the main differences manifested from Phase 2 to Phase 3, due to SOH families owning additional properties, thereby facilitating diverse living possibilities. Secondly, regarding the correlation between family structure and living space, compared to ABs, DHs played a unique role due to their larger size, potentially offering more residential flexibility and transitional possibilities during the temporary phase. For SOH and RH, RH results were largely consistent with the overall sample, whereas SOH displayed no correlation between the living space acquired before shantytown redevelopment and the contemporaneous family structure. This is attributed to the potential for multiple housing options and the lack of foresight regarding shantytown redevelopment events at the time of property acquisition.

Based on our findings, we propose the following two recommendations to promote family health during the shantytown redevelopment process. Firstly, during the temporary housing phase (Phase 2), 78% of families rent homes. The government should strengthen housing market regulation and housing security at this time, providing a diverse and ample market supply for families with different financial abilities to rent houses. This is to stabilize the rental market premium caused by shantytown redevelopment and prevent families from being forced into crowded cohabitation due to high rents and limited supply, which would impact family happiness levels. Secondly, in the resettlement phase (Phase 3), currently, the government-planned resettlement housing mostly consists of single residential units with two to three bedrooms. This relatively limited selection of housing types restricts residents' choices to accommodate unique family life cycles. The government should consider various family needs and offer different housing options when planning and

constructing resettlement houses [25], to satisfy residents' need to choose and promote healthy and positive development throughout the family life cycle.

This study, while offering valuable insights, acknowledges certain limitations that open avenues for future research. Firstly, due to the limitations of the questionnaire survey, the three-phase family structure and living space data obtained from the questionnaire survey only reflected the situation for the respondents' families at the respective times. The survey did not capture the conditions of other families formed during the disintegration process, nor the interactions among these families. Future research could conduct more detailed and in-depth interviews to comprehensively grasp the change in family structures and living spaces of all families originating from pre-redevelopment families, and to deeply understand the reasons for these families' disintegration or temporary cohabitation, as well as the interactions between them. Additionally, there are some external factors that might influence the change in family structure and its correlation with living space, such as properties in other regions, the area of the original residence, the number of resettlement housing units chosen, housing characteristics and flexible household needs. Future research could explore how these factors influence the change in family structures and living spaces.

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