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Public rental housing ownership conversion based on housing affordability in China

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ABSTRACT

According to the regulations of the Chinese government, tenants of public rental housing (PRH) can purchase their dwellings after a certain amount of time. However, since different regulations are enforced by individual local governments and the Chinese government's policies regarding sale prices are incomplete, it is difficult to determine appropriate sale prices. In order to cope with this challenge, we suggest a hybrid framework introducing residual income approach and inverse distance weight (IDW) interpolation method to determine the sale price. Variables considered to develop the framework are housing payment ability, neighborhood house's price, and distance from nearby residential buildings. To validate the proposed framework, the sale price of PRH in Chongqing is determined and then evaluated using cost–benefit analysis. The analysis results show that the model can present a reasonable sale price given that the net benefit is more than 0 when the sale price is 557 USD/m².

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Public Rental Housing; home Ownership; sale Price; housing Affordability; China Indemnificatory Housing; housing Policy

1. Introduction

In China, due to rapid urban development, both the floating population and the demand for accommodations are increasing. This situation has resulted in house price increments and difficulties in provision of appropriate quantity of dwellings in the central areas of Chinese cities (Chen, Guo, and Wu 2011; Gabriel and Nothaft 2001; Shi, Chen, and Wang 2016; Spence, Annez, and Buckley 2009; Zhang 2015b; Zou 2014).¹ To cope with this challenge, the Chinese government offers four types of indemnificatory housing,² economically affordable housing (EAH), low-rental housing (LRH), price-fixed housing (PFH), and public rental housing (PRH).³ Although LRH targets people with low-income, it is limited to the official residents of a region and is only available on lease. Although EAH is available for sale to people with low- and middle-income, its price is too high for them to afford. Similar to LRH, EAH can be availed by official residents alone. In addition, average people dwelling in LRH and EAH only account for 7% of urban households (Li et al. 2016). Since households belonging to low- to middle-income brackets encounter difficulties associated with housing

affordability,⁴ they require systematic governmental support with respect to housing policies (Zou 2014).

Accordingly, the government offered PRH to the “sandwich class”,⁵ which comprises people who cannot afford accommodations due to resident registration issues or economic reasons. Aliens, new employees, and recent college graduates are examples of this group. The Chinese government has announced an extensive plan to construct 14.4 million public rental houses from 2011 to 2015, which requires approximately 314.5 billion USD (Shi, Chen, and Wang 2016). In China, PRH only requires rent as dividends, which are lower than the market price. This results in the accumulation of governmental debts, which threaten continuous progress (Zhang 2015a). To solve this problem, the Chinese government has implemented a lotting-transfer housing policy for PRH, which enables tenants to purchase the rental house after a certain amount of time through negotiation with the lessor (Jiao 2015). Through such ownership conversion,⁶ the government can both increase the home ownership rate and improve its financial conditions (Cho 2011; Jang 2016; Jung 2015; Kim 2017; Kleinhans and Van Ham 2013; Zhang 2017).

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¹Housing difficulty refers to a situation in which the prices of houses exceed the housing affordability of average people, in general (Spence, Annez, and Buckley 2009).

²Indemnificatory housing incorporates the concept of housing welfare, contrary to commercial residential buildings.

³PRH is a type of indemnificatory housing that combines traditional PRH and LRH. The present-day PRH is a modified version of original PRH that provides low-price houses on rent to common people and enables the tenants to buy these houses after a specified amount of time (Jiao 2015).

⁴Housing affordability implies that individual housing issues are related to the social and physical experiences of the people themselves (Stone 2006).

⁵The sandwich class refers to people who can neither apply for LRH nor afford EAH and those who can neither apply for EAH nor buy regular commercial residential buildings. In particular, new college graduates without stable income have the highest potential of belonging to the sandwich class (Li et al. 2016).

⁶Ownership conversion: Since public rental houses in China are built for lease, their sale is prohibited. However, in some cities, such as Shanghai and Chongqing, they are built to attract tenants and tenants are allowed to buy the houses after a certain amount of time by discussing with the lessor (Jiao 2015). Even after they are purchased, these houses can be taken away from their owners by the government to prevent speculation.

Nonetheless, there has been no case of a public rental house ownership conversion due to the lack of specific criteria determining its price. In addition, various sale price regulations of local Chinese governments and incomplete policies of them, pertaining to PRH ownership conversion, lead to difficulties regarding the price settlement (Jiao 2015; Yang 2011). Therefore, in order to facilitate PRH ownership conversion, the criteria for the sale price of a public rental house require clarification. A challenge is that if only market price not reflecting the average income of residents is considered, the ownership conversion price would soar. Consequently, the vacancy rate of PRH is prone to increase since people are deciding not to rent the houses at all (Gong 2016; Yang, Yi, and Zhang 2010). On the other hand, a very low sale price also led to increase Chinese governments' debts (Gong 2016; Yang, Yi, and Zhang 2010). Although many researchers have tried to explore appropriate price while considering variables: market conditions, cost, and income, or their combinations, none of the previous studies present rigorous rationale to estimate a reasonable price that would satisfy both the tenants and government. As an alternative, we present a hybrid framework introducing residual income approach and inverse distance weighting (IDW) method in the case of ownership conversion while considering housing affordability of the sandwich class with low- to middle-income who are potential buyers. The hybrid framework estimates a reasonable price that satisfies both tenants and the government. In the framework, residual income approach enables the consideration of the financial status of potential buyers. On the contrary, IDW method enables the model to take into account the market mechanism. Finally, the analysis results are validated using a balanced cost-benefit analysis to show if the determined price will satisfy both parties, the Chinese local government and sandwich class.

2. Literature review

2.1. PRH ownership conversion

PRH is indemnificatory housing that provides a stable living environment for average people; therefore, it plays a key role in urban development and the life of average people in China (Jiao 2015). Since the formulation of the Twelve-Five Year Plan, which is a major plan to implement indemnificatory housing, PRH has been actively promoted countrywide. However, its expansion is slow due to the lack of funds and the constant accumulation of governmental debt (Zhang 2014).

According to Jang (2016), optimized PRH ownership conversion moment in Korea targeting the public goodness of tenants and lessors depends on the changes in macroeconomic situation. Cho (2011)

mentioned that the ownership of PRH can be converted with appraised values; therefore, business value analysis can contribute to decision-making. These studies proved that the ownership conversion of public housing can be utilized as a measure to improve the financial condition, which involves a continuous increase in governmental debts; however, the regulations pertaining to conversion prices are incomplete. For this reason, in Korea, no case of ownership conversion has been reported until 2018.

2.2. Market, cost and income approach in PRH ownership conversion

In academia, various researchers pay attention to introduce alternatives to determine sale price (Jiao 2015; Yang 2011). Approach focusing on market, cost, and income is the most popular ones to calculate the sale price of PRH (Yu 2012). The market approach sets the price after analyzing market price and making proportional calculations. Although it enables easy calculation of the sale price by simply considering the market price, the market method does not consider the differences of each household. The income approach considers the income and spending of each income bracket. However, its application is limited since it is difficult to calculate the income and spending of households, which poses a threat to the increase in governmental debt. Finally, the cost approach considers whether the government and investors can attain the break-even point based on the cost of production. Hence, it is beneficial to the continuous growth of PRH. However, a very high or a very low price from it can cast doubt on the meaning of PRH due to its inattention to market price leads to inattention to supply-demand relation (Yu 2012).

2.3. Challenges to determine PRH ownership conversion price

Fang (2012) proposed a public housing price calculation model which was mainly based on the housing payment ability of the sandwich class and conducted an empirical study on Chongqing National Statistical Office data. The proposed price estimation model was found to be reasonable and helpful to the government to ease the PRH system. However, they did not consider the feasibility of the calculated price. Later, Sun (2015) used the residual income approach to calculate the housing payment ability of the Jinzhong City according to income level, considering the ability of the people to pay the house and the income of each group classified by earnings. The study found that even though 70% of the rent of PRH was supplied by the government; however, the majority of ordinary people still found it difficult to pay for their accommodation. Moreover, this study only considered the

tenants' benefits regarding the continuing development of public rental dwellings. Yang et al. (2013) pointed out that the PRH promoted by the government is intended to protect the inhabitants, and the housing should satisfy both the homeowners' ability to pay and their accessibility to nearby public facilities. Moreover, they analyzed the accessibility of PRH in Beijing based on the housing's distance from public facilities. However, the study lacks calculations using data from the real world. Yu (2012) analyzed the factors affecting the rent calculation of PRH and proposed a rational estimation system by combining the cost and income approach and considering the housing payment ability of households. Hybrid approach combining cost and income aspects remain considerable points.

2.4. Income and the residual income approach

Regarding the income approach, previous studies have adopted a ratio method and a residual income method to determine the households' housing payment ability. The ratio method enables the identification of a household's housing payment ability by subtracting reasonable nonresidential expenses from the income of a household, provides a relatively accurate analysis of the housing shortage problems faced by low-income households using a ratio-to-income rationale, and clarifies the basis for the selection of real-life factors (Yang, Yi, and Zhang 2010). However, the ratio method is established by empirical studies, and there is no specific theoretical basis for the solvency of households for each income bracket and using specified fixed rates and objective variables (Ma 2017; Shin 2008). In addition, the ratio method has been criticized for not considering the housing payment ability aspect since it does not reflect the characteristics of households, such as their size. Moreover, it does not reflect qualitative changes, such as housing prices and consumers' income in housing over time, as well as lacking the theoretical basis for specific ratios or concepts (Kim 2017).

The cost of housing is the cost for paying the housing income, excluding non-housing expenses, which sharply increases with an increase in income and varies depending on each household's characteristics (Kim 2017). Therefore, an analytical method should take into account the characteristics of households.

The residual income approach, which complements the shortcomings of the ratio approach, depends on the household size and household type and income, and it determines a household's housing payment ability after considering whether there is a nonresidential fee per household, excluding housing costs (Shin 2008). The type and size of households can be considered in regional analyses (Shin 2008). The residual income approach is more logical than the ratio approach, since it considers the housing preferences and housing standards of

households in detail and calculates the maximum housing prices that can be paid by people from various income brackets (Yu 2012). It is possible to reduce the errors in surveys arising from the characteristics of each household and to determine one's ability to pay for a home from the relationship between the residual income of the household and the nonresidential cost (Ma 2017). Further, Sun (2015) developed a system for calculating the rent of public rental houses using a residual income approach. Yang, Yi, and Zhang (2010) used the residual income approach to measure the housing payment ability of ordinary people in each income bracket in Beijing and calculate the maximum sale prices that can be paid economically by low-cost rental housing suppliers. However, only a few studies have considered the income of each income bracket and the conversion of public rental houses into sale prices. Therefore, the current study uses the residual income approach to calculate the sale price of PRH in a more appropriate manner based on the type of households, income of households, and type of housing by considering the housing payment ability of each income bracket.

2.5. IDW method

Kim (2017) used several spatial interpolation methods to estimate the sales of residential properties and found that the IDW with 12 points interpolation method is the most effective for estimating apartment prices. To verify the accuracy of the proposed model, the researcher used the spatial interpolation method to estimate the apartment price from existing apartment data and obtained suitable results. In addition, Chen and Wu (2013) argued that the price calculated based on the analysis of the rate of return on capital is lower than the price calculated by market methods, making it hard to manage PRH and leading to the shortage of supply. Regarding the discussions so far, a method calculating the sale price based on the neighborhood price and distance of the house from the neighboring houses is found to be reasonable.

Using IDW interpolation, the sale price can be estimated based on the relationship between housing prices and local locations (Gong 2016). IDW interpolation is the method that implies weight with an inverse proportion amount of distance between the observation point and point for interpolation. The result of interpolation can be dynamically changed with the selection of observation points. It is noted that distance and housing price are inversely related, which is appropriate for the estimation of apartment price after development (Kim, Lee, and Park 2013). By adopting this method, a more appropriate price can be estimated, since the rental price of public rental houses is affected by their market price and people's income is expected to increase with the society's economic

development. In the sandwich class, in particular, social early adopters may encounter problems associated with temporary housing; however, considering the close relationship with the nearby market the appropriate value of PRH should be calculated.

2.6. Cost-benefit analysis

It is noted that cost-benefit analysis has been used earlier to examine the feasibility for PRH business. For instance, Cordes (2017) pointed out the benefits and limitations of using cost-benefit analysis and the social return on investment to appraise the impact of a social enterprise. Liu et al. (2017) proved the economic stability of Energy Efficiency Retrofit (EER) project by conducting a cost-benefit analysis of the EER project for all stages of its life cycle. Moon et al. (2017) analyzed the validity of the happy (public) dormitory business by using a cost-benefit analysis. Jung et al. (2016) clarified the economic effects of hiring a health-care manager in the construction industry.

3. Analysis framework and data

Considering reviews on literature and discussions so far, a hybrid framework introducing appropriate approach and methods to calculate the conversion sale price seems appropriate. We proposed a new framework integrating the residual income approach and IDW interpolation method: the former is developed from the income approach, and the latter is mainly based on the market approach. In order to validate

the proposed method, we adopted a balanced cost-benefit analysis considering the perspectives of both parties being tenants and the government. Given that no case exists in PRH ownership conversion, verification of proposed framework using real-world data, actual ownership conversion price, is impossible. Instead, we try to establish consensus while applying the framework to real-world case, Kangzhuang Good land PRH in Chongqing, China.

As mentioned, in China, each local government controls its own PRH; therefore, the regulations and methods for the calculation of PRH sale prices may differ by region. In Chongqing, the local government determines the price of PRH based on the investment cost and neighborhood price.

Figure 1 describes the proposed method's framework consisting of three main modules. First, the sale price is calculated by using the residual income approach (module A). Second, the results obtained from module A are modified by using IDW interpolation to obtain a reasonable price (module B). Finally, to validate the results obtained from modules A and B, a balanced cost-benefit analysis method is performed (module C). It is noted that to ensure the accuracy and convenience of calculation, the authors performed all the calculations in Python. By using Python, the authors could benefit from libraries, Numpy, to easily and accurately perform repeated judgments to determine the reasonable conversion price. The data required by and process of each module are thoroughly discussed in the following subsections.

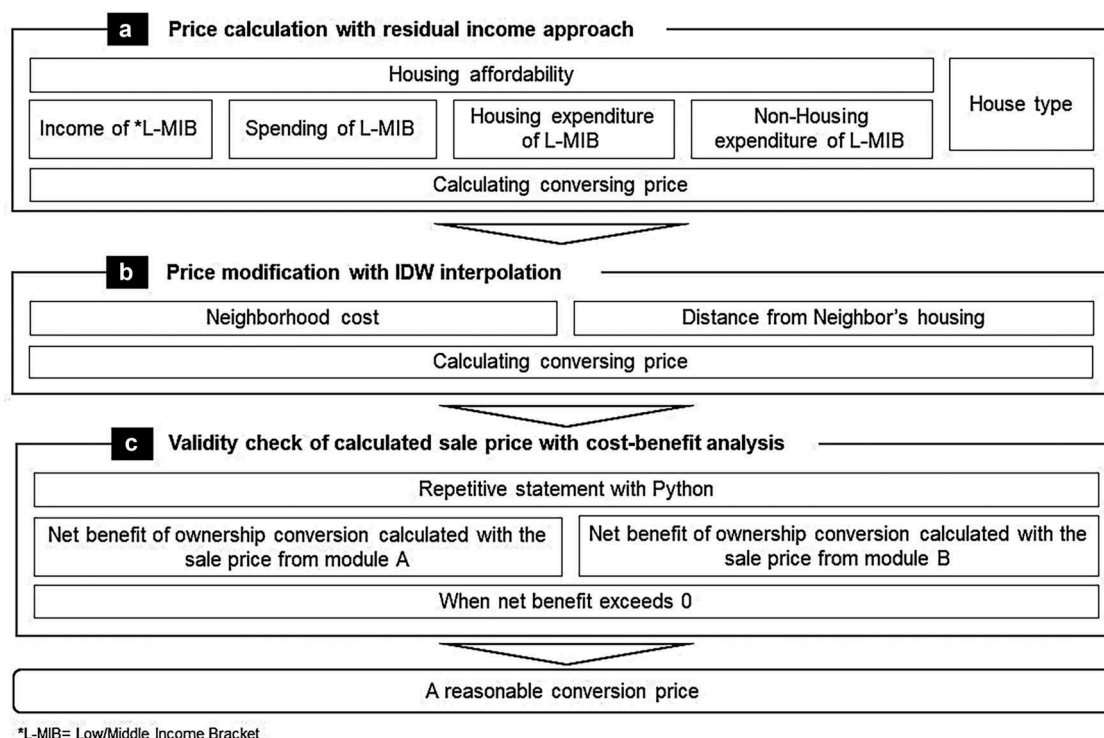


Figure 1. A framework to determine PRH ownership conversion price.

3.1. Module A: sale price calculation using the residual income approach

In module A, the sale price of PRH is calculated using the residual income approach based on housing affordability and house types. The study first estimated the housing affordability of low- and middle-income brackets in Chongqing and then calculated the conversion sale price. The calculation was conducted by using the residual income approach based on the public data for 2016, which were adopted from the Chongqing Statistical Yearbook.⁷

3.1.1. Housing affordability of tenant households in chongqing

We calculated the sale price for PRH that suits the housing affordability of the sandwich class in Chongqing. Using the residual income approach, housing affordability is determined by subtracting non-housing expenditure from housing expenditure; however, the difference is affected by several factors including: household type, household size, and income. The specific calculations are depicted in equations (1) to (3). Further, in accordance with the policy of level payment amortization of the Bank of China, the authors used equation (4) to calculate the maximum amount of money that could be afforded by each household type.

$$RI = MY \times N - NH > A \quad (1)$$

where RI denotes residual income, MY average monthly income, N household, and NH non-housing expenditure.

$$NH = (MBC - MMC) \times N \quad (2)$$

where MBC denotes expenditure and MMC denotes housing expenditure (including residential costs, such as electricity, gas, and water).

$$DP = HP_H \times (1 - m) \quad (3)$$

where DP denotes deposit and HP_H denotes the sale price of a house.

$$A = HP_H \times m \times \frac{i \times (1 + i)^{12 \times n}}{(1 + i)^{12 \times n} - 1} \quad (4)$$

where A denotes monthly repayment, m loan-to-value ratio (LTV),⁸ n loan period, and i interest rate.

3.1.2. Determination of variables for housing affordability calculation

This section explains the variables required for the module to calculate housing affordability.

According to the annual record released by the corresponding local government in 2016, Chongqing has a population of 33,718,400 as of 2015, comprising 125,454,000 households, as shown in Table 1. This translates to an average value of 2.69 people per household in Chongqing.

The PRH of Chongqing targets the low- to middle-income bracket. To determine whether the main target, that is, the low- to middle-income bracket, can afford their own houses through ownership conversion, the predetermined lease of 5 years, the authors evaluated their housing affordability. Table 2 presents the housing and non-housing expenditures calculated using the public data provided by the government.

Further, Table 3 depicts the supplied PRH house types for each household in Chongqing.

3.1.3. Housing affordability

Due to the regulations enforced by the Bank of China, annual repayment cannot exceed half of a debtor's income. Therefore, it compares debtors' residual income and half of his or her income and chooses the smaller amount to calculate monthly repayment.

From equation (4), the authors found that the P_{max} value of the low- to middle-income bracket was 13,915 USD (see Table 4).

The sale price of PRH in Chongqing varies by the size of the house. Table 5 presents the analysis results of the housing affordability of the low- to middle-income bracket. The housing affordability for each square meter ranges from 174 to 464 USD. Due to the limitations in the housing affordability of sandwich class in Chongqing, the sale price for each square meter is negatively correlated with the size of a public rental house. In December 2016, the sale price of a commercial residential building was 863 USD/m². Although the sale price did not exceed 80% of the market price under the regulations of the Chongqing government, the calculated sale price was higher than two times the maximum government-specified sale price.

3.2. Module B: modification of the sale price using IDW interpolation

While calculating the sale price of PRH, both the housing affordability of households and its neighborhood price

Table 1. Population and the number of households in each year.

Year	2011	2012	2013	2014	2015
Population	33,298,100	33,434,400	33,584,200	33,752,000	33,718,400
Households	12,052,000	12,206,400	12,367,800	12,486,700	12,545,400

Source: Chongqing Statistics Yearbook

⁷Chongqing Statistical Yearbook. <http://www.cqj.gov.cn/tjnj/2016/indexch.htm>.

⁸As of 2017, according to the notice issued by the Bank of China, people could take a loan for a maximum of 30 years and purchase a house with 25% of their own money and 75% of the bank loan. The interest rate for a loan period exceeding 5 years, among medium- and long-term loans, was 4.9%.

Table 2. Average income and expenditure for each household from each income bracket (2016).

Index	Low-income bracket	Low- to middle-income bracket	Middle-income bracket	Middle- to high-income bracket	High-income bracket
Income	978	1,811	2,848	4,142	6,866
Expenditure	1,162	1,572	2,148	2,932	4,571
Housing expenditure	202	273	389	552	830
Non-housing expenditure	960	1,299	1,759	2,380	3,741

All income values are in U.S. dollars.
Source: Chongqing Statistics Yearbook⁹.

Table 3. House types for each household type.

House types	30–40 m ²	40–50 m ²	50–60 m ²	70–80 m ²
1- To 2-person households	0	0		
3- To 4-person households			0	
Households with more than 4 people				0

Source: Temporary Measure for Management of PRH in Chongqing¹⁰

Table 4. Average income and expenditure per household belonging to each income bracket (2016).

Index	Low- to middle-income bracket
Income (A)	1,811
Expenditure (B)	1,572
Housing expenditure (C)	273
Nonhousing expenditure (D) (B-C)	1299
Residual income (E) (A-D)	512
Half the debtor's income (1/2A)	906
Monthly repayment (min{E, F}/12)	43
Maximum housing affordability, Pmax(H)	13,915

All values are in U.S. dollars.

Table 5. Sale prices for houses of different sizes.

Size (m ²)	Low- to middle-income bracket
S = 30	464
S = 40	348
S = 50	278
S = 60	232
S = 70	199
S = 80	174

All prices are in U.S. dollars per square meter.

should be considered to ensure that the price is reasonable and the government can compensate the funds expended in initial investment. Among 15 public rental house complexes that were ready for sale, we focused on the first public rental house complex of Chongqing, Kangzhuang Good land, constructed in 2011. We collected relevant data and analyzed the neighborhood cost and the market price of the nearby commercial residential buildings, Minxin Garden and Western of Kangju. Given that IDW interpolation requires at least three known points, we compared the market prices of four neighborhoods. Further, equations (5) and (6) were used for calculation (see Table 6, as well):

$$\delta = \sum_{i=1}^n r_i \times (R_{0i} - R_{0i}) \quad (5)$$

$$r_i = \frac{1}{(d_i)^2} / \sum_{i=1}^1 \frac{1}{(d_i)^2} \quad (6)$$

$$R_2 = R_1 + \delta \quad (7)$$

We calculated the modification factor δ by using R_{0i} (the neighborhood cost of Kangzhuang Good land), R_0 (the neighborhood cost of other public rental houses), and d_i (distance). The term r_i denotes distance-weighted coefficient. The modification factor δ helps modify the sale price of PRH calculated using the residual income approach. As a result, the sale price was modified using equation (7) to range from 386 to 676 USD.

3.3. Module C: validation of sale price of PRH using cost–benefit analysis

We used a cost–benefit analysis to check the validity of the calculated sale price and adopted Python to reduce the error rate during calculation as described in Figure 2.

In module C, we used the sale price, yearly rent, deposit, and paid rent obtained from modules A and B. The difference between the net benefit of price obtained from module A and the net benefit of price obtained from module B is computed using equation (8):

$$NPV = B_0 - C_0 + \frac{B_1 - C_1}{1 + i} + \frac{B_2 - C_2}{(1 + i)^2} + \dots + \frac{B_T - C_T}{(1 + i)^T} \quad (8)$$

In the equation, if the discount rate is calculated in year T , B_T is the benefit of year T , and C_T is the cost of year T . NPV summarizes the social value of the project into

⁹Chongqing Statistical Yearbook. <http://www.cqtj.gov.cn/>.

¹⁰Temporary Measure for Management of PRH in Chongqing. <http://www.cq.gov.cn/publicinfo/web/views/Show!detail.action?sid=371812>.

Table 6. Average income and expenditure per household from each income bracket (2016).

PRH	Commercial residential building	Neighborhood cost (USD)	Distance(km), d _i	r _i	Market price (USD), R _{0i}	δ
Kangzhuang Good land	Jinzhuoyuan	1,006	0.58	0.49	1,033	212
	Yinzhuoyuan Community	1,158	0.85	0.23		
	Dazhulin Nanzhuoyuan	926	0.85	0.23		
	Jiangyu Cheng	1,195	1.9	0.05		
Minxin Garden	Sunac Yujin-Phase 2	1,541	1.9	0.51	1,279	
	Sunac Zifengjun	1,174	3.2	0.18		
	Kangxingyuan	951	3.2	0.18		
	Maoxi Ji'an yuan	849	3.8	0.13		
Western of Kangju	Xiexin Chenglifang-East phase 1	1,116	0.51	0.72	1,116	
	Evergrande Group Weilaicheng	1,402	1.3	0.11		
	Beilu Guojicheng	995	1.3	0.11		
	Xuyang Taibeicheng	959	1.9	0.05		

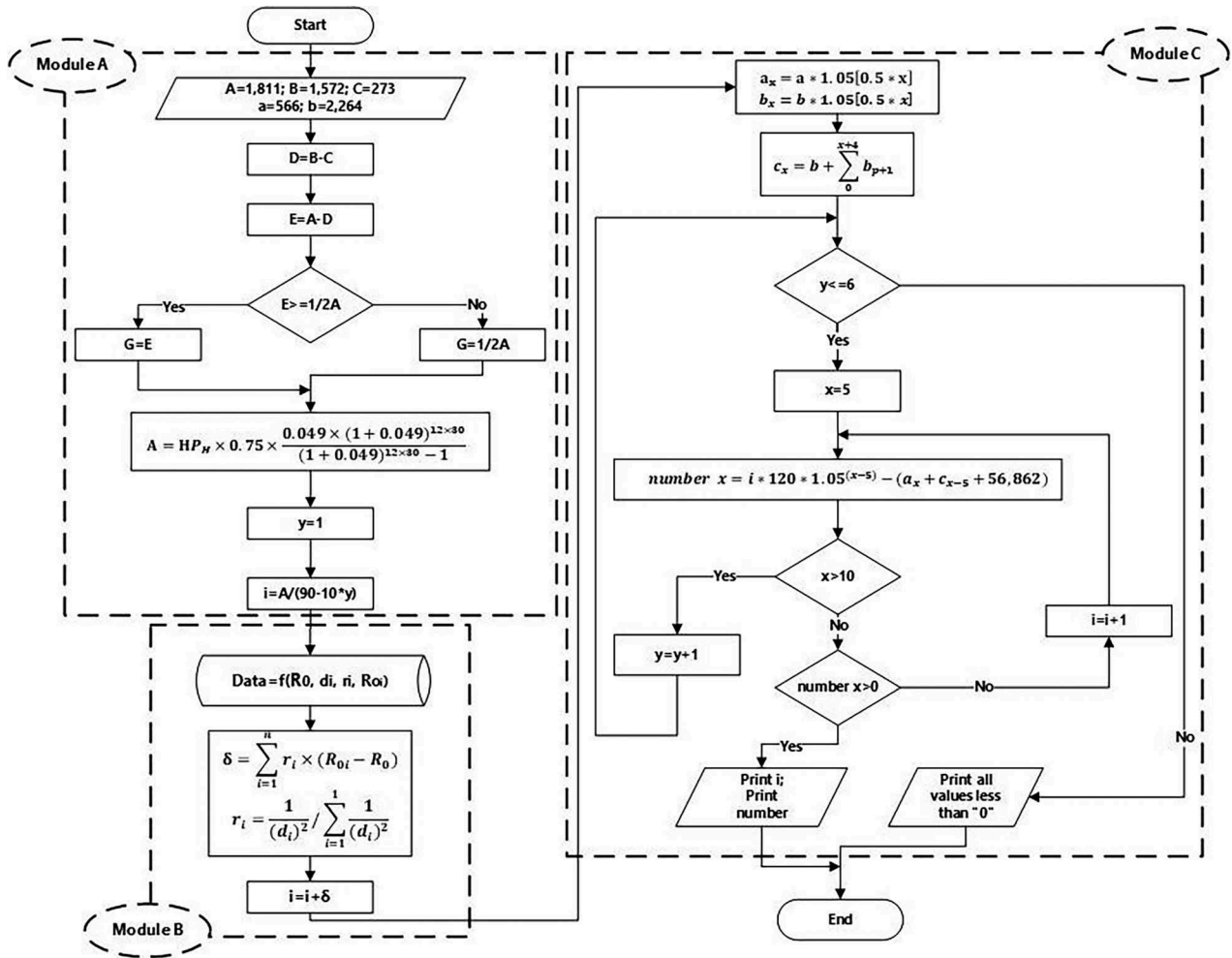


Figure 2. Coded calculation modules using Python.

a single number. The V_T is the NPV of year T and it is $B_T - C_T$, which implies the annual net benefit.

To reduce the error rate of the repeated judgment process, we coded a program to identify the point where the net benefit exceeded zero value. Net benefit of ownership conversion after 5 years of lease and that after 10 years of lease based on the sale price is calculated. When the net benefit exceeded zero, the sale price and the net benefit of PRH is determined. When the net benefit based on the sale price was lower than zero, it repeatedly stated, "all net benefits are lower than 0." Through the repeated judgment process, it computed a reasonable conversion price.

3.4. Results and discussion

In this study, we tested the validity of the sale price by analyzing the cost and benefits of PRH. First, we made assumptions regarding other conditions necessary for testing the validity of PRH. According to the notice regarding PRH, the lease, including the rent and deposit of PRH, will be renewed every 2 years within the limit of the 5% increase restricted by the law. Therefore, for the analysis, we assumed that the rent, deposit, and conversion price would increase by 5% every 2 years. We did not consider the management cost while calculating the net benefit since the Chongqing government calls for bids to select

Table 7. Net benefit values obtained introducing residual income approach.

Conversion period	Lease Year 0	Lease Year 1	Lease Year 2	Lease Year 3	Lease Year 4	Lease Year 5	
Deposit (A)	624	655	655	688	688	723	NPV > 0 → Approved NPV < 0 → Rejected
Total rent (B)	14,277	16,899	19,520	22,272	25,025	27,915	
Neighborhood market's price (D)	123,901	13,096	136,601	143,431	150,603	158,133	Net benefit (F) (E-A-B-C)
5-Year lease sale price (E)	55,680						-16,086
6-Year lease sale price (E)		58,464					-15,952
7-Year lease sale price (E)			61,387				-15,650
8-Year lease sale price (E)				64,457			-15,366
9-Year lease sale price (E)					67,679		-14,895
10-Year lease sale price (E)						71,063	-14,436

Note. All monetary values are in U.S. dollars.

a residence management company for PRH management. All the net benefits obtained from the residual income approach were lower than zero, as shown in Table 7.

If the net benefit is lower than zero, the project cannot be approved and the calculated price is not reasonable. On the contrary, if the net benefit is higher than zero, the project can be approved and the calculated price is reasonable. As shown in Table 7, since all the net benefits computed within the range of sale price calculated using the residual income approach considering only the housing affordability are lower than zero, the sale price is too low and, hence, not reasonable. The obtained results from the residual income approach were modified using IDW interpolation to obtain a reasonable price. Table 8 presents the net benefit of the sale price values after applying IDW interpolation. As shown in Table 8, all the net benefits are ranged with sale price calculated using the IDW method.

Moreover, the sale price obtained by integrating the residual income approach and IDW interpolation method was found reasonable and effective since the net benefit is higher than 0 when the sale price is 557 USD/m², as shown in Table 9.

4. Conclusions

As a type of indemnificatory housing, PRH should fulfill its purpose of ensuring social welfare. Hence, a reasonable and affordable conversion price for residents should be proposed to increase their non-housing expenditure and capital liquidity. In addition, the validity of PRH should be reviewed to ensure its continuous development and sustainability since the government contributes to the most of investment and operations of PRH.

On the other hand, although PRH aims to promote social welfare to provide a stable living environment for citizens with low- and mid-income, lowering the sale price without any limitations will affect the

Table 8. Net benefit values obtained by adopting IDW interpolation.

Conversion period	Lease Year 0	Lease Year 1	Lease Year 2	Lease Year 3	Lease Year 4	Lease Year 5	
Deposit (A)	624	655	655	688	688	723	NPV > 0 → Approved NPV < 0 → Rejected
Total rent (B)	14,277	16,898	19,520	22,272	25,025	27,915	
Neighborhood market's price (D)	123,901	130,096	136,601	143,431	150,603	158,133	Net benefit (F) (E-A-B-C)
5-Year lease sale price (E)	81,120						9,357
6-Year lease sale price (E)		85,176					10,760
7-Year lease sale price (E)			89,435				12,398
8-Year lease sale price (E)				93,907			14,084
9-Year lease sale price (E)					98,602		16,027
10-Year lease sale price (E)						103,532	18,033

All monetary values are in U.S. dollars.

Table 9. Net benefit values obtained through the implementation of Python.

	5-Year lease	6-Year lease	7-Year lease	8-Year lease	9-Year lease	10-Year lease	Sale price with net benefit greater than 0
Before modification			Within the range of 174–464 USD, all net benefits are less than 0.				
After modification	-4,906	-4,215	-2,426	-2,341	-1,263	1	557

maintenance and management of PRH as well as threatening its sustainability. Therefore, it is necessary to conduct a validity check of the sale price of PRH.

Given that no cases of PRH ownership conversion exist despite the relevant regulations established by the local government. For this reason, the process to calculate ownership conversion price must obtain rigorous rationale. The fundamental principle is to take the affordability of potential buyers, sandwich class into account to avoid financial liquidity, while not sacrificing the market mechanism guaranteeing the government or public party. We present a hybrid framework integrating the residual income approach and IDW interpolation method: the former enables the framework to encounter the affordability and the latter is to modify the initial calculation results by comparing those with neighbor dwellings. A balanced cost-benefit analysis was conducted to validate the determined conversion prices satisfying the both parties, potential buyers and governments.

Analysis results showed that the sale prices calculated by using only the residual income approach are too low to fulfill the market approach given that the NPV is lower than 0. Hence, modification of conversion price was conducted by introducing IDW interpolation method in order to increase the value of NPV from zero to greater values.

The framework proposed in this study will not only support the Chinese government but also public parties in other countries in order to establish new policies for facilitating the ownership conversion price of PRH. The policy can obtain rationale given that the tenants are able to self-prepare in order to reflect their housing affordability, and the governments can determine the sale price towards appropriate economic and financial situation relevant to PRH.

The framework presented in this study needs to be modified according to the unique systems of each country regarding available data and relevant regulations. Nevertheless, the validation using real-world data, PRH of Chongqing, remains considerable aspects. Three stage process consisting of residual income approach, IDW interpolation method and cost-benefit analysis enables to optimize the moment for PRH ownership conversion and sale price while enabling Chinese government to take the ability of each income group into account.

Despite the potentials of presented framework, further research needs to be conducted at the level of macro economy. Most of all, the influence of PRH ownership conversion upon the financial status of governments and living conditions of residents must be monitored over a period of time. Determined ownership conversion price based on the logical rationale can cause unexpected situations. In addition, housing market excluding PRH must be considered as well. Moreover, the PRH ownership conversion is likely to influence upon supply and demand of private housing. Hence,

the entire impacts must be explored in terms of dynamic approach rather than static one and relevant policy must be established or modified after cautious simulation in this aspect.

Disclosure statement

No potential conflict of interest was reported by the authors.

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