Research on the economic sustainability of affordable rental housing——Based on autoregressive integrated moving average and real option valuation model

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Abstract. Affordable rental housing constitutes a crucial element of China's housing security system. However, its construction imposes significant financial pressure on local governments. In the new phase of development, it is imperative to strike a balance between the needs of people's livelihood and the government's fiscal capacity. To achieve this objective, this paper proposes the hypothesis of renting before selling as a means of enhancing the economic sustainability of affordable rental housing. To comprehensively and accurately assess the economic sustainability of the project, we construct a real option valuation model to explore the option premium in the face of uncertainty and management flexibility, thereby expanding the value composition of the project. We used a rental project in Nanjing as a case study for empirical analysis. Our findings show that the economic sustainability of affordable rental housing has improved significantly under the "renting first and selling later" approach, and that the created real option model can comprehensively evaluate the project value. Finally, by calculating the project value under different starting years and sales ratios, further research was conducted on how to balance the economic sustainability and guarantee effectiveness of housing.

Keywords: Affordable rental housing; Economic sustainability; Lease before sale; Real option; ARIMA model.

1   Introduction

In July 2021, the State Council issued the "Opinions on Accelerating the Development of Affordable Rental Housing", which clarified the top-level design of China's housing security system at the national level for the first time, proposed the construction of a housing security system with public rental housing, affordable rental housing (hereinafter referred to as "rental housing") and co-ownership housing as the main body, and clarified the basic system of rental housing and related support policies. However, due to the immature operation model, long payback period and low return on investment, China's rental housing has brought great pressure to the local government's finances,

and is not conducive to the healthy development of the housing market. Therefore, exploring new operating models and implementing rent-to-sell policies is a necessary attempt to get rid of the current housing dilemma and achieve sustainable housing economy. Compared to the traditional net present value method, the real option model can obtain an option premium from the uncertainty and the corresponding management flexibility, thus giving a more accurate valuation of the project. Based on this, this paper first uses the ARIMA model to predict the future housing price trend, and then combines the real option theory to study the improvement of the economic sustainability of rental housing under the rent-to-sell scheme, which provides a useful reference for decision-makers to carry out the construction of rental housing.

2   Review of relevant research literature

Housing sustainability includes three main aspects: economic, ecological and social. Economic sustainability is part of housing sustainability and is the premise and foundation for other sustainable development of housing projects. Wu et al. [1] based on the mixed evaluation method of analytic hierarchy process-entropy weight method and cloud model, took the "Minxin Home" public rental housing project in Chongqing as a case study, and found that the weight of economic and social sustainability is higher than that of environmental, community and cultural sustainability. Mohamed [2] uses a system dynamics model to provide decision-makers with an analytical tool to assist them in selecting the best alternatives to building materials to meet the sustainability of the environmental and economic performance of affordable housing. Gan et al. [3] found that financial feasibility and cost recovery are the most important performance indicators of economic sustainability from the perspective of stakeholders, through fuzzy set theory and analysis of variance. Wu Wei et al. [4] studied a public rental housing project in Shanghai and found that controlling the payback period, rental pricing, occupancy rate and other factors have a significant effect on the economic sustainability of public rental housing. From the perspective of the private sector, Li [5] evaluated the economic sustainability of a hypothetical public rental housing in Nanjing, found that the project was not feasible under the existing scheme, and finally proposed an optimization scheme of free land use rights and government subsidies.

The value of a real asset investment project includes not only the value generated by the cash flow of the project, but also the value of the enterprise's future investment rights, i.e., investment income refers to the current asset use value plus the value of future real options. Nivedya M. Kottayi [6] proposed a framework for assessing the impact of climate change on pavement, using a step-by-step approach to assess the net present value (NPV) that is not conducive to investment under high uncertainty conditions, while real options provide flexible extension options to discover the potential value of the project. Real options are also widely studied in the field of real estate investment. Li [7] introduced the real option theory into private public rental housing and used the modified B-S model to evaluate the possibility of the private sector providing public rental housing. Shi [8] studied the possibility of the PPP model to solve the financing difficulties of public rental housing, and used the two-stage binary tree model

to estimate the project value and tap the potential investment value for the private sector. Zhang et al. [9] used the research method of combining real options and cash flow discounting to evaluate the value of the assets and interests of households under the co-ownership housing security model, and put forward suggestions for the government to regulate the amount of protection for households.

In summary, in assessing the economic sustainability of rental housing, traditional valuation methods cannot explore the potential value of the project, which may lead to misjudgment by investors. As an efficient valuation model, real options can increase the value of the project from the uncertainty of the project and the flexibility of management. Therefore, considering the uncertainty faced by the rental housing project and the irreversibility of physical investment, this paper uses real options to evaluate the sustainability of the rental housing economy more accurately, and uses the ARIMA model to predict the future housing price trend, in order to give the government and relevant institutions a more accurate judgment.

3   The current situation and the way out of the economic sustainability of rental housing

3.1   The main dilemmas faced by the economic sustainability of rental housing

There is a large funding gap and great pressure on local finances

The main sources of funding for affordable housing projects in China are financial subsidies from the central government, land transfer funds, and bank loans, while private investment is relatively small [10]. During the "14th Five-Year Plan" period, the country initially plans to invest in the construction of about 9 million units of rental housing, and the total investment scale is expected to be between 26,000 and 3.2 trillion yuan, with an average annual investment scale of about 600 billion yuan [11]. At present, the fiscal expenditure for affordable housing projects is expected to remain at 300 billion to 400 billion yuan. Although the amount of funding for affordable housing by governments at all levels has increased year by year, in general, due to the acceleration of urbanization in China, the further increase in housing demand, coupled with the poor financing channels in the field of housing barriers and the single main body of capital supply, the large gap between capital supply and demand is still one of the biggest obstacles restricting the construction of affordable housing. However, guaranteeing land for rental housing usually requires the transfer of land at a low price or even free of charge, and local governments also need to pay various taxes and other expenses, which further increases the pressure on local finances and makes local governments face severe problems in balancing revenue and expenditure [12].

High operating costs and low rental income

First of all, the capital investment required to build and maintain rental housing is large. In addition to the need for the government or construction agencies to invest a lot of money in housing construction in the early stage, to meet the housing needs of low-income families. The operation and management of rental housing in the later stage

also requires a lot of human resources and expertise. The management of rental housing includes tenant selection, contract management, repair and maintenance, etc., which require a professional management team and personnel to complete. In addition, rental housing is often geared towards low-income groups, and these households may not be able to afford normal maintenance costs, making it difficult to maintain and manage the home, further increasing operating costs. Secondly, rents for rental housing are usually low, and in order to ensure affordability, the government may need to provide rent subsidies or concessions. As a result, the rent of rental housing cannot be adjusted in the same market as the rent of commercial housing, and the rent is low, resulting in a relatively long payback period, which delays the recovery and reuse of government funds.

3.2   The main challenges to the economic sustainability of rental housing

The process of urbanization has slowed down and the demand for leasing has weakened

The Chinese Academy of Social Sciences predicts that China will see an "inflection point" of urbanization from rapid progress to gradual slowdown during the 14th Five-Year Plan period, and enter a relatively stable development stage after 2035 [13]. By the time urbanization was gradually completed, most of the rural population had migrated to the cities, and the growth rate of the urban population had slowed down. At this time, the city has built enough housing to meet people's needs, so the demand for affordable rental housing will also weaken. At the same time, in the process of urbanization, due to the increase in urban population and employment opportunities, the economic situation of a part of the population may improve, and they may be more able to buy their own housing, thus reducing the demand for affordable rental housing. Therefore, when the urbanization rate gradually peaks, the weakening demand for affordable rental housing is a possible trend.

Residents' consumption preferences renting is not as good as buying a house

First of all, buying a home gives you ownership of a property, while renting a home is only a temporary right of use. This means that the person who buys the house can enjoy the wealthy appreciation that comes with the property, while the person who rents the house does not enjoy this appreciation. Secondly, buying a home can provide a stable living environment. Renting a house may face problems such as rising rents and landlords not renewing the lease, while buying a home can provide a stable living environment that is not affected by these problems. In addition, buying a house can also enjoy the advantages of mortgage interest deduction and high freedom of home decoration, which are not available in rental housing. Therefore, the existence of housing property rights has a significant impact on the level of well-being, and the happiness level of residents with housing property rights is significantly higher than that of residents without housing property rights [14].

3.3   Measures to enhance the economic sustainability of rental housing

In the new stage of development, how to balance the government's financial capacity and residents' housing needs is a real challenge at present. The concept of rent-to-sell is to move from low-level primary security to high-quality housing security, which is the only way to improve the social security system and promote the realization of common prosperity [5], and is the transformation and upgrading of the concept of moderate inclusive security in the era of public rental housing to the concept of development-oriented security in the era of rental housing. On the one hand, through the use of the housing consumption method of renting first and then selling, the housing rental and purchase market has been opened, so as to get rid of the restrictions of the traditional housing consumption mode of "renting" and "buying", and effectively realize the benign interaction between housing security and the housing market. On the other hand, at a time when the housing market is selling weakly, rent-to-sell can stimulate residents' potential demand for housing, release consumption power, and further promote economic development.

The "rent-first" of rent-guaranteed housing is a key measure to alleviate the housing difficulties of new citizens and young people by renting housing, helping those who are temporarily unable to buy housing to solve their housing problems, and providing a relatively stable and affordable housing option. The "post-sale" of rental housing gives the tenant the right to acquire ownership of the public housing after the lease expires. During the lease period, tenants can gradually accumulate funds for the purchase of the house, understand the actual situation of the house and the living environment, so as to make better decisions about the purchase of the house. This model offers tenants an opportunity to gradually realize their dream of buying a home.

Having the right to housing not only allows the "sandwich layer" of the city to avoid falling into the "poverty trap", but also allows it to enjoy the wealth appreciation brought about by the country's development. At the same time, for the government, recovering investment as soon as possible is also conducive to alleviating the government's financial pressure, facilitating the subsequent increase in rental housing supply, and promoting the sustainable development of the housing security project. In addition, although rent-guaranteed housing is a public welfare undertaking, only a slightly profitable project can help the government take into account the social benefits and the lost opportunity cost of land, and then support the construction of rent-guaranteed housing, reasonably plan the location of rent-guaranteed housing, and avoid problems such as mismatch of people and land, and excessive commuting.

4   Construction of investment value evaluation model of rental housing based on ARIMA-real option

4.1   ARIMA Model

Model introduction

The ARIMA (Autoregressive Integrated Moving Average Model) model is based on the autocorrelation and moving average of time series data to model and predict, and is

composed of two parts: autoregressive (AR) and moving average (MA), which can process time series data with randomness, trend and seasonality. The three main parameters of the ARIMA model are p, d, and q, which represent the autoregressive order, the difference order, and the moving average order, respectively, and are usually represented by ARIMA (p, d, q).The corresponding algebraic expression for the stationary sequence ARIMA (p, q) model is:

$$x_t = \varphi_0 + \varphi_1 x_{t-1} + \cdots + \varphi_p x_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \cdots - \theta_q \varepsilon_{t-q}$$
$$\varphi_p \neq 0, \theta_q \neq 0 \quad\quad (1)$$
$$E(\varepsilon_t) = 0, \text{var}(\varepsilon_t) = \sigma_\varepsilon^2, E(\varepsilon_t \varepsilon_s) = 0, s \neq t$$

Modeling steps

The modeling process of an ARIMA model can be divided into the following four main steps:

1. Stationarity test. The ADF test was performed on the sequence plot to observe whether the sequence was stationary; For non-stationary time series, the difference of order d is performed first, and the time series is converted to stationary time series.

2. Determine the D, P, and Q values. d is the number of differentials performed in step 1. The values of p and q are generally estimated by observing the truncation of the autocorrelation graph (ACF) and the partial autocorrelation graph (PACF).

3. Parameter estimation. The goal of parameter estimation is to find the best combination of parameters so that the model can best fit the data. According to the principle that the smaller the AIC and BIC values, the better the model balance goodness-of-fit and complexity effect, the optimal ARIMA model parameters can be determined.

4. Make ARIMA model predictions. According to the model parameter table, the model formula combined with the time series analysis chart is comprehensively analyzed, and the order result of backward prediction is obtained.

4.2   Real Options Model

Investment value evaluation model of rental housing

As a widely used method of decision-making, the net present value method has many undeniable advantages, but has been criticized for its shortcomings in dealing with uncertainty, irreversibility, and managerial flexibility, which can be addressed through real options. Therefore, Trigeorgis[15] proposed a simplified model that bridges the NPV method and the Real Option Value (ROV) by introducing a new concept called Extended Net Present Value (ENPV), where the item value is expressed by the formula as:

$$\text{ENPV=NPV+ROV} \quad\quad (2)$$

The net present value portion of the net present value is calculated as follows:

$$\text{NPV} = \sum_{i=1}^{n}(CL_i - CO_i)(1 + i_c)^{-i} \quad\quad (3)$$

Where n is the economic life of the project; i_c is the benchmark rate of return or the target rate of return set by the investor; $(1+i_c)-i$ is the discount factor of the ith year; CI_i is the cash inflow in the ith year; CO_i is the cash outflow in the ith year.

Use the B-S option pricing model to solve the option value ROV

When the government builds a rental housing project, it is equivalent to obtaining an option-like contract. During the contract period, when the government is in the process of weakening rental demand or rising housing prices, the resale of rental housing is equivalent to exercising the option contract and can obtain an option premium. Myers et al. [16] calculated the option to permanently abandon the item to obtain liquidation value, and they regarded the option to abandon the item for liquidation as an American-style put option on interest-paying asset C, with liquidation value S as the strike price. Suppose the total value of the project C is subject to the following diffusion process:

$$dC=(r-\delta)\ Cdt+\sigma CdZt \tag{4}$$

where r is the risk-free rate; Instantaneous cash remuneration (like dividend income) representing the project; σ is the instantaneous standard deviation; Zt is a one-dimensional Brownian motion. The Real Option Value (ROV) is then the present value of future cash flows discounted at a risk-free rate, so you get:

$$ROV\ (S,\ C,\ t)=e-rtE[Max(St-C),0] \tag{5}$$

Based on the risk-neutral assumption and Ito's lemma, the value ROV of a waiver option must satisfy the following stochastic differential equations:

$$\frac{1}{2}\sigma^2C^2(ROV)cc+(r-\delta)C(ROV)v-(ROV)t-r(ROV)=0 \tag{6}$$

Obey:

$$\left.\begin{array}{c}ROV(C,0)=\max(S-C,0)\\ROV(0,t)=S\end{array}\right\} \tag{7}$$

Solving the stochastic differential equation of Eq. (6) yields:

$$\left.\begin{array}{c}ROV=S_te^{-rt}N(-d_2)-Ce^{-\delta t}N(-d_1)\\d_1=[Ln(C/S_t)+(r-\delta+\sigma^2/2)t]/\sigma\sqrt{t}\\d_2=d_1-\sigma\sqrt{t}\end{array}\right\} \tag{8}$$

Where t is the option exercise time; St denotes the discounted value of the implementation clean-up value; N(d1) and N(d2) are the cumulative probabilities of the variables less than d1 and d2, respectively, and are in the standard normal distribution.

5   Empirical research

In this paper, we select the A project of rental housing in Nanjing, and use the ARIMA-real option value evaluation method proposed in this paper to comprehensively evaluate the value of the project under the rent-to-sell scheme. In addition, the changes in the net present value of project A under different lease-to-resell periods are discussed.

5.1   Basic Data

The rental housing project A is planned and constructed in 2018 with a construction period of two years, and its main construction indicators are extracted from its feasibility study report, as shown in Table 1.

Table 1. Main construction indicators of Project A

index	numeric value	index	numeric value
Total Land Ar(m2)	26936.84	Residential area(m2)	66492.10
Total floor are(m2)	93357.10	Area of other districts(m2)	950.00
Number of Houses (Units)	887	Parking Spaces(pcs)	500

At the same time, looking at the original feasibility study report, the starting rent of 40.5 yuan per square meter per month, and an annual increase in rent of no more than 5%. The benchmark discount rate is 6%, and the net present value of the project is -239.3755 million yuan. It can be seen that the project is not economically sustainable when renting but not selling.

The following will discuss the changes in the investment value of rental housing under the rent-to-sell scheme.

5.2   Housing price prediction based on the ARIMA model

Data Sources

This paper selects the monthly housing price data of Pukou District, Nanjing from January 2012 to December 2022, and the data comes from the Anjuke database.

Stationarity test

After sorting out the original data, it is preliminarily judged to be a non-stationary time series. Therefore, the difference operation is performed on the monthly housing price series, and then the unit root test is performed by the ADF test method to further judge the stationarity of the series, and the ADF test results are shown in Table 2.

Table 2. ADF test table

variable	Differential order	t	P	AIC	Threshold		
					1%	5%	10%
Monthly Prices	0	-1.682	0.440	1595.211	-3.485	-2.885	-2.579
	1	-2.58	0.097*	1584.226	-3.485	-2.885	-2.579
	2	-4.438	0.000***	1576.462	-3.485	-2.885	-2.579

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively

The experimental results show that the sequence is of the second order stationary, that is, the value of the difference degree d is 2. Figure 1 shows the optimal difference series of monthly house price data after the second-order difference.
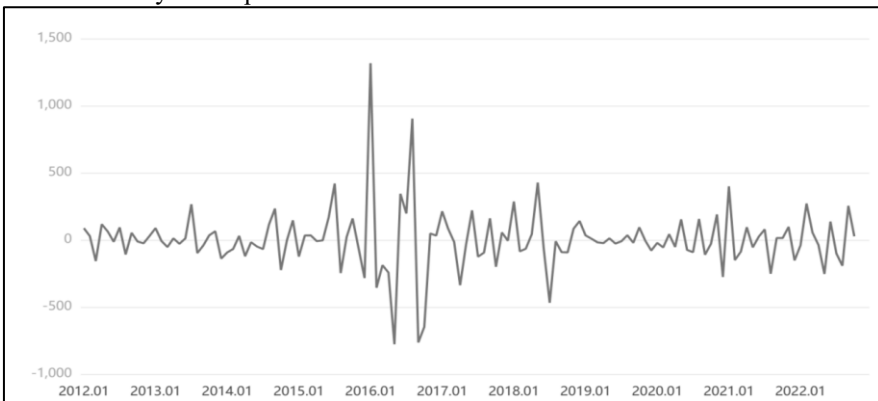

Fig. 1. Diagram of the optimal differential sequence

Model fitting

By comparing the AIC and BIC of different models, the combination of the smallest order of AIC and BIC was selected as the ideal order, and the P value of the parameters and the coefficients of each order was required to be statistically significant before it could be included in the model. In this paper, after several comparisons, it is determined that the model parameters are: p=1, d=2, q=1, and all parameters of the model are significant. Therefore, the model was finalized as ARIMA(1,2,1).

Model parameter estimation and formula confirmation

The ARIMA model was fitted using the ARIMA() function in the Statas models library based on the time series data and the parameters p, d, and q values of the model, and the results of regression fitting are shown in Table 3.

Table 3. Model parameters

	coefficient	standard deviation	t	P>|t|	0.025	0.975
constant	-1.247	2.728	-0.457	0.647	-6.595	4.1
ma.L1.D2.monthly prices	0.559	0.179	3.121	0.002	0.208	0.911
ma.L2.D2. monthly prices	-0.947	0.126	-7.498	0	-1.195	-0.699

Based on the variable monthly house price, the model results are the ARIMA model (1,2,1) test table and based on 2-difference data, and the model formula is as follows:

$$x(t)=-1.247+0.559*y(t-1)-0.947*\varepsilon(t-1) \tag{9}$$

Model Prediction

Through the model formula obtained above, the 60-month monthly housing price data is predicted backwards, after averaging the monthly data, the average annual house price from 2023 to 2027 is obtained, as shown in Table 4.

Table 4. Annual house price forecast

Time (years)	2023	2024	2025	2026	2027
Forecast value of house price (RMB/m²)	20570	19766	18781	17617	16274

5.3   Analysis of the investment value of rental housing based on ARIMA-real options

Static investment value estimation of the project

The cash inflow of this model mainly comes from the rental income of rental housing in the operation stage and the sales revenue from leasing to sale. For example, when the sale starts in the fourth year, the rental housing for the first three years is only rented and not sold, and the rent is the same as before. After 3 years of lease, the house can be resold from rent, the sale price is subject to the annual house price predicted by the ARIMA model, and the previous rent can be deducted from the purchase cost, such as the cash flow from lease to sale in the fourth year is shown in Table 5, and the net present value calculation process is the same as the original feasibility study report, NPV = 94.4803 million yuan.

Table 5. Cash flow statement of investment sold in the fourth year of Project A (unit: 10,000 yuan)

serial number	project	Construction period		operation period			
		1	2	3	4	5	6
1	Cash inflows	0	0	2908	2908	2908	122703
1.1	Operating income	0	0	2908	2908	2908	122703
2	Cash outflows	47847	15092	870	870	870	11374
2.1	Construction investment (excluding interest)	47847	15092	0	0	0	0
2.2	Liquidity	0	0	0	0	0	0
2.3	Operating costs	0	0	709	709	709	5384
2.4	Taxes and surcharges	0	0	161	161	161	5990
3	Net cash flow before income taxes	-47847	-15092	2038	2038	2038	111329
4	Adjusted income tax (25%)	0	0	279	279	279	20781
5	Net cash flow after income tax	-47847	-15092	1759	1759	1759	90548

Estimation of the value of real options of the project

In order to calculate the real option value in Equation (8), a total of 6 parameters are required, which will be confirmed one by one below.

The first parameter is the risk-free rate r, which is usually based on the government's debt yield. The interest rate on five-year Treasury bonds issued in 2018 was 4.27%, so r=4.27%.

The second parameter is the strike time t, i.e. the time from the acquisition of the option to the abandonment of the option, which in this case is the time from the start of construction to the time from the lease to the resale.

The third parameter is the volatility σ of the underlying price. Based on the monthly data of housing prices from 2018 to 2022, the σ=10.64% of this project is calculated according to the historical volatility estimation process.

The fourth parameter is the instantaneous cash return δ, which is equal to the risk-free rate.

The fifth parameter is the liquidation value St, which refers to the present value of the cash flow at the time of the sale of the rental property at time t. For example, when it is sold in the fourth year, S4 = 8650.09 miliion yuan

The sixth parameter is the total value of the project C, that is, the discounted cost of the development project excluding land costs, C = 407.4026 million yuan.

Substituting the six identified parameters into equation (6) yields:

$$ROV=S4e^{-rt}N(-d2)-Ce^{-\delta t}N(-d1)=35431 \text{ million yuan}$$

It can be seen that this project contains a huge option value, so that the net present value of project A expansion is:

$$\text{ENPV} = \text{NPV} + \text{ROV} = 9448 + 35431 = 44879 \ \text{million yuan}$$

Net present value analysis of project development under different circumstances
    In order to further study the change of the NPV of project expansion in the time dimension, the following is calculated for the expansion NPV of project A under different sales periods, as shown in Figure 2.
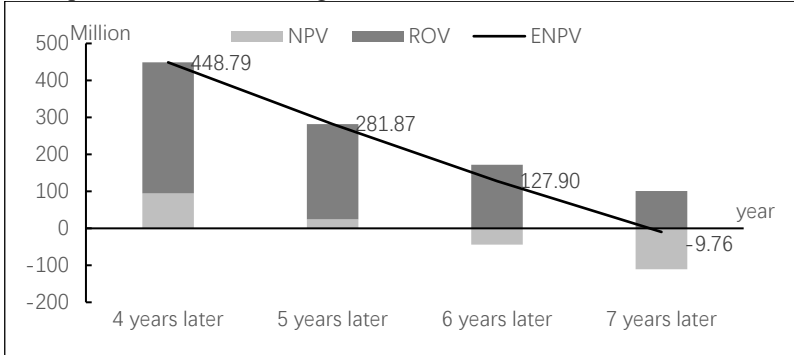

Fig. 2. Expanded net present value of Project A with different minimum sales periods

    It can be seen that when the rental housing is sold again in the 7th year of operation, the net present value of the expansion will be less than zero, that is, it will always operate at a loss. In the first 6 years, the net present value of rental housing expansion under the real option model can be greater than zero at any time from lease to sale. The following further explores the net present value of project expansion under different disposal ratios, as shown in Figure 3.
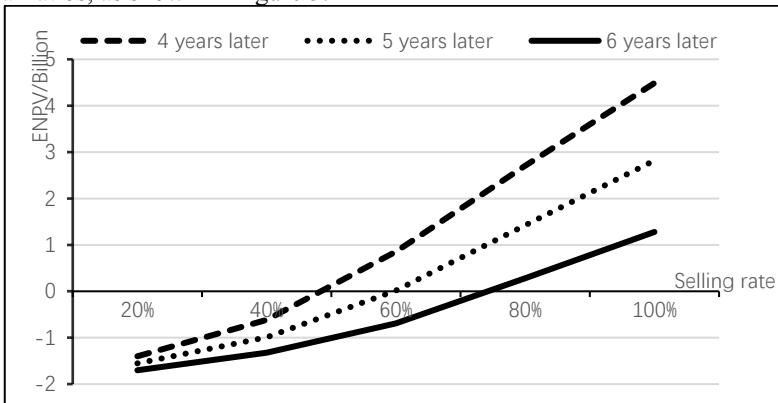

Fig. 3. Net present value of project A expansion under different sales ratios and minimum sales periods

If the government wants to take into account the rent-to-purchase ratio and the economic sustainability of the project, it needs to select the appropriate lease-to-resale ratio within a certain number of years; When you want to keep a part of your home for rent, you should sell the rest as soon as possible. The later the start of the sale period, the more homes should be rented and resold.

6   Conclusion

In view of the current dilemmas and challenges faced by rental housing, this paper puts forward the hypothesis of rent-to-sell and constructs a value evaluation model of rent-guaranteed housing through ARIMA-real option theory. Through the calculation of actual cases, the proposed real option model can obtain the option premium from the uncertainty and the corresponding management flexibility, so as to comprehensively evaluate the investment value of the project, and verify that the rent-to-sell scheme can improve the economic sustainability of rental housing. Finally, by calculating the expansion net present value of the project under different sales periods and sales ratios, it is found that the earlier the lease-to-resell time and the higher the sales ratio, the larger the expansion net present value of the project. This study on the guarantee of rental housing provides a theoretical exploration for future selection of the "rent first, buy later" model.

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