Research on the Specification of Automated Valuation Models for Residential Properties in China

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Abstract—**Recently the Chinese government has been preparing in many aspects for the levy of property tax, among which the development of the computer aided mass appraisal (CAMA) system is an important technical foundation. The computer aided mass appraisal (CAMA) system is an important tool in property assessment and taxation, and its reliability and accuracy highly depends on the proper specification of the automated valuation model (AVM) employed in the system. Based on the particularities of residential properties in urban China and the current data conditions in most Chinese cities, this paper improves the conventional direct market method suggested in literatures by introducing and combining the comparable sales method, and develops two improved direct market methods, namely, the direct market-comparable sales method and the hybrid method. The empirical results of the AV/MV ratio test studies indicate that these two improved methods can significantly increase the appraisal accuracy and better satisfy the requirements in the standards. So these methods are suggested for the CAMA system in China.**

Keywords- Automated valuation model (AVM), Comparable sales method., Computer aided mass appraisal (CAMA), Direct market method, Residential properties

I. INTRODUCTION

Recently the Chinese government has been preparing in many aspects for the levy of property tax, among which the development of the computer aided mass appraisal (CAMA) system is an important technical foundation. Similar with most countries and regions, the tax base of the property tax in China will be the properties' market values in each period[1]. Thus, it is necessary to provide the appraised market values of all the properties in each period, which can only be achieved with the help of an effective CAMA system. In fact, a combination of the mass appraisal for the majority of properties and the appraiser aided appraisal for few specific properties is typical in most countries and regions with property tax[2][3][4]. Therefore, the theoretical and practical issues related to the CAMA system have recently been highly concerned and wildly discussed in China[5][6][7][8][9].

Generally, the quality and performance of the CAMA system relies on two essentials: the collection of accurate and complete property transaction data, and a proper and effective automated valuation model (AVM)[2][10]. The lack of qualified property database used to be a major bottleneck in developing the CAMA system in China, so most researches focused on improving the property database[5][8][9]. But since 2004, with the establishment and development of the real estate information system in the major cities, the data conditions have been greatly improved, making the research and design of the AVMs a more important task. Many AVMs have been developed and are currently wildly used in the developed countries, while several international originations, such as the International Association of Assessing Officers (IAAO)[2][10], the International Valuation Standard Committee (IVSC) [11] and the Appraisal Foundation[12], have published several standards related to AVMs. The principles of such models have also been introduced by some Chinese researchers. However, considering the particularities of the housing market in urban China and the limitations of the current property database, such models may not be applicable in China. Accordingly, this paper focuses on the specification of AVMs, and aims to develop proper methods which can be suitable for the appraisal of residential properties in China, while the performances of the methods developed will also be tested.

The remainder of this paper is organized as follows. In the next section, the conventional direct market method, which is suggested in most current

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standards, is reviewed and its potential limitations when utilized in China are analyzed. In Section 3, two improved methods are developed, focusing on the combination of the direct market method and the comparable sales method. Then the performances of these two improved methods are tested in Section 4, using a typical AV/MV ratio test study. The last section summarizes this paper and suggests several key points in the further research and development of the CAMA system in China.

II. THE CONVENTIONAL METHODS

A. The Direct Market Method

The AVMs used in the CAMA systems in various countries and regions may differ in details, but their principles can generally ascribe to the three classical valuation approaches, the sales comparison approach, the cost approach and the income approach, of which the sales comparison approach is preferable, especially in the appraisal of residential properties[2][13][14]. The sales comparison approach can also be further categorized into three methods, that is, the direct market method, the comparable sales method and the time series method. In most literatures and standards, the direct market method is suggested to be preferable for the appraisal of residential properties whenever the data requirements can be satisfied[2]. Meanwhile, this method is also the most mature and wildly used one at present. Thus, we firstly choose the direct market method as the basic method for the CAMA system in China.

Conventionally, the direct market method applies as follows. Firstly, the samples in the property database are employed to establish a hedonic model, as shown in Eq.(1). Where, $P_{i,t}$ is the transaction price of unit i in period t; C is the intercept term; $N_{i,\,j}$ and $A_{i,\,k}$ are the project-level property characteristics and unit-level property characteristics, with α_j and β_k as the imputed characteristic prices, respectively; $D_{i,\,r}$ are the time dummy variables (1 if the unit was transacted in this period, and 0 otherwise), with coefficients of θ_r ; v_i is the error term.

$$\ln P_{i,t} = C + \sum_{j=1}^{m} N_{i,j}\alpha_j + \sum_{k=1}^{n} A_{i,k}\beta_k + \sum_{r=1}^{t} D_{i,r}\theta_r + \upsilon_i \qquad (1)$$

This model can be estimated by OLS or other econometric methods, and the coefficients estimated, as well as the characteristics of the target units, can then be used to calculate the appraisal value of the target units, as shown in Eq.(2).

$$\ln \hat{P}_{obj,s} = \hat{C} + \sum_{j=1}^{m} N_{obj,j}\alpha_j + \sum_{k=1}^{n} A_{obj,k}\beta_k + \sum_{r=1}^{t} D_{obj,r}\hat{\theta}_r \qquad (2)$$

B. The Potential Limitations of the Method and the Improvement

Although the direct market method discussed above is recommended in literatures and employed in the CAMA systems in many developed countries, it may not be suitable for the CAMA system in China. On one hand, it is wildly accepted that the reliability of the direct market method highly depends on the completeness of the characteristic variables available in the property database[2]: if the variables included can cover all, or at least most of the important property characteristics, the appraisal results can be expected to be reliable and accurate; otherwise, the results may be greatly biased. However, many important characteristics variables are not available in most cities in China at present, especially the project-level characteristics. For example, the location attribute is known to be the most important characteristic in determining the residential property value, and so the geography information system and methods such as spatial econometrics are suggested in the literatures and have been used in the AVMs in several developed countries[15]. But currently such systems or methods are not feasible in most cities in China, or even in the near future; instead, the location attribute always can only be reflected crudely via dummy variables, which will inevitable affect the reliability of the results. Accordingly, for the AVMs in the CAMA system in China, it is especially important to utilize the available information as effectively as possible and alleviate the effect of the missing characteristics (especially the lack of project-level characteristics).

On the other hand, the features of the residential properties in China are different with those in the west countries, which may also affect the performance of the AVMs. In urban China, most properties supplied and traded in the housing market are apartment units in projects. One project always includes hundreds or even thousands of housing units. Generally, units in one project usually have similar or even uniform project-level characteristics, as well as similar market values, and only differ in some unit-level characteristics, such as unit size, floor level and so on, which have been reflected in the current property database. Thus, the similarity between samples within the same project can be important information to be used in the AVMs in China, which has not been considered in the conventional direct market method discussed above.

As a conclusion of the discussion above, considering the limitations in the data conditions at present, the conventional direct market method may not be applicable and require some improvement, while the similarity in units within the same project can be an important source of assistant information. Therefore, we believe that the introduction of a comparable sales method and its combination with the conventional direct market method can be a

feasible and effective way in improving the conventional method. Based on this idea, two improved methods are developed in the next section, which combine the comparable sales method and the direct market method in different ways.

III. THE IMPROVED MODELS

A. The Direct Market–Comparable Sample Method

In the direct market–comparable sample method, the target units are sorted into two groups, and the direct market method and the comparable sample method are applied in each group respectively. It is expected that the appraisal accuracy of the latter group can be improved.

The hedonic model shown in Eq.(1) is still needed based on all the samples in the property database. Then, for each target unit, if there is not any sample in the property database which belongs to the same project as this target unit, its appraisal value would still be calculated by Eq.(2); otherwise, if the target unit has at least one sample within the same project in the property database, such sample can be selected as a comparable sample and the comparable sales method can be introduced. In this circumstance, the transaction price of the selected comparable sample can be used to calculate the appraisal value of the target unit, adjusted according to their difference in unit-level property characteristics, and the market price trend between the assessment date, s, and the date when the comparable sample was transacted, ζ. Both of these adjustments can be achieved using the coefficients estimated in Eq.(1), as shown in Eq.(3).

$$\ln \hat{P}_{obj,s} = \ln P_{comp,\tau} + \sum_{k=1}^{n} \beta_k (A_{obj,k} - A_{comp,k}) + \hat{\theta}_s - \hat{\theta}_\tau \qquad (3)$$

Especially, when there are more than one potential comparable samples for a target unit, the model shown in Eq.(4) should be firstly developed for the purpose of identifying comparable sample. The distances between the target unit and each potential comparable sample in the characteristic space are calculated as the measurement of similarity, weighted by the absolute value of the imputed characteristic prices estimated in Eq.(1). The most similar sample of the target unit, or in other words, the sample with the minimum D_{comp}, should finally be selected as the comparable sample.

$$D_{comp} = \sum_{k=1}^{n} |\beta_k| (A_{comp,k} - A_{obj,k})^2 \qquad (4)$$

B. The Hybrid Method

The hybrid method[11] also sorts the targets into two groups, but it combines the direct market method and the comparable sales method to a larger extent by modeling samples with and without comparable samples together in a single equation. So we expect that the appraisal accuracy of all the target units can be improved. This method was firstly developed in the field of housing price index compiling in the 1990s as a combination of the hedonic method and the repeat sales method[16][17], and has been proved to be more accurate than the conventional methods by utilizing the information more effectively[18][19].

In the hybrid method, the samples in the property database are also sorted into two groups. For each project, one transaction, which is always the first transaction in the project, is selected and labeled as the "base sample" in this project, and its transaction price is modeled by the hedonic model shown in Eq.(1). For the other samples, the repeat sales method is introduced to analyze the difference in prices between the sample and the base sample in that project, as shown in Eq.(5).

$$\begin{aligned} \ln P_{j,t+\Delta t} - \ln P_{i,t} &= \sum_{k=1}^{n} (A_{j,k} - A_{i,k}) \beta_k + \sum_{r=1}^{t} D'_{i,j,r} \theta_r + e_t \\ &= \sum_{k=1}^{n} S_{ji} \beta_k + \sum_{r=1}^{t} D'_{i,j,r} \theta_r + e_t \end{aligned} \qquad (5)$$

Where, $D'_{i,j,r}$ are the adjusted time dummy variables (1 if the sample was transacted in this period, -1 if the base sample was transacted in this period, and 0 otherwise), S_{ji} are the difference in unit-level characteristics between the samples and the base samples, e_t is the error term.

Then, the base samples modeled by the hedonic method in Eq.(1) and the other samples modeled by the repeated sales in Eq.(5) can be pooled and estimated in a single model, that is:

$$\begin{bmatrix} \ln P \\ \Delta \ln P \end{bmatrix} = \begin{bmatrix} N & A & D \\ 0 & S & D' \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \\ \theta \end{bmatrix} + \begin{bmatrix} \nu \\ e \end{bmatrix} \qquad (6)$$

Where, $\ln P$ are the transaction prices of the base samples; $\triangle \ln P$ are the differences in transaction prices between the samples and the base samples; N refers to the project-level characteristics; A refers to the unit-level characteristics of the base samples; S refers to the difference in unit-level characteristics between the samples and the base samples; D are the time dummy variables defined in Eq.(1), while

[11] The term "hybrid method" mentioned in the IAAO standards and literatures refers to a combination of the additive form and the multiplicative form of hedonic model in the direct market method, but in this paper a "hybrid method" refers to the combination of a hedonic model and a repeat sales model.

D' are the adjusted time dummy variables defined in Eq.(5); α, $\beta$and θ are the vectors of coefficients for project-level characteristics, unit-level characteristics and time dummies, respectively.

Eq.(6) can be estimated using GLS, GMM or other econometric methods, and the coefficients estimated can then be used to calculate the appraisal values of the target units. If the target unit does not have any sample within the same project in the property database, which means that it does not have a related base sample, its value can be calculated directly in the hedonic model shown in Eq.(2) using the coefficients estimated; otherwise, if the target unit has a base sample, this base sample can be treated as a comparable sample and so Eq.(3) can be used to estimate the appraisal value of the target unit, with the coefficients estimated in Eq.(6).

IV. EMPIRICAL TEST

A. The Ratio Test Study

There are several methods for AVMs testing discussed in the literatures, among which the AV/MV ratio test study is most mature and suggested in most standards[2][20][21]. So this method is chosen in this paper to test the quality of the two improved methods, compared with the conventional direct market method.

The AV/MV ratio test study is a type of statistical study based on comparison between the appraisal values resulting from certain AVM(s) and the market values (indicated by the transaction prices) of the same properties[20]. For this purpose, some residential units transacted in the assessment date should be selected as the target units. Then their values are appraised using the AVM(s) designed, and the ratios between the appraisal values and the transaction prices are calculated, which are labeled as the AV/MV ratios. Based on these ratios, several key indicators can be calculated to reflect the performance and quality of the AVM(s). The major descriptions and the requirements suggested in the IAAO standards are listed in Tab.1[20].

Table I. KEY INDICATORS IN THE RATIO TEST STUDIES

Statistic	Interpretation	Requirement
95% Mean Confidence Interval	Measuring the degree of accuracy of the appraisal values of the AVM(s).	[0.9,1.1]
Coefficient of Dispersion（COD）	Measuring the degree of uniformity of the appraisal values of the AVM(s).	≤10.0
Price-Related Differential（PRD）	Measuring the degree of vertical equity (systematic errors) of the appraisal values of the AVM(s).	[0.98,1.03]

Besides these three key indicators, the maximum and minimum value of the AV/MV ratios are always also reviewed in the test for the purpose of detecting outliers, although there are not quantitative requirements for these two indicators suggested in the standards.

B. Data

The data used in the test are collected in Chengdu, a major city in Southwest China and the capital of Sichuan Province, from 2004 to 2006. As required by the Ministry of Construction in China, all the transactions of newly developed residential units must be registered at municipal housing authorities and recorded in the real estate market information system. So supported by the municipal housing authority in Chengdu, our data set is able to cover all the units transacted in these 3 years. From 2004 to 2006, there were totally 193,260 units in 1561 projects transacted in the city.

Based on such data, two stimulant databases are developed for the purpose of ratio test studies. Firstly, 9579 samples, which accounts for 5% of the total volume, are sampled randomly as the property database in the CAMA system. Secondly, the 4th quarter of 2006 is set as the assessment date, and 100 units transacted in this quarter are sampled randomly as the target units to be appraised, where a sampling without recall is performed so that all the target units are not included in the property database. Holding these two databases constant in the tests for all the three methods, the difference in test results can only result from difference in the AVMs.

The variables included in these stimulant databases are listed in Tab.2. As expected in Section 2.2, there are several variables included which cover the most important unit-level characteristics, such as floor level, unit size, unit age and so on. However, there is only one group of project-level variables included, which reflect the location attribute of the project. And they are a group of dummy variables so can only reflect the districts where the projects locate. The other project-level characteristics, as well as more detailed location attributes, are not available. In fact, according to the current "Technical Code for Real Estate Market Information System" in China[22], the variables listed in Tab.2 are typical in most cities at present, or even in the near future. So we believe that a test based on these databases can reasonably reflect the feasibility and quality of the improved methods.

Table II. VARIABLES INCLUDED IN THE DATABASES

	Variable
Project-level characteristic	District where the project locates (a group of dummy variables)
Unit-level characteristic	Total floor level of the building, Floor level of the unit, Unit size,

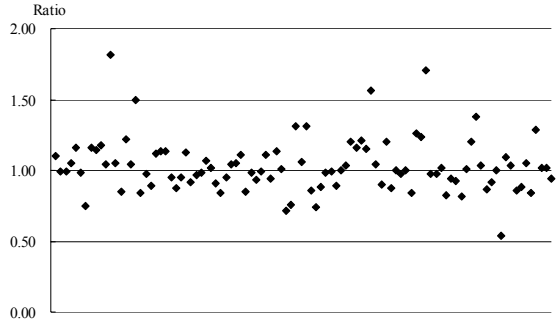
Transaction	Unit age Transaction price, Transaction date

C. Results and Analysis

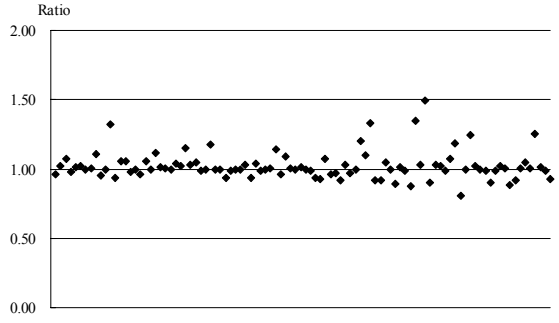
The two improved direct market methods, as well as the conventional method, are then used to appraise the target units sampled, based on the property database mentioned above. The estimation results of the equations used in these methods are not listed in detail here; instead, we focus on the results of the ratio test studies, with the key indicators listed in Tab.3 and the AV/MV ratios of the products shown directly in Fig.1.

Table III. RESULTS OF THE AV/MV RATIO STUDIES OF THE THREE METHODS

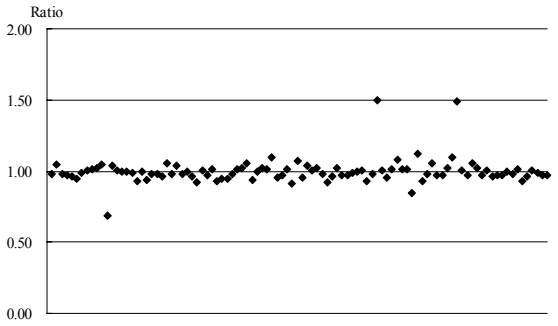
	The direct market method	The direct market-comparable sales method	The hybrid method
95% Mean Confidence Interval	[0.99，1.07]	[1.00，1.04]	[0.98，1.01]
COD	13.06	6.19	4.52
PRD	1.03	1.01	0.99
Max.	1.81	1.49	1.50
Min.	0.54	0.80	0.69



（a） The conventional direct market method



（b） The direct market-comparable sales Method



（c） The hybrid method

Figure 5 The AV/MV ratios of the three methods

According to these empirical results, the two improved methods can significantly increase the accuracy and reliability of the appraisal values, compared with the results of the conventional direct market method, while the effect of the hybrid method is especially outstanding. As listed in Tab.3, for the results of the conventional direct market method, the COD indicator is as larger as 13.06 and beyond the standard requirement listed in Tab.1, while the 95% mean confidence interval indicator and the PRD indicator are only at the edge of the requirements. So it seems that the conventional direct market method is not applicable in China at present due to the missing of some important project-level characteristics. The results are greatly improved when the comparable sample method is introduced and combined. For the results of the direct market-comparable sales method, the COD indicator is reduced to 6.19, which satisfies the requirement in the standards. The 95% mean confidence interval indicator and the PRD indicator are also improved; especially, the confidence interval is narrowed to [1.00，1.04]. The appraisal values resulted in the hybrid method are even more accurate. The 95% mean confidence interval indicator is further narrowed to [0.98，1.01], and the COD indicator and PRD indicator are 4.52 and 0.99, respectively. Meanwhile, the differences of these three methods can also be shown more directly in Fig.1, where the AV/MV ratios of the appraisal values by the two improved methods are totally more close to 1.0, especially for the hybrid method. Besides, several similar assessments and tests are also performed, using different groups of target units sampled, and the results are generally consistent with those discussed above. Thus, it is obvious that the two improved methods can significantly improve the appraisal accuracy and reliability compared with the conventional direct market method, as expected in the theoretical analysis in Section 2 and Section 3.

However, there are still two problems in these two improved methods. Firstly, as listed in Tab.4, these two methods can significantly increase the accuracy and reliability of the appraisal values of target units WITH comparable samples (or in other

words, target units which have samples within the same project in the property database), but have little, or even no, effect on the products of target units WITHOUT any comparable samples. However, the number of target units without comparable samples should be limited if the volume of the property database is large enough. For example, in these 100 randomly selected target units, there are only 5 units without any comparable samples. Especially when the help of appraisers can be introduced, it is feasible to include at least one sample for all projects in the property database.

Secondly, as shown in Fig.1, even in the products of the two improved methods, there still exist some (although fewer compared with the conventional method) "outliers"; or in other words, the appraisal values of some target units may largely depart from their transaction prices. And the outliers exist in units both with and without comparable samples. In fact, it has been proved in literature that such outliers are inevitable in CAMA, and such errors cannot be significantly eliminated only through the improvement in property database or AVM[2][10]. Accordingly, in almost all the countries and regions where the CAMA system are employed for property assessment and taxation, the result review, appeal and re-appraisal is included in the process[10][23], which should also be important in the CAMA system in China.

Table IV. RESULTS OF THE AV/MV RATIO STUDIES OF THE THREE METHODS: COMPARISON OF DIFFERENT TARGET UNITS

		The direct market method	The direct market-comparable sales Method	The Hybrid Method
Units WITH Comparable Sample(s) Obs: 95	95% Mean Confidence Interval	[0.99，1.06]	[1.00，1.04]	[0.98，1.00]
	COD	12.23	5.71	3.10
	PRD	1.03	1.01	1.00
	Max.	1.81	1.49	1.50
	Min.	0.54	0.80	0.69
Units WITHOUT Comparable Sample(s) Obs: 5	95% Mean Confidence Interval	[0.73，1.63]	[0.73，1.63]	[0.79，1.56]
	COD	23.65	23.65	21.36
	PRD	1.07	1.07	0.94
	Max.	1.16	1.16	1.04
	Min.	0.99	0.99	0.96

V. CONCLUSIONS

The development of the CAMA system, which can provide accurate, reliable and costless appraisal values for the properties, is an important technical foundation for property taxation, while the specification of AVM is a key factor in the CAMA system. Based on the analysis of the features of residential properties in urban China and the limitations of the current property database, this paper improves the conventional direct market method by introducing and combining with the comparable sales method, and establishes two new methods. The empirical results prove that the products of the two improved methods are significantly more accurate and reliable than those of the conventional direct market method, and satisfy the requirements in current standards. So these two methods are suggested to be feasible AVM candidates in the CAMA system for residential properties in China, especially for the purpose of property taxation.

Some further researches are still needed for the development of the CAMA system. Firstly, the specification of AVMs is only part (although the most important part) in the design of AVMs. For example, the hedonic model shown in Eq.(1), as well as the related models such as Eq.(3) and Eq.(5), can be set in a additive form, a multiplicative form or even a hybrid form, and it has been proved that such choice can also significantly affect the quality of the AVMs[2]. Besides, the choice of estimation methods of the models is also an important issue, while the classical methods such as OLS are usually found to be ineffective. Secondly, although the effect of the limitations in current property database can be partly alleviated by the methods suggested in this paper, it is still very helpful to further improve the property database and include more property characteristics, both in the project level and in the unit level. Finally, it is important to put the CAMA system into practice as early as possible. Since 2004, 10 provinces or cities in China have been selected by the government to levy the "virtual property tax" as a trial. More developments and improvements of the CAMA system could be expected if it could be included as part of this trial, at least in some of these provinces or cities.

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