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## Article

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## FINANCIAL ECONOMICS | RESEARCH ARTICLE

# The comparison of the hedonic, repeat sales, and hybrid models: Evidence from the Chinese paintings market

Fang Wang<sup>1\*</sup> and Xu Zheng<sup>1</sup>

**Abstract:** With the objective of evaluating the accuracy of price index models, we adopt a series of techniques to compare the performances of the hedonic, repeat sales, and hybrid models based on the data from the Chinese most representative painter, Qi Baishi during the period from 2000 to 2016. When applying the mean squared error (MSE) technique, the repeat sales model outperforms alternative models. However, according to the correlations and width confidence intervals, the hybrid model provides the most reliable estimates of price indices. The study also shows that the repeat sales model obtains relatively a lower total return estimate as well as a higher volatility than other two models. Our findings have important implications in identifying the precision of index models and provide supplements to art investment studies..

**Subjects:** Economics; Finance; Business, Management and Accounting

**Keywords:** Chinese paintings market; hedonic model; repeat sales model; hybrid model; art investment

**JEL codes:** C52; Z1

### 1. Introduction

The rapid growth in the Chinese paintings market has attracted increasingly attention in recent years. Until now, studies focusing on returns of Chinese artworks generally utilize the common hedonic or repeat sales models and there has been no study comparing the results and no uniform conclusion on these issues, thus creating confusion for investors. The aim of this study is to investigate the performances of the hedonic, hybrid along with repeat sales models in the Chinese paintings market in terms of (i) the accuracy of the various models and (ii) the influence on art return estimation using the data from the Chinese most influential painter, Qi Baishi during the period from

### ABOUT THE AUTHOR

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### PUBLIC INTEREST STATEMENT

The rapid growth in the Chinese paintings market has attracted increasingly attention in recent years. Studies focusing on returns of Chinese artworks generally utilize different models and there has been no study comparing the results and no uniform conclusion on these issues. This study investigates the performances of the common models by using the data from the Chinese most influential painter, Qi Baishi during the period from 2000 to 2016. Notably, it is the first time to combine main index construction models to provide an overall perspective on their performances in the Chinese paintings market.

2000 to 2016. Notably, it is the first time to combine main index construction models to provide a overall perspective on their performances in the Chinese paintings market.

The reason we choose data from Qi Baishi as the representative of the Chinese paintings market is that he has been known as the renowned Chinese painter of the twentieth century and one of the top-selling artists. According to the 2016 market annual report from Artprice, he ranked the third of the top world 500 artists by auction revenue and the twentieth of the top 100 auction performance in 2016. It is widely acknowledged that the price behavior of Qi Baishi's artworks exhibits consistent patterns of the Chinese paintings market and reveals useful aspects in terms of performance.

This paper, using both 8,218 hedonic data and 2,207 repeat sales data from Qi Baishi sold at China and global auction houses over the period 2000–2016, examines the performances of three common price index models: the hedonic, hybrid and the repeat sales models. In the hedonic model, all available transaction data are pooled. The logarithm of price is regressed as the dependent variable on a set of value-determining attributes and time dummies. One advantage of the hedonic model is that it makes efficient use of available data and may therefore give more reliable estimates of price indices (Renneboog & Spaenjers, 2013). However, it is criticized for disadvantages of implicit functional form and the change of item characteristics over time (Collins, Scorcu, & Roberto, 2009; Scorcu & Zanola, 2011; Wolverton & Senteza, 2000; Worthington & Higgs, 2004).

In contrast, by confining the analysis to a series of consecutive transactions of a given item at least twice during the sample period, the repeat sales model estimates a price index by regressing the price change of each item on a set of dummy variables. Researchers, such as Goetzmann (1993), Mei and Moses (2002), Pesando (1993), and Pesando and Shum (2008), employ this method to art investments. The main strength of the repeat sales model is that it does not require the specific information on item attributes. Nevertheless, since this approach is based on only a part of total sales observations and this subset may not represent the full sample, the weaknesses of using repeat sales model include the difficulty of controlling for the market trend during the sample period, as well as suffering from selection issues (Biey & Zanola, 2005; Kraeusel & Elstrand, 2008; Renneboog & Spaenjers, 2013).

The hybrid model, first advanced by Case and Quigley (1991) and then extended by Carter Hill, Knight, and Sirmans (1997), constructs the index by combining features of both the hedonic and repeat sales models. This method goes beyond the previous techniques since it allows one to correct for the effects of heterogeneity and serial correlation (Biey & Zanola, 2005). However, the shortcoming of the hybrid model is that it needs an extensive data-set together with the details on the concerned observations. In addition, the requirement of complicated econometric techniques and implementation skills also makes it difficult for some people using this method. Actually, the hybrid model are mainly used in the house market and only a few applications exist on the art market due to the difficulties to apply it to art items (Chanel, Gérard-Varet, & Ginsburgh, 1996).

Our paper makes several important contributions to the analysis of performances of the hedonic, hybrid, and repeat sales models in the Chinese paintings market. First, this is the first time to apply the hybrid model to construct the price index of the Chinese paintings market. Secondly, we present an overall perspective on the comparison of these price index models by examining the results concerning the accuracy and their effects on return estimation. Finally, we examine some fundamental characteristics of the Chinese artworks and their interactions on return performance. Consequently, our findings are expected to be helpful to the evaluation of model construction and art investments.

The remainder of the paper is organized as follows. In Section 2 we provide a brief explanation of each model. Section 3 describes details on the data-set. Empirical results are analyzed in Section 4. In the final Section 5 we summarize the key conclusions.

## 2. The models

### 2.1. The hedonic model

Let  $i = 1, \dots, N$  be the set of selling artworks, define  $P_{it}$  as the logarithm price of the painting  $i$  at time  $t$ ;  $X_{it}$  as a  $K \times 1$  vector of characteristics for the painting  $i$  and  $\alpha$  as a  $K \times 1$  vector of implicit prices of  $X_{it}$ ;  $\delta$  as a  $T \times 1$  vector of index numbers and  $D_{it}$  as a  $T \times 1$  vector of time dummies taking a value of one if a transaction on the painting  $i$  occurs in time  $t$  and zero otherwise, and  $\varepsilon_{it}$  as an error term. The hedonic regression equation can be expressed as:

$$P_{it} = \alpha' X_{it} + \delta' D_{it} + \varepsilon_{it} \quad (1)$$

### 2.2. The repeat sales model

Define  $P_{jt+s}$  as the logarithm price of the painting  $j$  at time  $t + s$ . The price difference between two sales of the painting  $j$  can be written as:

$$P_{jt+s} - P_{jt} = \Delta P_{j\tau} = \delta' \Delta D_{j\tau} + \Delta \varepsilon_{j\tau} \quad (2a)$$

where  $\Delta \varepsilon_{j\tau} = \varepsilon_{jt+s} - \varepsilon_{jt}$ , and

$$\Delta D_{j\tau} = \begin{cases} -1 & \text{if } \tau = t \\ 1 & \text{if } \tau = t + s \\ 0 & \text{otherwise} \end{cases} \quad (2b)$$

### 2.3. The hybrid model

Separate the whole set  $N$  into the subset of artworks that were sold only once during the sample period  $w = 1, \dots, I$  and the subset of artworks that were transacted more than once  $j = 1, \dots, J$ . The error term  $\varepsilon_{it}$  of Equation (1) is now decomposed into two parts: a time dependent random error term  $e_{it}$  and a time independent error term  $\eta_i$ . The hybrid model can then be represented as:

$$P_{wt} = \alpha' X_{wt} + \delta' D_{wt} + \eta_w + e_{wt} \quad (3a)$$

$$P_{jt} = \alpha' X_{jt} + \delta' D_{jt} + \eta_j + e_{jt} \quad (3b)$$

$$P_{jt+s} = \alpha' X_{jt} + \delta' D_{jt+s} + \eta_j + e_{jt+s} \quad (3c)$$

$$P_{jt+s} - P_{jt} = \Delta P_{j\tau} = \delta' \Delta D_{j\tau} + \Delta e_{j\tau} \quad (3d)$$

where all other variables are as previously defined.

Estimations of the hybrid model involve a series of intermediate steps. Note that specification error term  $\eta_w$  in the hybrid model is directly analogous to the unobserved heterogeneity term in the random effects model outlined in Greene (2003). Under this assumption, the covariance matrix associated with the hybrid model can be written as:

$$\Omega = \begin{bmatrix} \sigma_e^2 I & 0 & 0 \\ 0 & \sigma_e^2 I & -\sigma_e^2 I \\ 0 & -\sigma_e^2 I & 2\sigma_e^2 I \end{bmatrix} \quad (4)$$

Following Jones (2010), we estimate Equation (3d) using all  $J$  observations to obtain the residuals as a consistent estimate of  $\sigma_e^2$  and then apply a degrees of freedom correction:

$$\hat{\sigma}_e^2 = \frac{1}{2} \left( \frac{1}{J - T} \right) \sum_{j=1}^J \hat{e}_{j\tau}^2 \quad (5)$$

Analogously, a consistent estimate of  $\sigma_\epsilon^2$  is found by estimating Equation (1) using all  $W$  observations to obtain the residuals and then applying a degrees of freedom correction:

$$\hat{\sigma}_\epsilon^2 = \left( \frac{1}{W - K - T - 1} \right) \sum_{i=1}^N \hat{\epsilon}_{it}^2 \quad (6)$$

The covariance matrix  $\hat{\Omega}$  could then be constructed using  $\sigma_\epsilon^2$  and  $\sigma_\epsilon^2$ . Theoretically,  $\hat{\Omega}^{-1}$  can be found, and according to Cholesky decomposition, we could find the  $P$  matrix, where  $P'P = \hat{\Omega}^{-1}$ , and use this  $P$  matrix to transform the data prior to estimation via least squares. Practically, finding  $\hat{\Omega}^{-1}$  and  $P$  directly requires intensive computations, and it is not possible for large data sets. Fortunately, the structure of  $\hat{\Omega}$  is such that non-zero elements only exist on the on-diagonal of each block, and that the non-zero values within each block are identical. This means that the inverse of a proportionally much smaller version of  $\hat{\Omega}$  can be found to obtain the values and the location of the non-zero elements (Fogarty & Jones, 2011).

### 3. Data

The data employed in this study are obtained from Artron.net and span the period 2000 to 2016. The Artron database contains a number of relevant information of artworks sold at China and global major auctions, (e.g. sales record, artist's name, title of the work, year of production, materials, sales date, prices, dimension, signed or not). Buyers and sellers' transaction fees paid to auction houses are included in prices and are recorded in both renminbi (RMB) and local currencies.

Specifically, the explanatory variables  $X_{it}$  and  $D_{it}$  included in models are:

#### 3.1. Dimension

The variable *area* is a product of both width and length, which is measured in square meters. To examine whether the price increases with a diminishing effect, the variable *area*<sup>2</sup> is also included.

#### 3.2. Medium

In our study, the Chinese artworks are categorized in two different mediums. The categories are paper and silk, with silk as the reference variable.

#### 3.3. Mounting

Normally, the Chinese artworks can be mounted in several ways. We specify dummies *album of sheets*, *folding fan*, *folding screen*, *framed*, *hand scroll*, and *hanging scroll* to reflect in which type the painting is adopted, with *album of sheets* as the reference variable.

#### 3.4. Type

Traditional Chinese artworks are done either in black ink or colored. In this case, two dummy variables *ink* (as the reference variable) and *color* are created to identify whether the painting is in ink or colored.

#### 3.5. Auction houses

In this paper, the auction house dummies are specified by *beijing hanhai*, *beijing kuangshi*, *christie*, *guardian*, *poly*, and *sotheby*, which are main dominant auction houses in China and worldwide. We assign the dummy variable to take the value of one if the painting is classified into any of these six auction houses. Other auction houses are assigned to the references and take the value of zero.

#### 3.6. Period

Both semiannual and annual period are applied in this paper. On the semiannual basis, a series of dummy variables,  $D_t$ , with  $t = 2000s, \dots, 2016a$ , are introduced for each semiannual between the spring of 2000 and the autumn of 2016, regarding the spring of 2000 as the baseline variable and standardized to 100 in the price index. Similarly,  $t = 2000, \dots, 2016$  are introduced annually, considering 2000 as the baseline variable and standardized to 100 in the price index.

Table 1 summarizes the descriptive statistics of artworks sold. The number of samples, means, and standard deviations are presented, along with the minimum and maximum. The average artwork price of Qi Baishi from 2000 to 2016 is 1,742,045 RMB, ranging from 330 RMB to 425,500,000 RMB. According to the dimension, the average *area* is 0.3501m<sup>2</sup>, with the standard deviation of 0.3068. There are 8,163 artworks which have been painted on *paper*, accounting for 99.33% of the total samples. Among all mounting types, *hanging scroll* is the most prevalent (5,115), followed by *framed* (2,320), whereas there are only 27 artworks mounted in *hand scroll*. Furthermore, the artworks in *color* (6,254) are approximately three times more than those in *ink* (1,964).

**Table 1. Descriptive statistics**

<b>Panel A: Hedonic model</b>					
<b>Variable</b>	<b>Number</b>	<b>Mean</b>	<b>S.D.</b>	<b>Minimum</b>	<b>Maximum</b>
Price	8,218	1,742,045	7,009,035	330	425,500,000
<i>Dimension</i>					
Area	8,218	0.3501	0.3068	0.0000	13.4000
Area <sup>2</sup>	8,218	0.2166	2.2939	0.0000	179.5600
<i>Medium</i>					
Paper	8,163	0.9933	0.0815	0	1
Silk	55	0.0067	0.0815	0	1
<i>Mounting</i>					
Album sheets	84	0.0102	0.1006	0	1
Folding fan	610	0.0742	0.2622	0	1
Folding screen	62	0.0075	0.0865	0	1
Framed	2,320	0.2823	0.4501	0	1
Hand scroll	27	0.0033	0.0572	0	1
Hanging scroll	5,115	0.6224	0.4848	0	1
<i>Type</i>					
Color	6,254	0.7610	0.4265	0	1
Ink	1,964	0.2390	0.4265	0	1
<i>Auction houses</i>					
Beijing Hanhai	943	0.1147	0.3187	0	1
Beijing Kuangshi	632	0.0769	0.2665	0	1
Christie	608	0.0740	0.2618	0	1
Guardian	2,111	0.2569	0.4369	0	1
Poly	1,108	0.1348	0.3416	0	1
Sotheby	495	0.0602	0.2379	0	1
Others	2,321	0.2824	0.4502	0	1
<i>Period</i>					
2000s	62	0.0075	0.0865	0	1
2000a	105	0.0128	0.1123	0	1
2001s	85	0.0103	0.1012	0	1
2001a	76	0.0092	0.0957	0	1
2002s	131	0.0159	0.1253	0	1
2002a	102	0.0124	0.1107	0	1
2003s	11	0.0013	0.0366	0	1

(Continued)

**Table 1. (Continued)**

<b>Panel A: Hedonic model</b>					
<b>Variable</b>	<b>Number</b>	<b>Mean</b>	<b>S.D.</b>	<b>Minimum</b>	<b>Maximum</b>
2003a	260	0.0316	0.1750	0	1
2004s	338	0.0411	0.1986	0	1
2004a	317	0.0386	0.1926	0	1
2005s	269	0.0327	0.1779	0	1
2005a	342	0.0416	0.1997	0	1
2006s	230	0.0280	0.1649	0	1
2006a	215	0.0262	0.1596	0	1
2007s	224	0.0273	0.1628	0	1
2007a	265	0.0322	0.1767	0	1
2008s	246	0.0299	0.1704	0	1
2008a	151	0.0184	0.1343	0	1
2009s	235	0.0286	0.1667	0	1
2009a	494	0.0601	0.2377	0	1
2010s	457	0.0556	0.2292	0	1
2010a	432	0.0526	0.2232	0	1
2011s	528	0.0642	0.2452	0	1
2011a	430	0.0523	0.2227	0	1
2012s	240	0.0292	0.1684	0	1
2012a	250	0.0304	0.1718	0	1
2013s	293	0.0357	0.1854	0	1
2013a	226	0.0275	0.1635	0	1
2014s	268	0.0326	0.1776	0	1
2014a	231	0.0281	0.1653	0	1
2015s	162	0.0197	0.1390	0	1
2015a	176	0.0214	0.1448	0	1
2016s	173	0.0211	0.1436	0	1
2016a	194	0.0236	0.1518	0	1
<b>Panel B. Repeat sales model</b>					
<b>Variable</b>	<b>Number</b>	<b>Mean</b>	<b>S.D.</b>	<b>Minimum</b>	<b>Maximum</b>
Price <sub>t</sub>	1,609	977,891	3,044,355	6,600	92,000,000
Price <sub>t+s</sub>	2,207	2,375,188	7,464,974	1,150	195,500,000
2000s	23	-0.0177	0.1318	-1	0
2000a	37	-0.0276	0.1640	-1	0
2001s	27	-0.0168	0.1319	-1	1
2001a	36	-0.0217	0.1520	-1	1
2002s	49	-0.0267	0.1774	-1	1
2002a	32	-0.0190	0.1463	-1	1
2003s	7	-0.0032	0.0562	-1	0
2003a	100	-0.0476	0.2537	-1	1
2004s	158	-0.0648	0.3069	-1	1
2004a	153	-0.0503	0.2992	-1	1

(Continued)

**Table 1. (Continued)**

<b>Panel B: Repeat sales model</b>					
<b>Variable</b>	<b>Number</b>	<b>Mean</b>	<b>S.D.</b>	<b>Minimum</b>	<b>Maximum</b>
2005s	143	−0.0394	0.2853	−1	1
2005a	190	−0.0421	0.3237	−1	1
2006s	125	−0.0131	0.2613	−1	1
2006a	97	−0.0063	0.2232	−1	1
2007s	104	−0.0095	0.2416	−1	1
2007a	119	−0.0072	0.2500	−1	1
2008s	124	−0.0068	0.2545	−1	1
2008a	81	−0.0104	0.2116	−1	1
2009s	115	−0.0045	0.2483	−1	1
2009a	251	0.0000	0.3575	−1	1
2010s	229	0.0109	0.3391	−1	1
2010a	212	0.0385	0.3127	−1	1
2011s	269	0.0526	0.3511	−1	1
2011a	218	0.0444	0.3155	−1	1
2012s	105	0.0213	0.2213	−1	1
2012a	119	0.0208	0.2362	−1	1
2013s	131	0.0331	0.2433	−1	1
2013a	100	0.0276	0.2143	−1	1
2014s	128	0.0467	0.2392	−1	1
2014a	102	0.0326	0.2125	−1	1
2015s	59	0.0249	0.1616	−1	1
2015a	53	0.0208	0.1521	−1	1
2016s	54	0.0236	0.1547	−1	1
2016a	65	0.0295	0.1691	−0	1

Table 1 includes the statistics of artworks according to different auction houses as well. Of the six dominant auction houses, *guardian* is the most popular, with the number of 2,111. Relative to *christie* (608) and *sotheby* (495), *poly* (1,108), *beijing hanhai* (943) and *beijing kuangshi* (632) achieve higher proportions, suggesting that the majority of Chinese artworks of Qi Baishi has been sold in China.

## 4. Empirical results

### 4.1. Comparison of three price index models

The performances of three models are now evaluated. Table 2 reports the coefficient estimates and corresponding standard errors for semiannual and annual periods using the White (1980) heteroscedasticity-robust procedure. Columns (1) and (2) reveal the hedonic regression results. Results of the repeat sales method are shown on Columns (3) and (4). The hybrid model is estimated using the unrelated regression methodology and displayed in columns (5) and (6).

To evaluate and compare price index models in depth, we then use three key measures to assess the precisions of three price index models:

- (1) The mean squared error (MSE) based on an out-of-sample forecast (Goh, Costello, & Schwann, 2012).
- (2) The squared correlation between the actual and predicted values (Case & Szymanoski, 1995).
- (3) The width of a 95% confidence interval (Case & Szymanoski, 1995).



**Table 2. Empirical results**

<b>Panel A. Semiannual bases</b>						
<b>Variables</b>	<b>Hedonic model</b>		<b>Repeat sales model</b>		<b>Hybrid model</b>	
	<b>Coefficient</b>	<b>S.E.</b>	<b>Coefficient</b>	<b>S.E.</b>	<b>Coefficient</b>	<b>S.E.</b>
	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>	<b>(5)</b>	<b>(6)</b>
Constant	11.1982***	0.2069	0.2503***	0.0248	3.2991***	0.1682
<i>Dimension</i>						
Area	2.5465***	0.0559			3.3623***	0.0630
Area <sup>2</sup>	−0.1952***	0.0070			−0.2650***	0.0080
<i>Medium</i>						
Paper	−0.0357	0.1302			7.9030***	0.1110
Silk	[Left out]				[Left out]	
<i>Mounting</i>						
Album sheets	[Left out]				[Left out]	
Folding fan	−1.0341***	0.1173			3.0767***	0.1152
Folding screen	−0.8137***	0.1600			2.5819***	0.1704
Framed	−0.6175***	0.1098			3.4814***	0.1061
Hand scroll	−0.7271***	0.2119			3.6666***	0.2105
Hanging scroll	−0.6397***	0.1076			3.3154***	0.1043
<i>Type</i>						
Color	0.2341***	0.0250			0.5400***	0.0328
Ink	[Left out]				[Left out]	
<i>Auction houses</i>						
Beijing Hanhai	−0.1169***	0.0383			−0.1971***	0.0435
Beijing Kuangshi	0.0508	0.0440			0.2081***	0.0462
Christie	0.1623***	0.0439			0.2321***	0.0525
Guardian	−0.0096	0.0290			−0.0058	0.0333
Poly	−0.0996***	0.0361			0.1665***	0.0375
Sotheby	0.3218***	0.0481			0.2298***	0.0553
Others	[Left out]				[Left out]	
<i>Period</i>						
2000s	–	–	–	–	–	–
2000a	−0.0264	0.1534	−0.8872***	0.1344	−0.6201***	0.0955
2001s	−0.0767	0.1590	−0.8274***	0.1513	−0.8157***	0.1108
2001a	−0.0751	0.1634	−0.5556***	0.1389	−0.5787***	0.1069
2002s	0.0605	0.1469	−0.5348***	0.1298	−0.6576***	0.0877
2002a	−0.1999	0.1536	−1.0432***	0.1409	−0.8220***	0.1019
2003s	0.7585**	0.3136	−0.0483	0.2894	−0.6024**	0.2834
2003a	0.4682***	0.1347	−0.1850*	0.1106	−0.4837***	0.0638
2004s	0.7113***	0.1317	0.2401**	0.1064	−0.2264***	0.0556
2004a	0.9443***	0.1323	0.4113***	0.1080	−0.2174***	0.0575
2005s	1.1220***	0.1342	0.7463***	0.1088	−0.0725	0.0614
2005a	1.4316***	0.1316	0.8193***	0.1064	0.1089**	0.0552
2006s	1.1819***	0.1365	0.5380***	0.1120	−0.1077	0.0668
2006a	1.0318***	0.1375	0.5180***	0.1187	−0.1395*	0.0727

(Continued)

**Table 2. (Continued)**

Panel A. Semiannual bases						
Variables	Hedonic model		Repeat sales model		Hybrid model	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
	(1)	(2)	(3)	(4)	(5)	(6)
2007s	1.0493***	0.1370	0.5025***	0.1152	−0.1851***	0.0696
2007a	1.2939***	0.1346	0.7060***	0.1125	−0.0843	0.0664
2008s	1.2630***	0.1354	0.6854***	0.1131	−0.0735	0.0669
2008a	1.2180***	0.1438	0.6828***	0.1203	0.0905	0.0803
2009s	1.3615***	0.1362	0.6772***	0.1153	0.0070	0.0688
2009a	1.7093***	0.1286	0.9874***	0.1061	0.3114***	0.0518
2010s	2.0639***	0.1291	1.2625***	0.1076	0.6708***	0.0547
2010a	2.5414***	0.1297	1.6880***	0.1094	1.1266***	0.0580
2011s	2.8310***	0.1282	2.0089***	0.1075	1.3616***	0.0543
2011a	2.7568***	0.1297	1.8981***	0.1098	1.4460***	0.0586
2012s	2.5319***	0.1360	1.8316***	0.1221	1.1901***	0.0706
2012a	2.3981***	0.1356	1.7820***	0.1167	1.5522***	0.0844
2013s	2.6978***	0.1335	1.9308***	0.1181	1.4586***	0.0662
2013a	2.6555***	0.1370	1.7434***	0.1237	1.6879***	0.0717
2014s	2.6223***	0.1346	1.9391***	0.1206	1.6128***	0.0686
2014a	2.5841***	0.1366	1.7879***	0.1228	1.4346***	0.0721
2015s	2.6356***	0.1427	2.0247***	0.1401	1.5967***	0.0850
2015a	2.0664***	0.1411	1.4134***	0.1406	1.0829***	0.0835
2016s	2.3942***	0.1413	1.7709***	0.1419	1.3095***	0.0844
2016a	2.4238***	0.1395	1.6387***	0.1361	1.3108***	0.0807
Adjusted R <sup>2</sup>	0.5628		0.5042		0.9343	
F-statistics	221.4017		68.9894		3197.5440	
Included observations	8,218		2207		10,422	
Panel B. Annual bases						
Variables	Hedonic model		Repeat sales model		Hybrid model	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	11.1804***	0.1855	0.2946***	0.0274	0.8303***	0.1044
Dimension						
Area	2.5603***	0.0563			3.3257***	0.0630
Area <sup>2</sup>	−0.1957***	0.0070			−0.2601***	0.0079
Medium						
Paper	−0.0183	0.1310			7.3831***	0.1153
Silk	[Left out]				[Left out]	
Mounting						
Album sheets	[Left out]				[Left out]	
Folding fan	−1.0383***	0.1182			2.9726***	0.1162
Folding screen	−0.7899***	0.1613			2.5463***	0.1719
Framed	−0.6233***	0.1106			3.3672***	0.1071

(Continued)

**Table 2. (Continued)**

<b>Panel B. Annual bases</b>						
<b>Variables</b>	<b>Hedonic model</b>		<b>Repeat sales model</b>		<b>Hybrid model</b>	
	<b>Coefficient</b>	<b>S.E.</b>	<b>Coefficient</b>	<b>S.E.</b>	<b>Coefficient</b>	<b>S.E.</b>
	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>	<b>(5)</b>	<b>(6)</b>
Hand scroll	−0.7345***	0.2134			3.5191***	0.2140
Hanging scroll	−0.6452***	0.1085			3.2086***	0.1053
<i>Type</i>						
Color	0.2293	0.0252			0.5766***	0.0321
Ink	[Left out]				[Left out]	
<i>Auction houses</i>						
Beijing Hanhai	−0.1308***	0.0382			−0.2294***	0.0434
Beijing Kuangshi	0.0383	0.0442			0.2101***	0.0464
Christie	0.1638***	0.0441			0.2011***	0.0520
Guardian	−0.0248	0.0291			−0.0318	0.0333
Poly	−0.0942***	0.0362			0.1427***	0.0377
Sotheby	0.3179***	0.0479			0.2057***	0.0549
Others	[Left out]				[Left out]	
<i>Period</i>						
2000	−	−	−	−	−	−
2001	−0.0602	0.1060	−0.8032***	0.0995	−0.5917***	0.0809
2002	−0.0417	0.0982	−0.8789***	0.0915	−0.6344***	0.0706
2003	0.4928***	0.0953	−0.3059***	0.0834	−0.3568***	0.0652
2004	0.8368***	0.0838	0.1884***	0.0656	−0.0765***	0.0466
2005	1.3074***	0.0847	0.6344***	0.0683	0.2360***	0.0534
2006	1.1205***	0.0884	0.3623***	0.0755	0.0407	0.0553
2007	1.1914***	0.0874	0.4632***	0.0752	0.0473	0.0545
2008	1.2572***	0.0899	0.5248***	0.0779	0.1621***	0.0576
2009	1.6070***	0.0839	0.7106***	0.0729	0.4024***	0.0484
2010	2.3057***	0.0826	1.2671***	0.0730	1.0831***	0.0488
2011	2.8075***	0.0821	1.7245***	0.0748	1.6069***	0.0498
2012	2.4723***	0.0878	1.5805***	0.0859	1.4689***	0.0589
2013	2.6892***	0.0873	1.6269***	0.0882	1.8006***	0.0593
2014	2.6144***	0.0876	1.6307***	0.0905	1.7620***	0.0608
2015	2.3473***	0.0927	1.5074***	0.1072	1.5384***	0.0693
2016	2.4183***	0.0916	1.4931***	0.1056	1.5340***	0.0681
Adjusted $R^2$	0.5556		0.4098		0.9220	
F-statistics	332.3532		96.7448		3977.9050	
Included observations	8,218		2,207		10,425	

\* indicates significance at the 10%, respectively.

\*\* indicates significance at the 5%, respectively.

\*\*\* indicates significance at the 1%, respectively.

#### 4.1.1. The mean squared error (MSE) based on an out-of-sample forecast

The first measure we adopt is the MSE based on an out-of-sample forecast. This procedure, proposed by Goh et al. (2012), is simple to deal with and effective in examining the precisions of the price index models.

Specifically, for each price index model, we split its data-set into two sub-samples. The sub-sample 1 consists of 70% of the full sample and is used to compute the indices. The parameter estimates obtained in the first sub-sample are then applied to the sub-sample 2, which involves the remaining 30% of the full sample and is used to forecast prices for each observation. In this way, there are two sets of prices in the sub-sample 2: one is the forecast price,  $\hat{y}_i$ , and the other is the actual price  $y_i$ . To evaluate their relative precisions, we then use the standard forecast analysis statistics in terms of the MSE for each price index model, which is represented by  $\frac{1}{n} \sum_{i=1}^n (\hat{y}_i - y_i)^2$ . In this equation,  $n$  denotes the number of observations used to forecast the price,  $\hat{y}_i$  is the forecast price for observation  $i$ , and  $y_i$  is the actual price of observation  $i$ . Since the MSE is combined with both the bias and the variance, a lower MSE value for a particular price index generally indicates a better accuracy.

Table 3 presents the estimated semiannual and annual MSEs for the three price index models, respectively. It reveals that at both levels of time frequency, the repeat sales model generates the lowest MSEs. However, Case and Szymanoski (1995) note that the fact that standard deviation of the disturbance term in the repeat sales model smaller than those in the hedonic and hybrid models could be explained for two reasons. One reason is that the pure random noise component of the disturbance term is assumed to be positively related to the length of time elapsed between transactions, which is likely to be smaller for the repeat sales model than for other two model. The other reason is that the repeat sales model normally incorporates additional information on repeat transactions that are ignored in the hedonic model. Therefore, it is probably that the smaller estimated MSEs of the repeat sales model could be interpreted merely as a reflection of the smaller standard deviation of the disturbance term rather than an evidence that the repeat sales model is more precise than other two models.

Additionally, although the hybrid model stands out as a relative accurate price index model in most housing literatures (Jones, 2010; Goh et al., 2012; Quigley, 1995), that is not the case in our study. Even if the hybrid model has the advantage of combining features of both the hedonic and repeat sales model, it yields the highest estimated MSEs at both levels of time frequency (1.5265 semiannual and 1.5554 annual), underperforming the other price index models. Biey and Zanola (2005) also find that the standard deviation of the disturbance term of the hybrid model are higher than those of the hedonic and repeat sales models when investigating the performance of Picasso prints and attribute to the limited number of repeat sales in the sample. Similarly, our finding provides a certain support to Meese and Wallace (1991), who argue that the hybrid model appears not to produce reliable estimates of the price indices. Figure 1 depicts the MSEs of the three models based on an out-of-sample forecast at both semiannual and annual time frequencies, where the red line and the blue line represent the forecast value and the standard error, respectively.

#### 4.1.2. Correlation between actual and predicted values

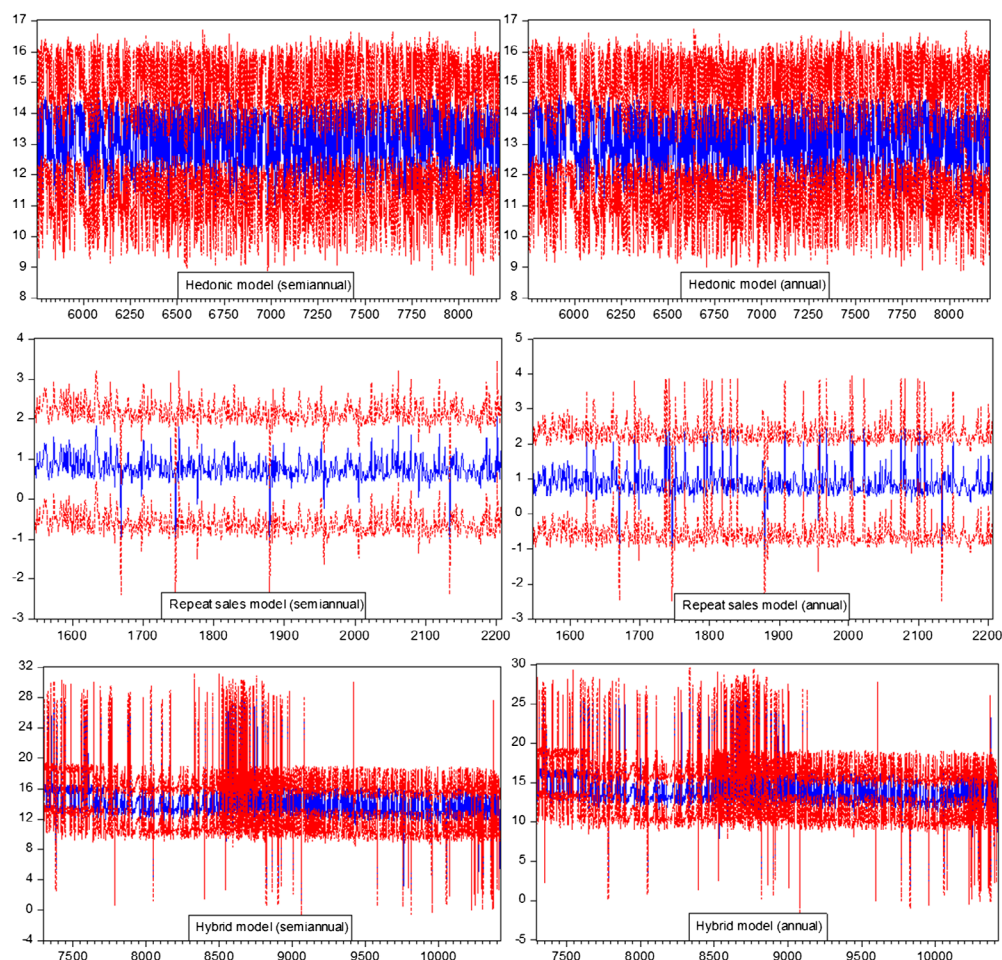
The second measure commonly used as means of assessing price index models is the correlation between actual and predicted values from econometric models, which provides a direct measure of the reliability. Normally, a high correlation can be interpreted as an indication of little error in the model, while a low correlation would indicate a large amount of error.

**Table 3. Mean squared error (MSE) of the three models**

Index models	Index frequency	
	Semiannual	Annual
Hedonic	1.1536	1.1619
Hybrid	1.5265	1.5554
Repeat sales	0.9497	1.0994

**Figure 1. The MSEs of the hedonic, hybrid and repeat sales models based on an out-of-sample forecast at both semiannual and annual time frequencies.**

Note: The red line and the blue line represent the forecast value and the standard error, respectively.



**Table 4. Correlations between actual and predicted values of various models**

Index models	Index frequency	
	Semiannual	Annual
Hedonic	0.5654	0.5572
Hybrid	0.9367	0.9223
Repeat sales	0.5116	0.4141

Table 4 presents the squares of the estimated correlation coefficients between actual and predicted values based on the hedonic, hybrid, and repeat sales models ( $r_{yy}^2$ ). As shown, the hybrid model generates overwhelming higher correlations than the corresponding hedonic and repeat sales models, demonstrating its more accurate prediction ability. Moreover, correlations of the three price index models on the basis of semiannual frequency are slightly higher than those on the basis of annual frequency, suggesting relative better predictions.

#### 4.1.3. Width of a 95% confidence interval

The third measure used is the width of a 95% confidence interval, which reflects both the estimated standard deviation of the disturbance term and the precision with which the individual parameters of the model. In view of this, we calculate the estimated semiannual and annual price indexes along with their corresponding 95% confidence intervals, which are reported in Table 5. Overall, the

**Table 5. Annual and semiannual prices indexes**

Panel A. Semiannual price indexes									
Period	Hedonic model			Repeat sales model			Hybrid model		
	Index	95% C.I.		Index	95% C.I.		Index	95% C.I.	
		Low	High		Low	High		Low	High
2000s	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2000a	97.39	97.07	97.72	41.18	40.95	41.41	117.79	117.57	118.01
2001s	92.62	92.30	92.94	43.72	43.44	44.00	96.86	96.65	97.06
2001a	92.76	92.44	93.09	57.38	57.04	57.71	122.76	122.51	123.02
2002s	106.24	105.90	106.58	58.58	58.26	58.90	113.45	113.26	113.64
2002a	81.88	81.61	82.15	35.23	35.03	35.44	96.26	96.07	96.44
2003s	213.51	212.07	214.97	95.29	94.15	96.45	119.89	119.24	120.54
2003a	159.72	159.25	160.18	83.11	82.73	83.50	134.99	134.83	135.16
2004s	203.66	203.08	204.24	127.14	126.58	127.71	174.61	174.42	174.80
2004a	257.11	256.38	257.85	150.88	150.20	151.56	176.19	175.99	176.38
2005s	307.10	306.21	307.99	210.91	209.95	211.87	203.67	203.43	203.91
2005a	418.55	417.37	419.75	226.90	225.89	227.91	244.16	243.90	244.42
2006s	326.05	325.09	327.01	171.25	170.45	172.05	196.62	196.37	196.87
2006a	280.62	279.78	281.45	167.87	167.04	168.70	190.47	190.20	190.74
2007s	285.57	284.73	286.42	165.29	164.49	166.08	181.97	181.73	182.22
2007a	364.69	363.63	365.75	202.58	201.63	203.53	201.27	201.01	201.53
2008s	353.59	352.56	354.63	198.45	197.52	199.39	203.46	203.20	203.72
2008a	338.05	337.00	339.10	197.94	196.94	198.93	239.73	239.36	240.10
2009s	390.21	389.06	391.36	196.84	195.89	197.79	220.51	220.22	220.80
2009a	552.51	550.98	554.05	268.44	267.25	269.63	298.98	298.69	299.28
2010s	787.65	785.45	789.85	353.41	351.82	355.00	428.26	427.81	428.71
2010a	1269.78	1266.23	1273.35	540.86	538.39	543.33	675.61	674.86	676.36
2011s	1696.16	1691.47	1700.87	745.53	742.19	748.88	854.52	853.63	855.42
2011a	1574.89	1570.48	1579.31	667.31	664.26	670.37	929.80	928.75	930.85
2012s	1257.74	1254.05	1261.44	624.40	621.23	627.59	719.86	718.89	720.84
2012a	1100.23	1097.01	1103.46	594.17	591.28	597.07	1034.02	1032.35	1035.71
2013s	1484.70	1480.43	1489.01	689.50	686.11	692.91	941.57	940.38	942.77
2013a	1423.20	1419.00	1427.43	571.67	568.72	574.62	1184.27	1182.65	1185.91
2014s	1376.75	1372.75	1380.77	695.23	691.74	698.74	1098.54	1097.10	1099.99
2014a	1325.07	1321.17	1329.00	597.72	594.66	600.79	919.27	918.00	920.55
2015s	1395.15	1390.87	1399.48	757.37	752.96	761.81	1081.06	1079.30	1082.83
2015a	789.63	787.23	792.05	410.98	408.58	413.40	646.71	645.68	647.75
2016s	1095.91	1092.57	1099.27	587.58	584.12	591.07	811.19	809.88	812.51
2016a	1128.89	1125.49	1132.30	514.86	511.94	517.79	812.22	810.97	813.48
Panel B. Annual price indexes									
Period	Hedonic model			Repeat sales model			Hybrid model		
	Index	95% C.I.		Index	95% C.I.		Index	95% C.I.	
		Low	High		Low	High		Low	High
2000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2001	94.16	93.94	94.38	44.79	44.60	44.97	99.52	99.36	99.67

(Continued)

**Table 5. (Continued)**

**Panel B. Annual price indexes**

Period	Hedonic model			Repeat sales model			Hybrid model		
	Index	95% C.I.		Index	95% C.I.		Index	95% C.I.	
		Low	High		Low	High		Low	High
2002	95.92	95.71	96.12	41.53	41.37	41.68	95.36	95.23	95.49
2003	163.69	163.35	164.03	73.65	73.39	73.90	125.87	125.72	126.03
2004	230.90	230.48	231.32	120.73	120.40	121.06	166.60	166.45	166.74
2005	369.65	368.98	370.33	188.59	188.05	189.13	227.70	227.47	227.93
2006	306.64	306.05	307.23	143.66	143.21	144.11	187.31	187.11	187.50
2007	329.17	328.55	329.80	158.92	158.42	159.42	188.55	188.35	188.75
2008	351.54	350.86	352.22	169.02	168.47	169.57	211.48	211.25	211.72
2009	498.78	497.88	499.69	203.51	202.89	204.13	268.93	268.68	269.18
2010	1003.15	1001.36	1004.94	355.06	353.98	356.14	531.19	530.70	531.69
2011	1656.89	1653.96	1659.84	560.98	559.23	562.73	896.93	896.08	897.79
2012	1184.93	1182.68	1187.18	485.75	484.01	487.50	781.30	780.42	782.19
2013	1472.02	1469.25	1474.81	508.79	506.92	510.66	1088.62	1087.38	1089.86
2014	1365.92	1363.34	1368.51	510.75	508.83	512.68	1047.36	1046.14	1048.59
2015	1045.71	1043.62	1047.81	451.49	449.48	453.51	837.53	836.41	838.64
2016	1122.69	1120.47	1124.92	445.11	443.15	447.07	833.86	832.77	834.95

Note: C.I. refers to the confidence interval.

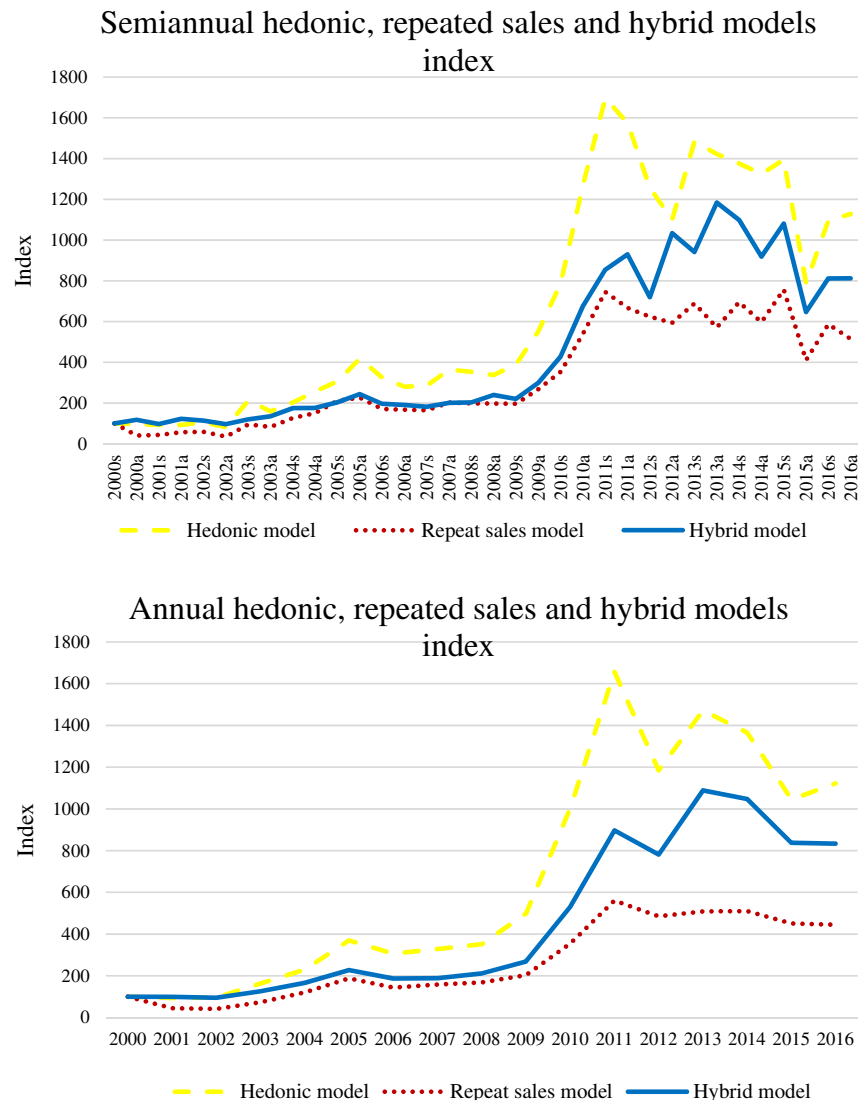
hedonic, hybrid, and repeat sales models show a similar trend in Table 5: there has been a noticeable increase from the year 2000 to 2011, and then followed by a strongly fluctuation till 2016. Such situation could also be demonstrated in Figure 2, which presents the indices constructed with three models at the annual and semiannual time levels, respectively. Figure 2 reveals that in general, the patterns of three indices seem almost alike, although the repeat sales index always tracks below the hedonic and the hybrid indices at different time levels.

To make the estimate efficiency comparison across models much clearer, Figure 3 plots the 95% confidence interval for each model around a constant index value of unity. The dashed lines, dotted lines, and continuous lines represent the 95% confidence intervals (the level of price volatility) estimated from the hedonic model, the repeat sales model and the hybrid model, respectively. In line with our expectation, for both time levels, the hybrid model provides the narrowest confidence interval among three models. This result, combined with the result of the correlation between actual and predicted values, suggests that the hybrid model to some extent provide the most efficient estimates, which confirms the findings by Biey and Zanola (2005) and Fogarty and Jones (2011).

#### 4.2. Evaluations of three price index models

Besides the estimate efficiency, we also compare different returns evaluated by different models. In general, the estimated return on art varies with data, methodology, and the time period under consideration (Ashenfelter & Graddy, 2003). Specifically, an important difference between the repeat

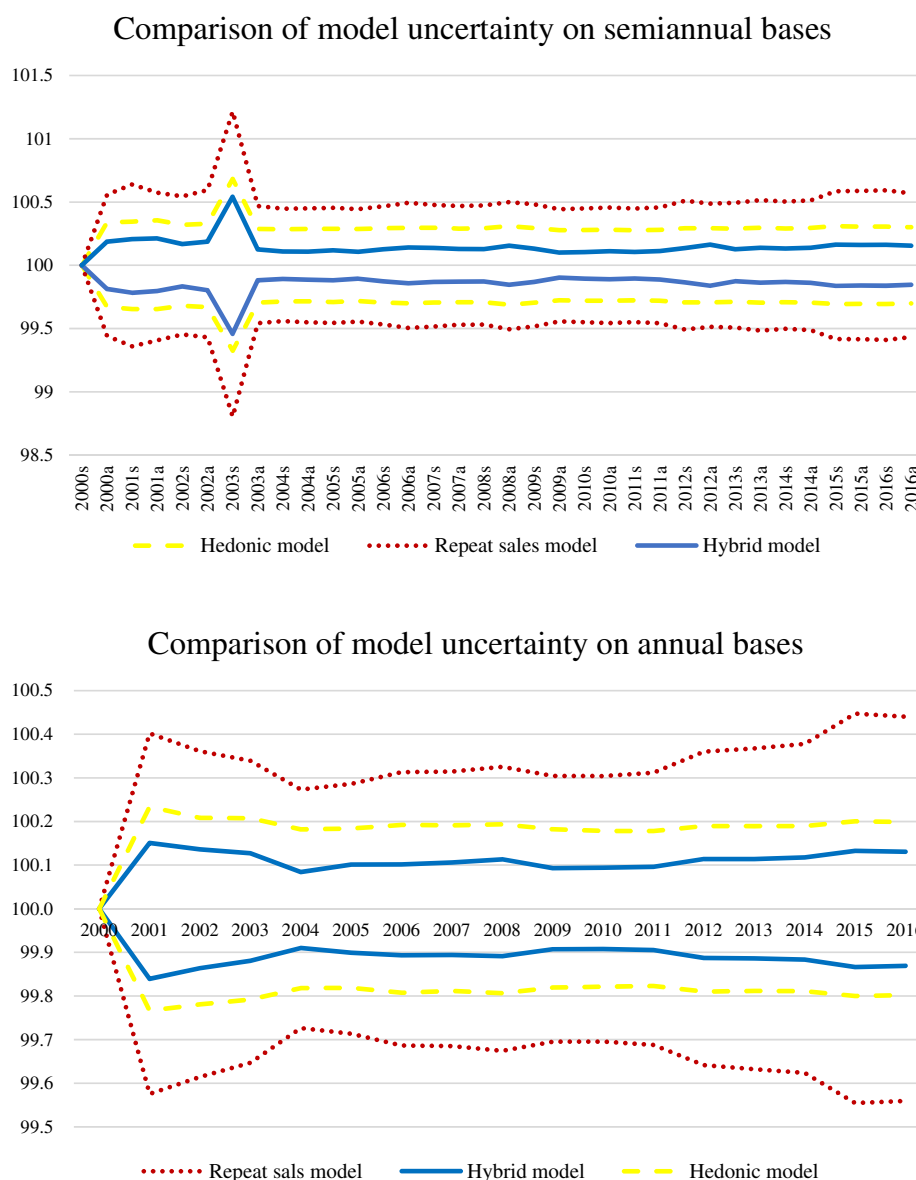
**Figure 2. Annual and semiannual hedonic, repeat sales and hybrid price indexes of Qi Baishi during the period from 2000 to 2016.**



sales model and others is that the repeat sales model relies on only a subset of transactions and the utilized sample has been relatively small and selective, which may have a significant impact on the return estimates. Table 6 presents the estimated returns for the three price index models during the period 2000 to 2016. The highest return has been achieved by the hedonic model, which yields 0.0734 semiannually and 0.1511 annually. The return differences between the hybrid model and the hedonic model are not distinct, which the former is on average 13% lower than the latter in both time levels. The repeat sales model performs the worst, obtaining the lowest estimated returns and the highest risk at both time levels. By contrast, the hybrid model provides the lowest estimated volatility even at different time levels, notably surpasses all other models. This result somewhat contradicts the finding of Renneboog and Spaenjers (2013), which argues that, with respect to



**Figure 3. Semiannual and annual comparisons of model uncertainty.**



artworks, the hedonic model has found somewhat lower returns than the repeat sales model. Considering that only part of Qi baishi's artworks appear in the art market more often, those artworks with high appreciation and esthetic value by the collectors may be transacted infrequently.

**Table 6. Annual and semiannual returns**

Panel A. Semiannual returns						
	Hedonic model		Repeat sales model		Hybrid model	
Period	Index	Returns	Index	Returns	Index	Returns
2000s	100.00	–	100.00	–	100.00	–
2000a	97.39	–0.0264	41.18	–0.8872	117.79	0.1637
2001s	92.62	–0.0503	43.72	0.0598	96.86	–0.1957
2001a	92.76	0.0016	57.38	0.2718	122.76	0.2370
2002s	106.24	0.1356	58.58	0.0208	113.45	–0.0789
2002a	81.88	–0.2604	35.23	–0.5084	96.26	–0.1643
2003s	213.51	0.9585	95.29	0.9950	119.89	0.2195
2003a	159.72	–0.2903	83.11	–0.1367	134.99	0.1187
2004s	203.66	0.2430	127.14	0.4251	174.61	0.2573
2004a	257.11	0.2331	150.88	0.1712	176.19	0.0090
2005s	307.10	0.1777	210.91	0.3349	203.67	0.1449
2005a	418.55	0.3096	226.90	0.0731	244.16	0.1813
2006s	326.05	–0.2498	171.25	–0.2814	196.62	–0.2165
2006a	280.62	–0.1501	167.87	–0.0200	190.47	–0.0318
2007s	285.57	0.0175	165.29	–0.0155	181.97	–0.0456
2007a	364.69	0.2446	202.58	0.2034	201.27	0.1008
2008s	353.59	–0.0309	198.45	–0.0206	203.46	0.0108
2008a	338.05	–0.0450	197.94	–0.0026	239.73	0.1641
2009s	390.21	0.1435	196.84	–0.0056	220.51	–0.0836
2009a	552.51	0.3478	268.44	0.3102	298.98	0.3044
2010s	787.65	0.3546	353.41	0.2750	428.26	0.3593
2010a	1269.79	0.4776	540.86	0.4255	675.61	0.4559
2011s	1696.16	0.2895	745.53	0.3209	854.52	0.2349
2011a	1574.89	–0.0742	667.31	–0.1108	929.80	0.0844
2012s	1257.74	–0.2249	624.40	–0.0665	719.86	–0.2559
2012a	1100.23	–0.1338	594.17	–0.0496	1034.02	0.3622
2013s	1484.71	0.2997	689.50	0.1488	941.57	–0.0937
2013a	1423.21	–0.0423	571.67	–0.1874	1184.27	0.2293
2014s	1376.75	–0.0332	695.23	0.1957	1098.54	–0.0752
2014a	1325.08	–0.0383	597.72	–0.1511	919.27	–0.1782
2015s	1395.17	0.0515	757.37	0.2367	1081.06	0.1621
2015a	789.63	–0.5692	410.98	–0.6113	646.71	–0.5138
2016s	1095.91	0.3278	587.58	0.3575	811.19	0.2266
2016a	1128.89	0.0297	514.86	–0.1321	812.22	0.0013
Mean	0.0734		0.0497		0.0635	
S.E.	0.2787		0.3386		0.2112	
Panel B. Annual returns						
	Hedonic model		Repeat sales model		Hybrid model	
Period	Index	Returns	Index	Returns	Index	Returns
2000	100.00	–	100.00	–	100.00	–
2001	94.16	–0.0602	44.79	–0.8032	99.52	–0.0048

(Continued)

**Table 6. (Continued)**

Panel B. Annual returns						
	Hedonic model		Repeat sales model		Hybrid model	
Period	Index	Returns	Index	Returns	Index	Returns
2002	95.92	0.0185	41.53	-0.0756	95.36	-0.0427
2003	163.69	0.5345	73.65	0.5730	125.87	0.2776
2004	230.90	0.3440	120.73	0.4943	166.60	0.2803
2005	369.65	0.4706	188.59	0.4460	227.70	0.3125
2006	306.64	-0.1869	143.66	-0.2721	187.31	-0.1953
2007	329.17	0.0709	158.92	0.1010	188.55	0.0066
2008	351.54	0.0657	169.02	0.0616	211.48	0.1148
2009	498.78	0.3499	203.51	0.1857	268.93	0.2403
2010	1003.15	0.6987	355.06	0.5566	531.19	0.6807
2011	1656.89	0.5018	560.98	0.4574	896.93	0.5239
2012	1184.93	-0.3353	485.75	-0.1440	781.30	-0.1380
2013	1472.02	0.2170	508.79	0.0463	1088.62	0.3317
2014	1365.92	-0.0748	510.75	0.0039	1047.36	-0.0386
2015	1045.71	-0.2671	451.49	-0.1233	837.53	-0.2236
2016	1122.69	0.0710	445.11	-0.0142	833.86	-0.0044
Average	0.1511		0.0933		0.1326	
S.E.	0.3068		0.3617		0.2584	

For this reason, it is possible that the return estimates derived from the repeat sales model might be lower than those obtained using other models.

## 5. Conclusions

In this paper, we review both the advantages and disadvantages of the hedonic, hybrid and repeat sales models and apply a series of techniques to examine their performances in the Chinese paintings market by analyzing the artworks of Qi Baishi over the period 2000–2016. Applying the mean squared error (MSE) technique, the result shows that the repeat sales model outperforms alternative models. However, according to the correlations and width confidence intervals, the hybrid model provides the most efficient estimates, making it a more attractive approach for measuring price changes in the Chinese paintings market. Additionally, the empirical result reveals that, the repeat sales model gives the lowest estimated returns as well as the highest volatility among three models. Our findings, not only have important implications in identifying the accuracy of index models, but also provide a certain supplement to art investment studies.

It is worth noting that there exist some limitations in our paper. Although the hybrid model has the best explanatory power in terms of correlations and width confidence intervals, it ranks the worst in the MSE measure. In other words, none of the price index models seems to be consistently superior accurate to the others. Apart from the data used in our paper, absence of a convincing proxy for measuring index accuracy and pooling data together across time may also result in such inconsistency (Ansah, 2013). We fully expect that, in further studies, there would be a methodology demonstrated to provide more accurate and robust estimations in the price index construction and be applied in more general settings.

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