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# Asset price indices for Japanese art auction market: An application to the Japanese artist

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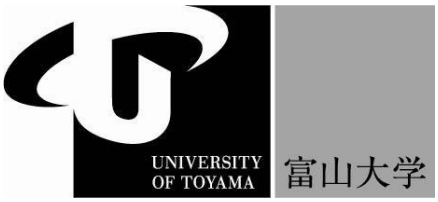


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# Asset price indices for Japanese art auction market: An application to the Japanese artist

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**Abstract**

This research is one of the few to analyzed a Japanese art auction market. We found the hedonic price index of artworks in Japan's art auction market, between 2006 and 2019. Considering the sample selection bias in the auction and the price index measurement by the traditional hedonic time dummy model of log-price, we presented the estimation of the hammer price by the exponential type II Tobit model. Using the difference between the conditional expectation of the logarithmic price, a new price index that takes into account the variation of selection bias was defined. Art price index by the ordinary least squares estimation without considering the sales selection has a negative bias in the Japanese art auction market.

**Keywords:** Japanese art auction market, Hedonic price, Art price index, Exponential type II Tobit model

**JEL classification:** C10, C24, G12, Z11

## 1. Introduction

Investors always explore alternative investments to raise the variety of their portfolio as the financial market globalizes. For assets except for financial products, the works of art have been chosen as investments for a long time. As stated in Singer and Lynch (1997), the highest category of art is a quasi substitute for financial instruments (liquid wealth). Global turnover of 1.89 billion $ in 2019 has doubled in 10 years in the art markets of the world[1]. Those circumstances of conspicuous price increasing are that unprecedented large-scale monetary easing was carried out in the United States, European countries, China, Japan, and other countries to escape from the stagnant economy after the financial crisis of 2008.

Japanese art market represents another important marketplace in Asia after China and Hong Kong. The art market of Japan expands for three consecutive years (2016-2018), and the amount of domestic art auction sales reached $124 million in 2018[2]. Most Japanese collectors are interested in the Impressionists and Modern Western Arts and payout many masterpieces. Therefore, the import of artworks the amount of money is about $300 million. Because the art price in Japan also correlates with the economic indicators such as the stock prices or the GDP growth rate, the import amounts of money of the art exceeded $5.5 billion for the bubble economy period in the late 1980s. However, the size of the art auction market in Japan is not significant compared to the size of the Japanese economy. The two major auction houses, Sotheby's and Christie's do not hold even periodical auction in Tokyo.

Japan was opened from the closed-door policy in the 1860s. Western culture rapidly influenced in Japan. Since then, the western technique of art has been adopted in Japanese art. Although Western Arts have the majority in the art market of Japan, another genre based on Japanese art history (Japanese-style painting, ceramic sculpture, artifact, hanging scroll, folding screen, etc.) is famous, too. Recently, several Japanese artists are evaluated in the international art market. For example, Tsuguharu Foujita, Yayoi Kusama, Takashi Murakami, Yoshitomo Nara, and Kazuo Shiraga, the other outstanding Japanese artists have strong market demand.

This research is one of the few to analyzed a Japanese fine art auction market. We present the hedonic price index of artworks in Japan's art auction market, between 2006 and 2019. The hedonic regression model has been widely applied to the analysis of the effect of artworks' characteristics on the hammer price of artworks. There is Chanel et al. (1996) as a study that analyzes famous Impressionists and Post-impressionists artists. Ginsburgh et al. (2019) is a research focused on a particular artist (Pieter Brueghel the Younger). Some studies have focused on the domestic art market of a particular country. For example, Rengers and Velthuis (2002),

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[1] According to *The Contemporary Art Market Report* 2019, from https://www.artprice.com/ retrieved January 31, 2020.

[2] *Japanese Art Industry Market Research Report* 2018 by Art Tokyo Association

Witkowska (2014), Pradier, Gardes, Greffe and Mendoza (2016), Galbraith and Hodgson (2018), Garay (2019), and Fedderke and Li (2020) analyzed using auction data from the domestic market (Netherlands, Poland, France, Canada, Venezuela, and South Africa). No study measures the price index of artworks by Japanese artists in the Japanese domestic home market.

As is often the case with the auctions, the items are unsold without a successful bid, not just for art auction markets. In many cases, the reason is that the bidding does not reach the reserve price level set by the seller. Ashenfelter and Graddy (2011) show that price variations of artworks at auction are highly correlated with the art auction sale rate. Even as mentioned above, there is no research examining the price index, including whether or not the items are sold using the hedonic approach. Price indices measured only for sold items may have a sample selection bias. Taking this into account, Collins, Scorcu, and Zanola (2009) estimate the type II Tobit model of hedonic price function (i.e., outcome function) using Heckman's (1979) two-step estimation procedure. However, their estimated prices do not take into account the conditional expected value of the hammer price, and the price index measurement does not capture the change in the inverse Mills ratio or truncated joint distribution of selection and outcome errors. Therefore, in this paper, considering the sample selection bias in the auction and the price index measurement by the traditional hedonic time dummy model of log-price, we show the maximum likelihood estimation of the hammer price by the exponential type II Tobit model (Wooldridge 2010). Then we present a new approach to measuring the price index by the conditional marginal effects.

The paper proceeds as follows. In the next Section 2, we offer the estimation methodology used in the paper. Section 3 describes the data and its characteristics, while the empirical results obtained are presented in section 4. Finally, section 5 concludes.

## 2. Hedonic price index

Even if commodities to be out on the markets had the same purpose of use, they have much differentiation aspects of features, qualities, and functions. The differences in features, qualities, and functions are often reflected in the market price of the commodities. Meanwhile, the market prices reflect consumers' evaluations of the characteristics. The price is a bundle of attributes or characteristics, which are the aggregate value of qualities and functions. Such a characteristic is common to the asset price determination, not only the consumption goods.

The hedonic approach is the method of estimating the attributes prices with regression analysis. We express art asset prices as hedonic price regression models that consist of factors such as characteristics of works, the genre of works, the individuality of artists, and some other factors.

We regress logarithmic price on categorical variables to be related to characteristics of the

works, and express the hedonic price model as follow[3]:

$$\log P_{it} = \alpha + \beta_t + \boldsymbol{Q}_i'\boldsymbol{\gamma}_1 + \boldsymbol{G}_i'\boldsymbol{\gamma}_2 + \boldsymbol{S}_i'\boldsymbol{\gamma}_3 + \boldsymbol{H}_i'\boldsymbol{\gamma}_4 + \boldsymbol{R}_i'\boldsymbol{\gamma}_5 + \boldsymbol{A}_i'\boldsymbol{\gamma}_6 + \epsilon_i \quad (1)$$

where the dependent variable $\log P_{it}$ is the logged hammer price of a work $i = 1,2,\cdots,n$ and period of year $t = 0,1,2,\cdots,T$; $\alpha$ is a coefficient of a constant term; $\beta_t$ is the time effect of sold year $t$ (i.e., coefficient of year dummy variable); $\boldsymbol{Q}_i$ is the dummy vector for the quarter of the year; $\mathbf{G}_i$ is the dummy vector for the genre of works such as Oil painting, print, ceramic art, among other things; $\boldsymbol{S}_i$ is the dummy vector for the size of works as numero category (length of long side); $\boldsymbol{H}_i$ is the dummy vector for transacted auction house; $\boldsymbol{R}_i$ is the dummy vector for comments included in the condition report of works such as cracking, defect, damage, among other things; $\boldsymbol{A}_i$ is the dummy vector for the name of artists; $\boldsymbol{\gamma}_1, \boldsymbol{\gamma}_2, \boldsymbol{\gamma}_3, \boldsymbol{\gamma}_4, \boldsymbol{\gamma}_5, \boldsymbol{\gamma}_6$ are the coefficients vector for the characteristic vectors; and $\epsilon_i$ is the error term independently and identically normally distributed $N(0, \sigma^2)$. Using the notation of explanatory variable vectors $\boldsymbol{X_i} = (\mathbf{1}', \boldsymbol{Q}_i', \boldsymbol{G}_i', \boldsymbol{S}_i', \boldsymbol{H}_i', \boldsymbol{R}_i', \boldsymbol{A}_i')'$ and the coefficients vectors $\boldsymbol{\gamma} = (\alpha, \boldsymbol{\gamma}_1', \boldsymbol{\gamma}_2', \boldsymbol{\gamma}_3', \boldsymbol{\gamma}_4', \boldsymbol{\gamma}_5', \boldsymbol{\gamma}_6')'$, The model in (1) can be rewritten as $\log P_{it} = \beta_t + \boldsymbol{X}_i'\boldsymbol{\gamma} + \epsilon_i$.

The expectation of log-price is $E(\log P_{it}\,|\boldsymbol{X}_i) = \beta_t + \boldsymbol{X}_i'\boldsymbol{\gamma}$. Given the explanatory variables, log-price change between period 0 and $t$ is $\Delta_t = E(\log P_{it}\,|\boldsymbol{X}_i) - E(\log P_{i0}\,|\boldsymbol{X}_i) = \beta_t$, where $\beta_0 = 0$ since a time dummy variable for the initial period is omitted to escape the dummy variable trap. Therefore, we define the hedonic price index in reference period $t$ relative to base period 0 as follow:

$$HPI_t = \exp(\hat{\beta}_t). \quad (2)$$

Due to auctions having high proportions of unsold works, ordinary least squares estimation of the equation (1) results in selection bias because they observe when an artwork is sold. Let the selection function whether it was sold be given by

$$Z_{it}^* = b_t + \boldsymbol{W}_i'\boldsymbol{c} + u_i \quad (3)$$

where $Z_{it}^*$ is the latent variable that unobserved propensity to select into the sample; $b_t$ is the time effect of sold year $t$ (i.e., coefficient of year dummy variable); $\boldsymbol{W}_i$ is the vector of regressors containing common components with (1); $\boldsymbol{c}$ is the coefficients vector for the $\boldsymbol{W}_i$; $u_i$ is the error term identically normally distributed with mean zero and variance one. Replacing equation (1) with exponential outcome function as

$$P_{it}^* = \exp(\beta_t + \boldsymbol{X}_i'\boldsymbol{\gamma} + \epsilon_i). \quad (4)$$

Binary variable $Z_{it}$ and hammer price $P_{it}$ is given by:

$$Z_{it} = \begin{cases} 1 & \text{if } Z_{it}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad P_{it} = \begin{cases} P_{it}^* & \text{if } Z_{it}^* > 0 \\ \text{N.A.} & \text{otherwise} \end{cases}.$$

The hammer price is equal to $P_{it}^*$ if the artwork is sold; otherwise, it is the missing value (or

[3] Most empirical findings favour the logarithmic model over its counterpart (Diewert 2003, de Haan 2004).

zero). The errors $u_i$ and $\epsilon_i$ are conditional on explanatory variables, jointly normal, $E(u_i) = 0$, $E(u_i^2) = 1$, $E(\epsilon_i) = 0$, $E(\epsilon_i^2) = \sigma^2$, and $E(\epsilon_i u_i) = \rho\sigma$. The probability of sale is $\Pr(Z_{it}^* > 0) = \Pr(b_t + \boldsymbol{W}_i'\boldsymbol{c} + u_i > 0) = \Pr(b_t + \boldsymbol{W}_i'\boldsymbol{c} + (\rho/\sigma)\epsilon_i + \nu_i > 0)$, where we use $u_i = (\rho/\sigma)\epsilon_i + \nu_i$ and $\nu_i \sim N(0, 1-\rho^2)$. Because $\epsilon_i = \log P_{it}^* - \beta_t - \boldsymbol{X}_i'\boldsymbol{\gamma}$, we have selection probability (i.e., sale rate of artworks) given $\log P_{it}^*, \boldsymbol{X}_i, \boldsymbol{W}_i$:

$$\Pr(Z_{it} = 1 | \log P_{it}^*, \boldsymbol{X}_i, \boldsymbol{W}_i) = \Phi\left(\frac{b_t + \boldsymbol{W}_i'\boldsymbol{c} + (\rho/\sigma)(\log P_{it}^* - \beta_t - \boldsymbol{X}_i'\boldsymbol{\gamma})}{\sqrt{1-\rho^2}}\right),$$

and density of $\epsilon_i$ given $\boldsymbol{X}_i$: $\phi\big((\log P_{it} - \beta_t - \boldsymbol{X}_i'\boldsymbol{\gamma})/\sigma\big)/\sigma\, P_{it}$, where $\Phi$ and $\phi$ are respectively, the normal distribution function and normal density function. Combining the expression with the density $Z_{it} = 0$ gives the full log-likelihood function for this exponential type II Tobit model as (see Wooldridge 2010, pp.697-703)

$$\log L = \sum_{Z_{it}=0} \log\Phi(-b_t - \boldsymbol{W}_i'\boldsymbol{c}) + \sum_{Z_{it}=1} \log\Phi\left(\frac{b_t + \boldsymbol{W}_i'\boldsymbol{c} + (\rho/\sigma)(\log P_{it} - \beta_t - \boldsymbol{X}_i'\boldsymbol{\gamma})}{\sqrt{1-\rho^2}}\right) + \sum_{Z_{it}=1} \left\{\log\phi\left(\frac{\log P_{it} - \beta_t - \boldsymbol{X}_i'\boldsymbol{\gamma}}{\sigma}\right) - \log\sigma - \log P_{it}\right\}. \quad (5)$$

We can estimate the parameters by maximum likelihood method.

The unconditional expectation of log-price (UELP) is a weighted sum of conditional on $\boldsymbol{X}_i$, $\boldsymbol{W}_i$ and $Z_{it}^*$ expected value: $E(\log P_{it} | \boldsymbol{X}_i, \boldsymbol{W}_i) = E(\log P_{it}^* | \boldsymbol{X}_i, \boldsymbol{W}_i, Z_{it}^* > 0) \cdot \Phi(b_t + \boldsymbol{W}_i'\boldsymbol{c})$ since the price is unobserved ($Z_{it}^* \le 0$) when the item is unsold with probability $\Phi(-b_t - \boldsymbol{W}_i'\boldsymbol{c})$. Accordingly, we can write the UELP as

$$E(\log P_{it} | \boldsymbol{X}_i, \boldsymbol{W}_i) = \{\beta_t + \boldsymbol{X}_i'\boldsymbol{\gamma} + \rho\sigma\lambda(b_t + \boldsymbol{W}_i'\boldsymbol{c})\}\Phi(b_t + \boldsymbol{W}_i'\boldsymbol{c}).$$

where $E(\epsilon_i | \boldsymbol{X}_i, \boldsymbol{W}_i, Z_{it}^* > 0) = \rho\sigma\lambda(b_t + \boldsymbol{W}_i'\boldsymbol{c})$ since the error term $\epsilon_i$ in (4) has truncated normal distribution under the condition $Z_{it}^* > 0$ and the function $\lambda(\cdot)$ is inverse Mills ratio: $\lambda(b_t + \boldsymbol{W}_i'\boldsymbol{c}) = \phi(b_t + \boldsymbol{W}_i'\boldsymbol{c})/\Phi(b_t + \boldsymbol{W}_i'\boldsymbol{c})$. Considering $\lambda(b_t + \boldsymbol{W}_i'\boldsymbol{c})\Phi(b_t + \boldsymbol{W}_i'\boldsymbol{c}) = \phi(b_t + \boldsymbol{W}_i'\boldsymbol{c})$, the UELP becomes $E(\log P_{it} | \boldsymbol{X}_i, \boldsymbol{W}_i) = (\beta_t + \boldsymbol{X}_i'\boldsymbol{\gamma})\Phi(b_t + \boldsymbol{W}_i'\boldsymbol{c}) + \rho\sigma\phi(b_t + \boldsymbol{W}_i'\boldsymbol{c})$. The difference in UELP between period 0 and $t$ is $\Delta_t^U = E(\log P_{it} | \boldsymbol{X}_i, \boldsymbol{W}_i) - E(\log P_{i0} | \boldsymbol{X}_i, \boldsymbol{W}_i)$, namely :

$$\Delta_t^U = \beta_t\Phi(b_t + \boldsymbol{W}_i'\boldsymbol{c}) + \boldsymbol{X}_i'\boldsymbol{\gamma}\big(\Phi(b_t + \boldsymbol{W}_i'\boldsymbol{c}) - \Phi(\boldsymbol{W}_i'\boldsymbol{c})\big) + \rho\sigma\big(\phi(b_t + \boldsymbol{W}_i'\boldsymbol{c}) - \phi(\boldsymbol{W}_i'\boldsymbol{c})\big).$$

We omit the time dummy variables of the base period at the equation (3) and (4) to escape the dummy variable trap $(\beta_0 = b_0 = 0)$. Using the difference of UELP $\Delta_t^U$, the unconditional hedonic price index in reference period $t$ relative to base period 0 is defined as follows:

$$UHPI_t = \exp\big[\hat{\beta}_t\overline{\Phi}_t + \overline{\boldsymbol{X}}'\hat{\boldsymbol{\gamma}}(\overline{\Phi}_t - \overline{\Phi}_0) + \hat{\rho}\hat{\sigma}(\overline{\phi}_t - \overline{\phi}_0)\big]. \quad (6)$$

where $\overline{\boldsymbol{X}} = \frac{1}{n}\sum_{i=1}^n \boldsymbol{X}_i$ $\overline{\Phi}_t = \frac{1}{n}\sum_{i=1}^n \Phi(\hat{b}_t + \boldsymbol{W}_i'\hat{\boldsymbol{c}})$, $\overline{\Phi}_0 = \frac{1}{n}\sum_{i=1}^n \Phi(\boldsymbol{W}_i'\hat{\boldsymbol{c}})$, $\overline{\phi}_t = \sum_{i=1}^n \phi(\hat{b}_t + \boldsymbol{W}_i'\hat{\boldsymbol{c}})$ and $\overline{\phi}_0 = \sum_{i=1}^n \phi(\boldsymbol{W}_i'\hat{\boldsymbol{c}})$; $\hat{\beta}_t$, $\hat{\boldsymbol{\gamma}}$, $\hat{\rho}$, $\hat{\sigma}$, $\hat{b}_t$ and $\hat{\boldsymbol{c}}$ are maximum likelihood estimators in (5).

Conditional expectation of log-price (CELP) is $E(\log P_{it}^* | \boldsymbol{X}_i, Z_{it}^* > 0) = \beta_t + X_i'\gamma + \rho\sigma\lambda(b_t + \boldsymbol{W}_i'\boldsymbol{c})$. The difference in CELP between period 0 and $t$ is $\Delta_t^C = E(\log P_{it}^* | \boldsymbol{X}_i, Z_{it}^* >$

$0) - E(\log P_{i0}^* | \boldsymbol{X}_i, Z_{it}^* > 0)$, namely:

$$\Delta_t^C = \beta_t + \rho\sigma[\lambda(b_t + \boldsymbol{W}_i'\boldsymbol{c}) - \lambda(\boldsymbol{W}_i'\boldsymbol{c})].$$

Using the difference of CELP $\Delta_t^C$, the conditional hedonic price index in reference period $t$ relative to base period $0$ is defined as follows:

$$CHPI_t = \exp\left[\hat{\beta}_t + \hat{\rho}\hat{\sigma}\left(\bar{\lambda}_t - \bar{\lambda}_0\right)\right]. \quad (7)$$

where $\bar{\lambda}_t = (1/n)\sum_{i=1}^n\{\phi(\hat{b}_t + \boldsymbol{W}_i'\hat{\boldsymbol{c}})/\Phi(\hat{b}_t + \boldsymbol{W}_i'\hat{\boldsymbol{c}})\}$, $\bar{\lambda}_0 = (1/n)\sum_{i=1}^n\{\phi(\boldsymbol{W}_i'\hat{\boldsymbol{c}})/\Phi(\boldsymbol{W}_i'\hat{\boldsymbol{c}})\}$. We can consider that $\hat{\beta}_t$ is the time effect concerning sold artworks and $\hat{\rho}\hat{\sigma}\left(\bar{\lambda}_t - \bar{\lambda}_0\right)$ is the adjusted term of selectivity bias.

Table 1. Descriptive statistics

Note: Works (1) is the number of exhibited works. Works (2) is the number of sold works. Ratio is sale rates: Works (2)/Works (1). "Hammer price" is the final price in auction. SD is standard deviation of hammer price. CV is coefficient of variation of hammer price. IQR is interquartile range of hammer price.

| | Works (1) | Works (2) | Ratio | Hammer price (¥1,000) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Mean | Median | SD | CV | IQR |
| Year | | | | | | | | |
| 2006 | 3,880 | 3,517 | 0.91 | 1,245 | 240 | 3,867 | 3.1 | 715 |
| 2007 | 4,889 | 4,236 | 0.87 | 1,049 | 210 | 3,818 | 3.6 | 595 |
| 2008 | 4,337 | 3,435 | 0.79 | 920 | 210 | 3,379 | 3.7 | 570 |
| 2009 | 3,818 | 3,171 | 0.83 | 724 | 190 | 3,109 | 4.3 | 475 |
| 2010 | 4,529 | 3,667 | 0.81 | 863 | 220 | 2,827 | 3.3 | 560 |
| 2011 | 4,503 | 3,473 | 0.77 | 764 | 240 | 2,079 | 2.7 | 520 |
| 2012 | 4,106 | 3,097 | 0.75 | 922 | 265 | 3,388 | 3.7 | 613 |
| 2013 | 4,214 | 3,535 | 0.84 | 1,000 | 300 | 3,083 | 3.1 | 680 |
| 2014 | 4,662 | 3,665 | 0.79 | 960 | 280 | 3,420 | 3.6 | 590 |
| 2015 | 5,175 | 4,125 | 0.80 | 920 | 260 | 4,310 | 4.7 | 550 |
| 2016 | 4,913 | 3,682 | 0.75 | 958 | 260 | 3,307 | 3.5 | 630 |
| 2017 | 5,069 | 3,747 | 0.74 | 1,070 | 260 | 4,000 | 3.7 | 640 |
| 2018 | 4,997 | 3,771 | 0.75 | 1,262 | 260 | 5,662 | 4.5 | 655 |
| 2019 | 2,842 | 2,022 | 0.71 | 862 | 220 | 2,557 | 3.0 | 543 |
| Quarter of the year | | | | | | | | |
| 1st quarter | 16,976 | 13,891 | 0.82 | 979 | 240 | 3,967 | 4.1 | 560 |
| 2nd quarter | 14,779 | 11,636 | 0.79 | 1,008 | 250 | 3,804 | 3.8 | 610 |
| 3rd quarter | 14,547 | 11,366 | 0.78 | 934 | 280 | 3,022 | 3.2 | 650 |
| 4th quarter | 15,632 | 12,250 | 0.78 | 971 | 230 | 3,632 | 3.7 | 595 |
| Genre of works | | | | | | | | |
| Others | 3,635 | 3,023 | 0.83 | 1,185 | 180 | 4,811 | 4.1 | 670 |
| Oil painting | 11,901 | 9,136 | 0.77 | 1,821 | 640 | 5,292 | 2.9 | 1,180 |
| Watercolor and acrylic painting | 11,104 | 8,755 | 0.79 | 817 | 170 | 3,726 | 4.6 | 400 |
| Japanese-style painting (Nihonga) | 24,569 | 19,212 | 0.78 | 929 | 260 | 3,138 | 3.4 | 580 |
| Print | 10,261 | 8,661 | 0.84 | 286 | 120 | 702 | 2.5 | 200 |
| Ceramic art, sculpture and artifact | 464 | 356 | 0.77 | 353 | 110 | 1,225 | 3.5 | 190 |

Table 1. Descriptive statistics, continued

| | Works (1) | Works (2) | Ratio | Hammer price (¥1,000) Mean | Median | SD | CV | IQR |
|---|---|---|---|---|---|---|---|---|
| Size of works | | | | | | | | |
| Numero [mm (Length of long side)] | | | | | | | | |
| 0 [180] | 2,596 | 2,123 | 0.82 | 460 | 150 | 2,064 | 4.5 | 250 |
| 1 [220] | 2,149 | 1,763 | 0.82 | 849 | 200 | 2,078 | 2.4 | 535 |
| 2 [240] | 1,034 | 850 | 0.82 | 656 | 180 | 1,810 | 2.8 | 383 |
| 3 [273] | 2,156 | 1,721 | 0.80 | 922 | 260 | 2,877 | 3.1 | 580 |
| 4 [333] | 6,298 | 5,064 | 0.80 | 737 | 235 | 2,123 | 2.9 | 500 |
| 5 [350] | 2,358 | 1,887 | 0.80 | 693 | 180 | 1,977 | 2.9 | 500 |
| 6 [410] | 8,272 | 6,395 | 0.77 | 746 | 260 | 2,198 | 2.9 | 555 |
| 8 [455] | 8,225 | 6,524 | 0.79 | 812 | 240 | 2,586 | 3.2 | 530 |
| 10 [530] | 8,474 | 6,567 | 0.77 | 846 | 280 | 3,092 | 3.7 | 578 |
| 12 [606] | 5,342 | 4,191 | 0.78 | 999 | 250 | 3,126 | 3.1 | 602 |
| 15 [652] | 2,531 | 2,073 | 0.82 | 1,312 | 350 | 4,022 | 3.1 | 890 |
| 20 [727] | 5,288 | 4,243 | 0.80 | 1,304 | 240 | 4,645 | 3.6 | 723 |
| 25 [803] | 2,102 | 1,692 | 0.80 | 931 | 150 | 3,859 | 4.1 | 432 |
| 30 [910] | 2,346 | 1,850 | 0.79 | 1,668 | 380 | 6,108 | 3.7 | 980 |
| 40 [1000] | 843 | 666 | 0.79 | 1,243 | 214 | 4,112 | 3.3 | 799 |
| 50 [1167] | 825 | 672 | 0.81 | 2,084 | 580 | 7,523 | 3.6 | 1,239 |
| 60 [1303] | 226 | 188 | 0.83 | 2,666 | 680 | 8,327 | 3.1 | 1,863 |
| 80 [1455] | 162 | 128 | 0.79 | 1,970 | 845 | 4,148 | 2.1 | 1,473 |
| 100 [1620] | 202 | 155 | 0.77 | 2,788 | 1,200 | 4,542 | 1.6 | 2,070 |
| 120 [1940] | 100 | 72 | 0.72 | 5,815 | 1,100 | 21,512 | 3.7 | 1,667 |
| 150 [2273] | 171 | 141 | 0.82 | 4,578 | 550 | 17,980 | 3.9 | 1,650 |
| 200 [2590] | 21 | 15 | 0.71 | 2,590 | 1,400 | 4,184 | 1.6 | 2,800 |
| 300 [2910] | 50 | 36 | 0.72 | 2,489 | 930 | 4,628 | 1.9 | 1,500 |
| 500 [3333] | 163 | 127 | 0.78 | 6,593 | 1,600 | 15,806 | 2.4 | 3,725 |
| Auction houses | | | | | | | | |
| [A] (Koto Ward, Tokyo) | 45,315 | 34,218 | 0.76 | 657 | 200 | 2,302 | 3.5 | 470 |
| [B] (Chuo Ward, Tokyo) | 14,188 | 12,764 | 0.90 | 1,617 | 360 | 5,039 | 3.1 | 970 |
| [C] (Koto Ward, Tokyo) | 2,431 | 2,161 | 0.89 | 2,175 | 656 | 7,909 | 3.6 | 1,415 |
| Comments included in the condition report of works (multiple comment) | | | | | | | | |
| No comments | 10,256 | 7,700 | 0.75 | 390 | 160 | 1,366 | 3.5 | 310 |
| Cracking | 1,990 | 1,272 | 0.64 | 805 | 400 | 1,261 | 1.6 | 570 |
| Defect | 232 | 165 | 0.71 | 477 | 190 | 764 | 1.6 | 430 |
| Damage | 130 | 99 | 0.76 | 343 | 120 | 577 | 1.7 | 268 |
| Scratch | 355 | 254 | 0.72 | 989 | 260 | 2,757 | 2.8 | 500 |
| Fold | 1,369 | 1,007 | 0.74 | 295 | 145 | 458 | 1.6 | 230 |
| Stain | 14,483 | 10,503 | 0.73 | 354 | 160 | 967 | 2.7 | 283 |
| Wrinkle | 1,799 | 1,305 | 0.73 | 343 | 160 | 704 | 2.1 | 260 |
| Fading | 14,027 | 10,360 | 0.74 | 313 | 150 | 688 | 2.2 | 260 |
| Tears | 404 | 273 | 0.68 | 426 | 170 | 752 | 1.8 | 320 |
| Flaking | 1,368 | 819 | 0.60 | 872 | 300 | 4,158 | 4.8 | 450 |
| Adhesive/Tape stains | 872 | 652 | 0.75 | 382 | 180 | 503 | 1.3 | 350 |
| Cratering | 112 | 79 | 0.71 | 447 | 210 | 722 | 1.6 | 425 |
| Insects | 109 | 68 | 0.62 | 275 | 170 | 334 | 1.2 | 275 |
| Soiled | 824 | 616 | 0.75 | 479 | 165 | 1,824 | 3.8 | 340 |
| Mold | 17 | 17 | 1.00 | 1,069 | 350 | 1,414 | 1.3 | 1,560 |
| Discoloration | 274 | 186 | 0.68 | 244 | 135 | 326 | 1.3 | 223 |
| Retouching/Repairing | 489 | 298 | 0.61 | 892 | 345 | 1,613 | 1.8 | 660 |
| No frame | 227 | 171 | 0.75 | 536 | 150 | 1,501 | 2.8 | 265 |

## 3. Data

Our dataset consists of the price and characteristics of 61,934 artworks created by Japanese artists presented for auction by the three Japanese auction houses A (Koto Ward, Tokyo), B (Chuo Ward, Tokyo) and C (Koto Ward, Tokyo) from first quarter 2006 to third-quarter 2019 period. The number of sold artworks is 49,143, and the sale rate is 79%.

Table 1 shows the descriptive statistics of the characteristics of artworks. “Works (1)” is the number of exhibited works. “Works (2)” is the number of sold works. “Ratio” is the sale rate: Works (2)/Works (1). “Hammer price" is the final price in the auction. We summaries the number of works and hammer prices of sold works concerning characteristics of works, which are classified by transaction period (year and a quarter), the genre of works, size of works, auction houses, and remarks about the conditions of works.

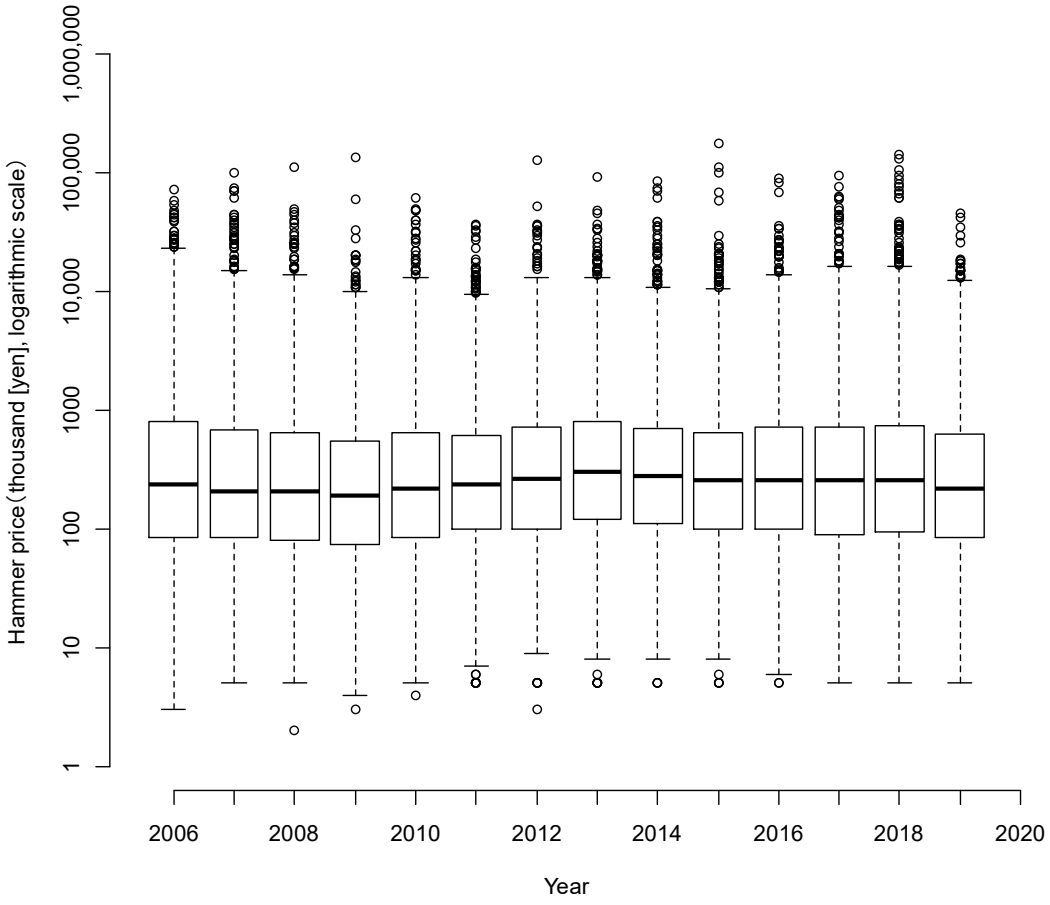


Figure 1. Boxplot of hammer price (¥1,000) of sold artworks

The number of exhibited works is stable in each year from 2006 to 2019. Approximately 4,000-5,000 works are observed every year in Table 1. The data size has slightly much in the first and fourth periods among the quarter of the year. Japanese-style painting (Nihonga) is characterized by its being the most a lot in the genre. There are many observations of #6, #8 and #10 at the size (numero) of works. The tendency that the mean of hammer prices becomes high is seen so that size becomes big. The artworks more than 70% are given by auction house [A]. Comments are referred to works, stain and fading are outstanding in the condition report. Additionally, descriptive statistics of 255 artists are shown in Table A1 (see appendix).

Figure 1 shows the box plot diagram of (logarithmic scale) hammer price (¥1,000) at auction from 2006 to 2019. The height of the lower limit is $Q1 - 1.5 \times IQR$, and of the upper limit is $Q3 + 1.5 \times IQR$, where $Q1$ is the first quartile, $IQR$ is Interquartile range, and $Q3$ is the third quartile. We observed some outliers every year.

Figure 2 shows the quarterly buy-in rate, which is one minus sale rate, and the sample mean of price change rate, which is against the same quarter of the previous. The correlation coefficient between the two variables is 0.0349 ($p$-value = 0.8097), which is not significant. It is not possible to find a relationship between the buy-in rate and the price change per quarterly. The exponential type II Tobit model estimation tests the correlation between the error terms of these two variables after controlling characteristic variables of artworks.

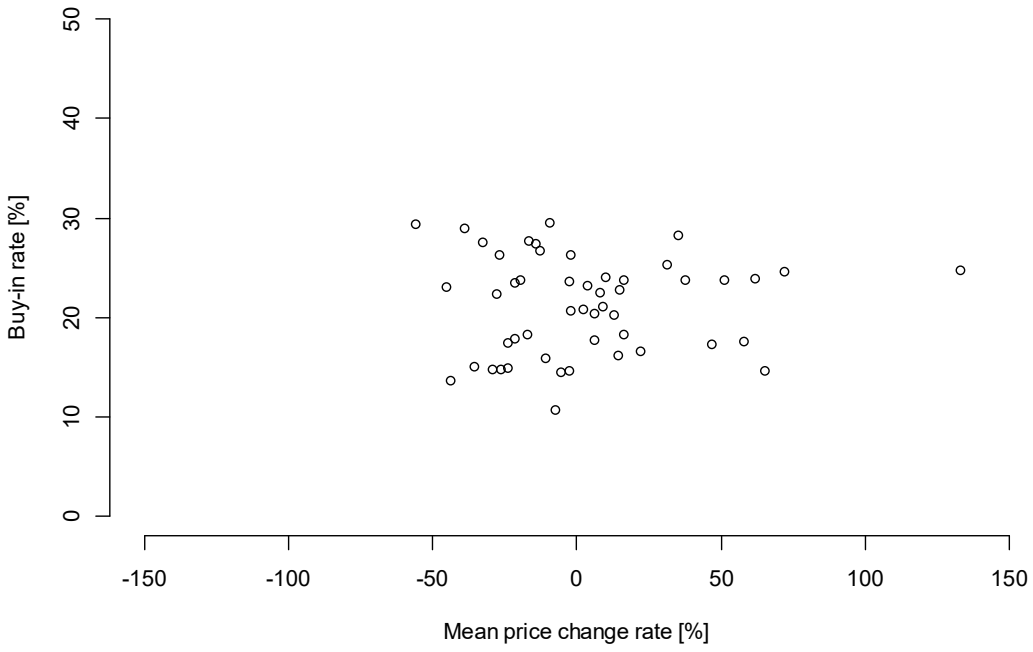


Figure 2 Buy-in rate and mean price change

Note: Buy-in rate is one minus sale rate. Mean price change rate is against to the same quarter of the previous year.

## 4. Empirical results

Table 2 shows the estimation results of (5), which was performed using full sample (sold and unsold 61,934 artworks) by the maximum likelihood method (outcome part in the exponential type II Tobit) and the estimation results of (1) using uncensored observations (sold 49,143 artworks) by the ordinary least squares method with White's heteroscedasticity-consistent standard error. We present the result of the different estimated method in parallel for comparison.

Time effects, which are coefficients of the year dummy variable, are significantly negative. Hammer price is showing a tendency to decrease as compared to reference year, 2006. Artworks prices tend to be sold at significantly lower in the fourth quarter compared to the first quarter. “Oil-painting,” “Watercolor and acrylic painting,” and “Japanese-style painting (Nihonga)” are sold at higher on comparison with reference category “others” in the genre of works. Hammer price of “Print” and “Ceramic art, sculpture, and artifact” is significantly lower than “others.” The difference in the size of works is significantly reflected in the hammer price. The bigger the size of works becomes, the higher the price of works increases. The artwork is bought at the price that exhibited one is higher than the auction house [A] in [B] or [C]. If there are the comments such as “Cracking,” “Fold,” “Stain,” “Wrinkle,” “Fading,” “Flaking,” “Discoloration,” “Retouching/Repairing” and “No frame” in the condition report of works, the works tend to be sold at a significantly lower price. Two hundred fifty-four artist dummy variables were included in regression but not reported in the table. One hundred seventy-four of the 254 artist dummies in equation (4) and One hundred seventy-seven of the 254 artist dummies in equation (1), were significant at 5% level.

Table 3 shows the estimation results of the selection part in the exponential type II Tobit model and what kind of characteristic of the effects of the work on sale rate. The explanatory variables in equation (3) are the same as in equation (4), except that the artist dummy variables are not used. The categorical variables of years, quarters of the year, and the genre of works are significant for sale rate. If the comments such as “Cracking,” “Fold,” “Stain,” “Fading,” “Flaking,” “Insects,” “Discoloration,” and “Retouching/Repairing” are included in the condition report of works, the sale rate of the works falls significantly.

Table 2. Estimation results of hedonic price

Note: The *, **, and *** symbols denote statistical significance at the 5%, 1%, and 0.1% levels. (a) Maximum likelihood estimation results of outcome equation part of (5) using full sample 61,934. (b) Ordinary least square estimation results of hedonic price model (1) using uncensored observations 49,143. (c) White's heteroscedasticity-consistent standard error.

| Parameter/categories | Variable | Exponential Type II Tobit [a] | | | OLS[b] | | |
|---|---|---|---|---|---|---|---|
| | | coef. | s.e. | | coef. | s.e.[c] | |
| α | constant term | 10.813 | 0.101 | *** | 10.882 | 0.104 | *** |
| β/ Year | 2007 | -0.074 | 0.028 | ** | -0.036 | 0.026 | |
| (reference category: | 2008 | -0.287 | 0.029 | *** | -0.164 | 0.027 | *** |
| 2006) | 2009 | -0.287 | 0.030 | *** | -0.221 | 0.028 | *** |
| | 2010 | -0.289 | 0.029 | *** | -0.192 | 0.027 | *** |
| | 2011 | -0.359 | 0.029 | *** | -0.220 | 0.027 | *** |
| | 2012 | -0.409 | 0.030 | *** | -0.248 | 0.028 | *** |
| | 2013 | -0.181 | 0.029 | *** | -0.118 | 0.027 | *** |
| | 2014 | -0.332 | 0.029 | *** | -0.209 | 0.027 | *** |
| | 2015 | -0.269 | 0.029 | *** | -0.179 | 0.027 | *** |
| | 2016 | -0.308 | 0.029 | *** | -0.158 | 0.028 | *** |
| | 2017 | -0.398 | 0.030 | *** | -0.232 | 0.028 | *** |
| | 2018 | -0.350 | 0.029 | *** | -0.194 | 0.028 | *** |
| | 2019 | -0.571 | 0.035 | *** | -0.311 | 0.034 | *** |
| $\gamma_1$/ Quarter of the year | 2nd quarter | 0.017 | 0.015 | | 0.049 | 0.014 | *** |
| (reference category: | 3rd quarter | -0.027 | 0.015 | | 0.035 | 0.014 | * |
| 1st quarter) | 4th quarter | -0.091 | 0.015 | *** | -0.031 | 0.014 | * |
| $\gamma_2$/ Genre of works | Oil painting | 1.656 | 0.037 | *** | 1.845 | 0.039 | *** |
| (reference category: | Watercolor and acrylic painting | 0.093 | 0.035 | ** | 0.224 | 0.037 | *** |
| others) | Japanese-style painting (Nihonga) | 0.589 | 0.112 | *** | 0.690 | 0.139 | *** |
| | Print | -1.033 | 0.035 | *** | -0.985 | 0.035 | *** |
| | Ceramic art, sculpture and artifact | -0.448 | 0.082 | *** | -0.291 | 0.085 | *** |
| $\gamma_3$/ Size of works | #1 | 0.264 | 0.039 | *** | 0.239 | 0.035 | *** |
| (reference category: | #2 | 0.325 | 0.049 | *** | 0.298 | 0.046 | *** |
| numero #0) | #3 | 0.415 | 0.040 | *** | 0.417 | 0.034 | *** |
| | #4 | 0.437 | 0.033 | *** | 0.424 | 0.028 | *** |
| | #5 | 0.436 | 0.039 | *** | 0.451 | 0.036 | *** |
| | #6 | 0.513 | 0.031 | *** | 0.552 | 0.027 | *** |
| | #8 | 0.538 | 0.032 | *** | 0.549 | 0.028 | *** |
| | #10 | 0.654 | 0.032 | *** | 0.697 | 0.029 | *** |
| | #12 | 0.737 | 0.034 | *** | 0.782 | 0.031 | *** |
| | #15 | 0.816 | 0.039 | *** | 0.825 | 0.037 | *** |
| | #20 | 0.774 | 0.034 | *** | 0.807 | 0.032 | *** |
| | #25 | 0.676 | 0.042 | *** | 0.708 | 0.041 | *** |
| | #30 | 1.131 | 0.040 | *** | 1.186 | 0.038 | *** |
| | #40 | 0.976 | 0.056 | *** | 1.026 | 0.053 | *** |
| | #50 | 1.430 | 0.055 | *** | 1.460 | 0.052 | *** |
| | #60 | 1.484 | 0.092 | *** | 1.485 | 0.096 | *** |
| | #80 | 1.545 | 0.110 | *** | 1.618 | 0.110 | *** |
| | #100 | 1.658 | 0.100 | *** | 1.740 | 0.104 | *** |
| | #120 | 1.721 | 0.142 | *** | 1.859 | 0.165 | *** |
| | #150 | 1.619 | 0.106 | *** | 1.635 | 0.140 | *** |
| | #200 | 1.937 | 0.306 | *** | 2.012 | 0.265 | *** |
| | #300 | 1.670 | 0.201 | *** | 1.884 | 0.309 | *** |
| | #500 | 2.010 | 0.110 | *** | 1.990 | 0.129 | *** |

Table 2. Estimation results of hedonic price, continued

Note: The *, **, and *** symbols denote statistical significance at the 5%, 1%, and 0.1% levels. (d) Standard error of the regression of (1).

| Parameter/categories | Variable | Type II Tobit | | | OLS | | |
|---|---|---|---|---|---|---|---|
| | | coef. | s.e. | | coef. | s.e. | |
| $\gamma_4$/ Auction houses (reference category: [A]) | Auction house [B] | 0.539 | 0.015 | *** | 0.369 | 0.015 | *** |
| | Auction house [C] | 1.263 | 0.037 | *** | 1.066 | 0.039 | *** |
| $\gamma_5$/ Comments included in the condition report of works (reference category: No comments) | Cracking | -0.084 | 0.037 | * | -0.002 | 0.027 | |
| | Defect | -0.081 | 0.092 | | -0.057 | 0.087 | |
| | Damage | -0.200 | 0.120 | | -0.217 | 0.120 | |
| | Scratch | 0.202 | 0.074 | ** | 0.238 | 0.074 | ** |
| | Fold | -0.174 | 0.039 | *** | -0.149 | 0.033 | *** |
| | Stain | -0.182 | 0.017 | *** | -0.129 | 0.014 | *** |
| | Wrinkle | -0.108 | 0.035 | ** | -0.113 | 0.030 | *** |
| | Fading | -0.151 | 0.017 | *** | -0.154 | 0.015 | *** |
| | Tears | -0.087 | 0.073 | | -0.080 | 0.069 | |
| | Flaking | -0.117 | 0.044 | ** | 0.033 | 0.036 | |
| | Adhesive/Tape stains | 0.205 | 0.048 | *** | 0.211 | 0.041 | *** |
| | Cratering | 0.193 | 0.133 | | 0.227 | 0.121 | |
| | Insects | -0.212 | 0.141 | | -0.110 | 0.111 | |
| | Soiled | -0.006 | 0.049 | | 0.012 | 0.047 | |
| | Mold | 0.601 | 0.301 | * | 0.242 | 0.289 | |
| | Discoloration | -0.318 | 0.086 | *** | -0.201 | 0.068 | ** |
| | Retouching/Repairing | -0.151 | 0.068 | * | -0.008 | 0.060 | |
| | No frame | -0.258 | 0.092 | ** | -0.263 | 0.094 | ** |
| $\gamma_6$/ Artist (reference category: Toshinobu Onosato) | 254 dummy variables | (Yes) | | | (Yes) | | |
| | Number of observations | 61,934 | | | 49,143 | | |
| | Censored observations | 12,791 | | | - | | |
| | Loglikelihood | -103,699 | | | - | | |
| | Adjusted R-Squared | - | | | 0.439 | | |
| σ | sigma | 1.237 | 0.006 | *** | 1.097(d) | | |
| ρ | rho | 0.745 | 0.009 | *** | - | | |

Table 3. Estimation results of selection part in exponential type II Tobit

Note: *** $p$-value<0.001, ** $p$-value<0.01, * $p$-value<0.05.

| Categories | Variable | coef. | s.e. | |
|---|---|---|---|---|
| | constant term | 1.617 | 0.049 | *** |
| Year | 2007 | -0.191 | 0.036 | *** |
| (reference category: | 2008 | -0.450 | 0.035 | *** |
| 2006) | 2009 | -0.274 | 0.037 | *** |
| | 2010 | -0.373 | 0.035 | *** |
| | 2011 | -0.490 | 0.035 | *** |
| | 2012 | -0.559 | 0.036 | *** |
| | 2013 | -0.305 | 0.037 | *** |
| | 2014 | -0.461 | 0.035 | *** |
| | 2015 | -0.380 | 0.035 | *** |
| | 2016 | -0.491 | 0.035 | *** |
| | 2017 | -0.499 | 0.035 | *** |
| | 2018 | -0.454 | 0.035 | *** |
| | 2019 | -0.746 | 0.039 | *** |
| Quarter of the year | 2nd quarter | -0.074 | 0.016 | *** |
| (reference category: | 3rd quarter | -0.166 | 0.016 | *** |
| 1st quarter) | 4th quarter | -0.162 | 0.016 | *** |
| Genre of works | Oil painting | -0.586 | 0.029 | *** |
| (reference category: | Watercolor and acrylic painting | -0.344 | 0.029 | *** |
| others) | Japanese-style painting (Nihonga) | -0.276 | 0.027 | *** |
| | Print | -0.203 | 0.030 | *** |
| | Ceramic art, sculpture and artifact | -0.386 | 0.068 | *** |
| Size of works | #1 | 0.096 | 0.043 | * |
| (reference category: | #2 | 0.124 | 0.054 | * |
| numero #0) | #3 | 0.020 | 0.042 | |
| | #4 | 0.045 | 0.034 | |
| | #5 | 0.022 | 0.041 | |
| | #6 | -0.069 | 0.032 | * |
| | #8 | -0.010 | 0.033 | |
| | #10 | -0.088 | 0.033 | ** |
| | #12 | -0.070 | 0.035 | * |
| | #15 | 0.003 | 0.041 | |
| | #20 | -0.027 | 0.035 | |
| | #25 | -0.047 | 0.043 | |
| | #30 | -0.097 | 0.041 | * |
| | #40 | -0.086 | 0.057 | |
| | #50 | -0.024 | 0.058 | |
| | #60 | 0.104 | 0.104 | |
| | #80 | -0.071 | 0.114 | |
| | #100 | -0.077 | 0.103 | |
| | #120 | -0.183 | 0.141 | |
| | #150 | 0.278 | 0.121 | * |
| | #200 | -0.254 | 0.297 | |
| | #300 | -0.059 | 0.200 | |
| | #500 | 0.282 | 0.113 | * |

Table 3. Estimation results of selection part in type II Tobit, continued

Note: *** $p$-value<0.001, ** $p$-value<0.01, * $p$-value<0.05

| Categories | Variable | coef. | s.e. | |
|---|---|---|---|---|
| Auction houses (reference category: [A]) | Auction house [B] | 0.588 | 0.017 | *** |
| | Auction house [C] | 0.487 | 0.036 | *** |
| Comments included in the condition report of works (reference category: No comments) | Cracking | -0.101 | 0.032 | ** |
| | Defect | -0.037 | 0.088 | |
| | Damage | 0.079 | 0.122 | |
| | Scratch | -0.037 | 0.071 | |
| | Fold | -0.076 | 0.038 | * |
| | Stain | -0.140 | 0.016 | *** |
| | Wrinkle | -0.002 | 0.033 | |
| | Fading | -0.053 | 0.017 | ** |
| | Tears | -0.009 | 0.067 | |
| | Flaking | -0.269 | 0.037 | *** |
| | Adhesive/Tape stains | -0.003 | 0.047 | |
| | Cratering | -0.050 | 0.125 | |
| | Insects | -0.245 | 0.122 | * |
| | Soiled | -0.039 | 0.048 | |
| | Mold | 4.553 | 1641.000 | |
| | Discoloration | -0.273 | 0.078 | *** |
| | Retouching/Repairing | -0.265 | 0.058 | *** |
| | No frame | 0.076 | 0.092 | |

Table 4. Art price index

| | exponential type II Tobit | | | | OLS |
|---|---|---|---|---|---|
| Year | $\exp(\hat{\beta}_t)$ | $\exp[\hat{\rho}\hat{\sigma}(\bar{\lambda}_t - \bar{\lambda}_0)]$ | $CHPI_t$ | $UHPI_t$ | $HPI_t$ |
| 2006 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2007 | 0.929 | 1.067 | 0.991 | 0.578 | 0.964 |
| 2008 | 0.750 | 1.187 | 0.891 | 0.207 | 0.849 |
| 2009 | 0.751 | 1.125 | 0.844 | 0.321 | 0.801 |
| 2010 | 0.749 | 1.155 | 0.865 | 0.258 | 0.825 |
| 2011 | 0.698 | 1.220 | 0.852 | 0.158 | 0.803 |
| 2012 | 0.664 | 1.256 | 0.834 | 0.120 | 0.780 |
| 2013 | 0.834 | 1.118 | 0.933 | 0.365 | 0.889 |
| 2014 | 0.718 | 1.203 | 0.863 | 0.179 | 0.811 |
| 2015 | 0.764 | 1.188 | 0.908 | 0.210 | 0.836 |
| 2016 | 0.735 | 1.258 | 0.924 | 0.128 | 0.854 |
| 2017 | 0.672 | 1.263 | 0.848 | 0.115 | 0.793 |
| 2018 | 0.705 | 1.231 | 0.867 | 0.148 | 0.824 |
| 2019 | 0.565 | 1.317 | 0.744 | 0.072 | 0.733 |

Table 4 shows the art price index that calculates using equation (2), (6), and (7). Some complex effects are arising from auction buy-ins on the overall market price dynamics. The $CHPI_t$ by the exponential type II Tobit model has two-fold elements: price variations related to the entire art market and fluctuations in truncated bias. The $UHPI_t$ are much smaller than the $CHPI_t$ since the sales rate tends to decrease during the observation period. The $HPI_t$ calculated by OLS estimation has a bias, its value tends to be slightly lower than $CHPI_t$.


Figure 3. Art price indices (base year 2006 = 1)

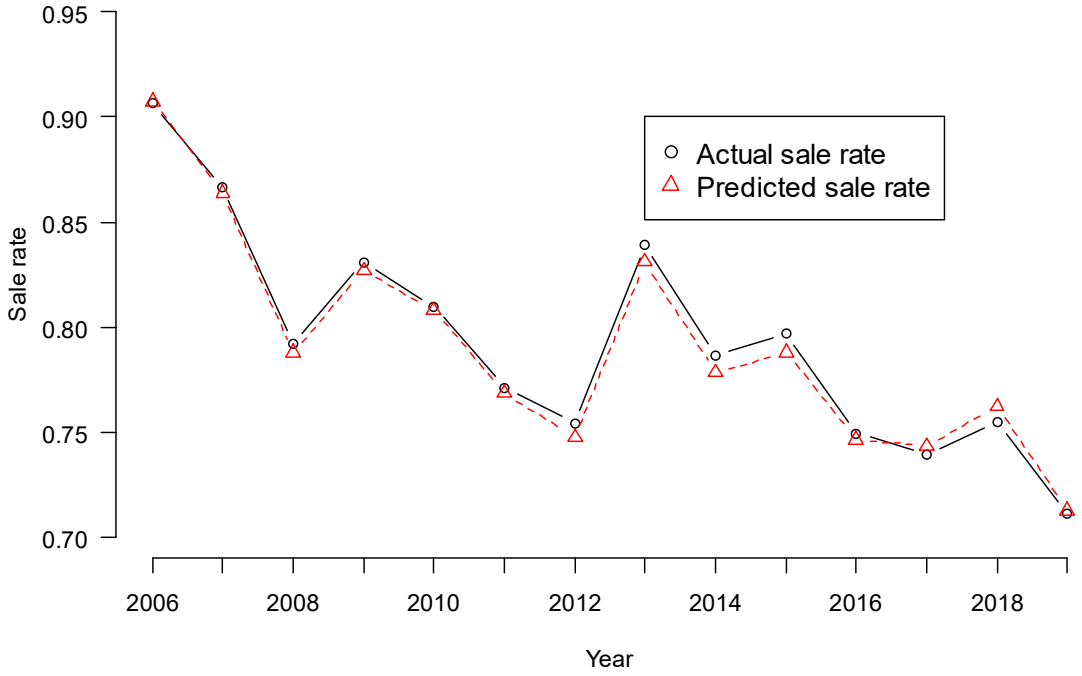


Figure 4. Actual and predicted sale rate

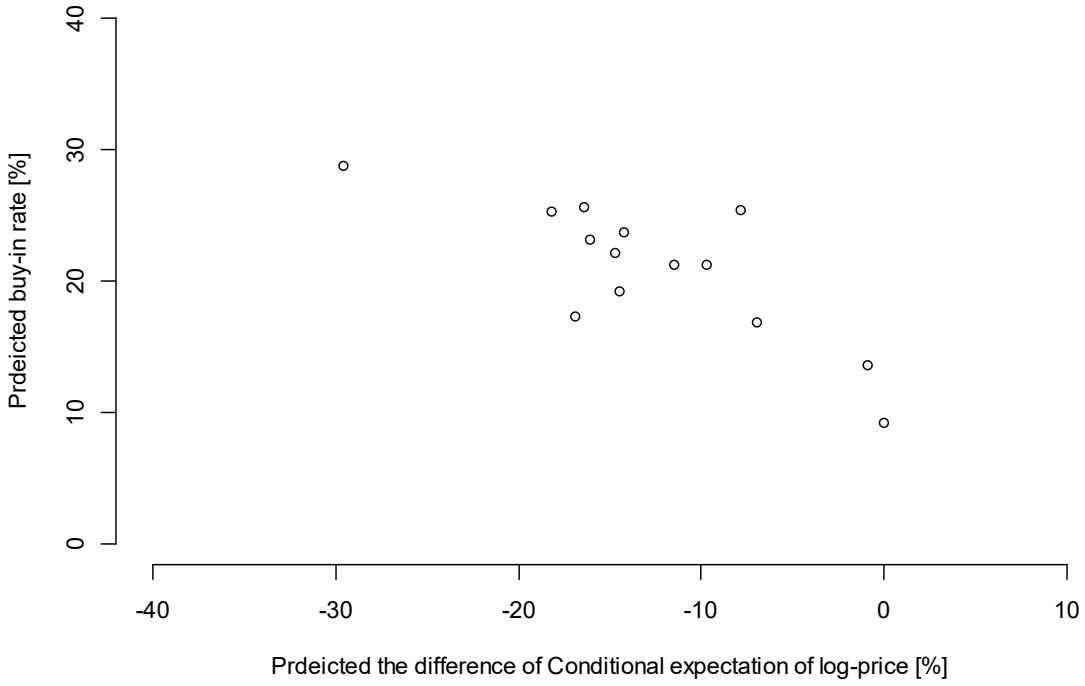


Figure 5. Predicted buy-in rate and difference of conditional expectation of log-price

Figure 3 shows the two art price indices. It can be seen that the level of the $CHPI_t$. by the exponential type II Tobit, which takes into account the selection bias, is slightly higher than the $HPI_t$ based on OLS estimation that was calculated using only samples of sold works. The average rate of price change per year is $-2.0\%$ for $CHPI_t$ (7.0% standard deviation) and $-2.1\%$ for $HPI_t$ (7.2% standard deviation). These indicate that the hedonic price index based on OLS estimation has a lower bias because the change in sales rate is not taken into account. $HPI_t$ is 4.3% lower on average than $CHPI_t$.

Figure 4 shows the actual and predicted sale rate which is the mean of $\Phi\left(\hat{b}_t + W_i'\hat{c}\right)$. It turns out that the fit of the sale rate function is almost perfect. In Table 2, the correlation coefficient $\rho = E(\epsilon_i u_i)/\left\{E\left(u_i^2\right) \cdot E\left(\epsilon_i^2\right)\right\}^{1/2}$ is significantly estimated to be $\hat{\rho} = 0.745$ ($p$-value: 0.009) by maximum likelihood method. In other words, it can be seen that the selection mechanism has an outcome for art price determination. In Figure 5, we plot the buy-in rate which is calculated as $\left\{1 - \Phi\left(\hat{b}_t + W_i'\hat{c}\right)\right\} \times 100\%$ against the difference of conditional expectation of log-price $\Delta_t^C$ in each year from 2006 to 2019. When artwork prices tend to fall, the buy-in rate tends to rise.

## 5. Concluding remarks

We derived the hedonic price index of artworks in Japan's art auction market, between

2006 and 2019. The number of Japanese artists analyzed was 255, and 61,934 artworks were auctioned during the period, of which 49,143 artworks were made successful bids. The sale rate of artworks in auctions is not always stable, which may have affected the price of works. Naturally, there may be regarded as the bias in the price index of a sample that selects only sold artworks. This paper presented a revised price index.

The hedonic approach is very commonly used in estimating auction prices. In this paper, year, the quarter of the year, the genre of works, size of works, auction houses, condition reports, and the artist names were used as explanatory variables for the log price hedonic model. Considering the sample selection bias in the auction, measuring the price index also needs to be reconsidered. Besides, the outcome function in the sample selection model can be expressed by replacing the traditional hedonic time dummy model of log-price with an exponential function. Therefore, we presented the maximum likelihood estimation of the hammer price by the exponential type II Tobit model. Using the difference between the conditional expectation of the logarithmic price, conditional hedonic price index that takes into account the variation of selection bias was defined.

The hedonic price index based on OLS estimation has a lower bias because the change in sales rate is not taken into account. The hedonic price index based on OLS is 4.3% lower on average than the conditional hedonic price index in the Japanese art auction market. We found that the error terms in the selection function and the error terms in the outcome hammer price equation are significantly correlated. When artwork prices tend to fall, the buy-in rate tends to rise.

## Acknowledgments

This research has greatly benefited from many helpful suggestions by Akihito Takei (Quick Corp.) and Atsushi Kato (Kyoto University of Art & Design).

## Appendix A

Table A1 shows descriptive statistics of 255 Japanese artists as the sample for this research.

Table A1 Descriptive statistics of 255 artists (decreasing order of the number of works)

Note. Works (1) is the number of exhibited works. Works (2) is the number of sold works. Ratio is sale rates: Works (2)/Works (1). "Hammer price" is the final price in auction. SD is standard deviation of hammer price. CV is coefficient of variation of hammer price. IQR is interquartile range of hammer price.

| Artist name | Year born | Year died | Works (1) | Works (2) | Ratio | Hammer price (¥1,000) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Median | SD | CV | IQR |
| Tsuguharu Foujita | 1886 | 1968 | 2,333 | 1,939 | 0.83 | 1,898 | 180 | 6,801 | 3.6 | 590 |
| Yayoi Kusama | 1929 | - | 2,326 | 2,110 | 0.91 | 2,666 | 840 | 7,951 | 3.0 | 1,820 |
| Shiko Munakata | 1903 | 1975 | 2,061 | 1,642 | 0.80 | 1,029 | 500 | 2,281 | 2.2 | 900 |
| Kaii Higashiyama | 1908 | 1999 | 1,558 | 1,381 | 0.89 | 1,652 | 230 | 7,082 | 4.3 | 380 |
| Ikuo Hirayama | 1930 | 2009 | 1,389 | 1,182 | 0.85 | 916 | 240 | 3,167 | 3.5 | 340 |
| Matazo Kayama | 1927 | 2004 | 1,313 | 1,061 | 0.81 | 1,271 | 180 | 4,214 | 3.3 | 475 |
| Hiro Yamagata | 1948 | - | 1,081 | 1,043 | 0.96 | 128 | 65 | 263 | 2.1 | 60 |
| Hiroshi Senju | 1958 | - | 967 | 829 | 0.86 | 1,190 | 320 | 1,851 | 1.6 | 1,580 |
| Takashi Murakami | 1962 | - | 928 | 814 | 0.88 | 436 | 140 | 5,051 | 11.6 | 217 |
| Chinami Nakajima | 1945 | - | 894 | 785 | 0.88 | 386 | 110 | 1,074 | 2.8 | 95 |
| Hiroki Oda | 1914 | 2012 | 871 | 762 | 0.87 | 216 | 140 | 266 | 1.2 | 223 |
| Tamako Kataoka | 1905 | 2008 | 849 | 705 | 0.83 | 1,176 | 480 | 2,133 | 1.8 | 480 |
| Yozo Hamaguchi | 1909 | 2000 | 845 | 677 | 0.80 | 257 | 140 | 416 | 1.6 | 135 |
| Kiyoshi Saito | 1907 | 1997 | 836 | 650 | 0.78 | 185 | 130 | 194 | 1.1 | 155 |
| Ryuzaburo Umehara | 1888 | 1986 | 832 | 607 | 0.73 | 2,351 | 170 | 6,080 | 2.6 | 1,895 |
| Kiyoshi Hasegawa | 1891 | 1980 | 761 | 598 | 0.79 | 465 | 280 | 560 | 1.2 | 430 |
| Takanori Ogisu | 1901 | 1986 | 745 | 581 | 0.78 | 1,989 | 150 | 3,805 | 1.9 | 2,315 |
| Gyokudo Kawai | 1873 | 1957 | 677 | 555 | 0.82 | 1,055 | 440 | 1,557 | 1.5 | 1,200 |
| Masuo Ikeda | 1934 | 1997 | 659 | 552 | 0.84 | 160 | 90 | 185 | 1.2 | 146 |
| Seiji Togo | 1897 | 1978 | 639 | 504 | 0.79 | 745 | 600 | 702 | 0.9 | 1,050 |
| Yasuo Kazuki | 1911 | 1974 | 631 | 505 | 0.80 | 1,420 | 550 | 2,042 | 1.4 | 1,820 |
| Yoshitomo Nara | 1959 | - | 607 | 527 | 0.87 | 2,345 | 886 | 5,433 | 2.3 | 2,095 |
| Ryohei Koiso | 1903 | 1988 | 597 | 424 | 0.71 | 1,340 | 200 | 4,418 | 3.3 | 533 |
| Morikazu Kumagai | 1880 | 1977 | 580 | 449 | 0.77 | 915 | 240 | 2,588 | 2.8 | 410 |
| Yuki Ogura | 1895 | 2000 | 576 | 461 | 0.80 | 345 | 90 | 968 | 2.8 | 75 |
| Shinsui Ito | 1898 | 1972 | 554 | 409 | 0.74 | 1,004 | 360 | 2,183 | 2.2 | 1,035 |
| Togyu Okumura | 1889 | 1990 | 507 | 412 | 0.81 | 613 | 110 | 1,507 | 2.5 | 624 |
| Koji Kinutani | 1943 | - | 495 | 409 | 0.83 | 1,182 | 800 | 1,272 | 1.1 | 1,760 |
| Kazumasa Nakagawa | 1893 | 1991 | 466 | 377 | 0.81 | 1,470 | 440 | 1,980 | 1.3 | 2,200 |
| Taikan Yokoyama | 1868 | 1958 | 460 | 406 | 0.88 | 3,808 | 1,600 | 6,679 | 1.8 | 4,130 |
| Reiji Hiramatsu | 1941 | - | 460 | 382 | 0.83 | 436 | 380 | 432 | 1.0 | 515 |
| Hirosuke Tasaki | 1898 | 1984 | 442 | 333 | 0.75 | 496 | 450 | 500 | 1.0 | 450 |
| Insho Domoto | 1891 | 1975 | 434 | 310 | 0.71 | 334 | 195 | 415 | 1.2 | 300 |
| Yukio Kodama | 1916 | 1992 | 432 | 344 | 0.80 | 665 | 500 | 556 | 0.8 | 590 |
| Shoen Uemura | 1875 | 1949 | 431 | 376 | 0.87 | 1,592 | 65 | 6,212 | 3.9 | 1,357 |
| Sumio Goto | 1930 | 2016 | 426 | 346 | 0.81 | 672 | 500 | 577 | 0.9 | 745 |
| Sadamasa Motonaga | 1922 | 2011 | 425 | 363 | 0.85 | 1,548 | 580 | 2,883 | 1.9 | 1,300 |
| Toshiyuki Hasekawa | 1891 | 1940 | 420 | 372 | 0.89 | 881 | 360 | 1,978 | 2.2 | 640 |
| Yasushi Sugiyama | 1909 | 1993 | 390 | 299 | 0.77 | 2,777 | 360 | 7,014 | 2.5 | 1,250 |
| Takeshi Hayashi | 1896 | 1975 | 382 | 266 | 0.70 | 1,652 | 470 | 3,497 | 2.1 | 1,130 |
| Teppei Sasakura | 1954 | - | 371 | 316 | 0.85 | 162 | 95 | 161 | 1.0 | 126 |
| Seison Maeda | 1885 | 1977 | 363 | 259 | 0.71 | 1,563 | 640 | 2,964 | 1.9 | 1,540 |
| Kokuta Suda | 1906 | 1990 | 336 | 213 | 0.63 | 221 | 150 | 215 | 1.0 | 190 |
| Setsuko Migishi | 1905 | 1999 | 326 | 243 | 0.75 | 1,189 | 600 | 1,406 | 1.2 | 1,864 |
| Ryonosuke Fukui | 1923 | 1986 | 326 | 261 | 0.80 | 370 | 290 | 381 | 1.0 | 415 |
| Keigetsu Matsubayashi | 1876 | 1963 | 322 | 240 | 0.75 | 190 | 120 | 204 | 1.1 | 163 |
| Shinichi Saito | 1922 | 1994 | 319 | 257 | 0.81 | 424 | 400 | 264 | 0.6 | 310 |
| Kansetsu Hashimoto | 1883 | 1945 | 311 | 197 | 0.63 | 435 | 160 | 1,252 | 2.9 | 235 |
| Toshio Arimoto | 1946 | 1985 | 306 | 274 | 0.90 | 1,087 | 395 | 2,446 | 2.2 | 650 |
| Hiroshige Utagawa | 1797 | 1858 | 303 | 267 | 0.88 | 688 | 190 | 2,557 | 3.7 | 340 |
| Seigo Takatsuka | 1930 | 2007 | 293 | 238 | 0.81 | 454 | 260 | 414 | 0.9 | 510 |

| Artist name | Year born | Year died | Works (1) | Works (2) | Ratio | Hammer price (¥1,000) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Median | SD | CV | IQR |
| Saburo Miyamoto | 1905 | 1974 | 291 | 221 | 0.76 | 1,032 | 520 | 1,905 | 1.8 | 870 |
| Toshimitsu Imai | 1928 | 2002 | 289 | 222 | 0.77 | 937 | 195 | 2,333 | 2.5 | 575 |
| Wasaku Kobayashi | 1888 | 1974 | 288 | 221 | 0.77 | 296 | 250 | 234 | 0.8 | 240 |
| Kiyoshi Yamashita | 1922 | 1971 | 287 | 229 | 0.80 | 514 | 210 | 1,048 | 2.0 | 400 |
| Atsushi Uemura | 1933 | - | 285 | 219 | 0.77 | 450 | 70 | 690 | 1.5 | 650 |
| Yumeji Takehisa | 1884 | 1934 | 276 | 215 | 0.78 | 788 | 285 | 1,301 | 1.6 | 770 |
| Kumi Sugai | 1919 | 1996 | 270 | 190 | 0.70 | 450 | 85 | 1,008 | 2.2 | 299 |
| Hitone Noma | 1901 | 1979 | 264 | 178 | 0.67 | 579 | 520 | 359 | 0.6 | 508 |
| Katsumi Ukita | 1930 | 1989 | 262 | 212 | 0.81 | 1,367 | 1,100 | 1,220 | 0.9 | 1,210 |
| Saneatsu Mushanokoji | 1885 | 1976 | 253 | 188 | 0.74 | 116 | 100 | 73 | 0.6 | 69 |
| Taro Okamoto | 1911 | 1996 | 247 | 204 | 0.83 | 390 | 130 | 1,515 | 3.9 | 238 |
| Takeo Yamaguchi | 1902 | 1983 | 247 | 196 | 0.79 | 1,430 | 250 | 3,177 | 2.2 | 1,531 |
| Ryushi Kawabata | 1885 | 1966 | 247 | 173 | 0.70 | 670 | 400 | 906 | 1.4 | 540 |
| Tessai Tomioka | 1837 | 1924 | 246 | 165 | 0.67 | 611 | 320 | 865 | 1.4 | 410 |
| Seiho Takeuchi | 1864 | 1942 | 244 | 185 | 0.76 | 568 | 250 | 988 | 1.7 | 430 |
| Kazuo Shiraga | 1924 | 2008 | 244 | 205 | 0.84 | 5,137 | 480 | 18,325 | 3.6 | 2,139 |
| Keiko Minami | 1911 | 2004 | 242 | 228 | 0.94 | 90 | 80 | 55 | 0.6 | 56 |
| Shoko Uemura | 1902 | 2001 | 241 | 196 | 0.81 | 659 | 80 | 1,531 | 2.3 | 607 |
| Tsutomu Fujii | 1948 | 2017 | 240 | 189 | 0.79 | 326 | 220 | 391 | 1.2 | 300 |
| Toshio Matsuo | 1926 | 2016 | 236 | 168 | 0.71 | 542 | 460 | 438 | 0.8 | 600 |
| Shigeru Morita | 1907 | 2009 | 235 | 158 | 0.67 | 577 | 440 | 439 | 0.8 | 415 |
| Horin Fukuoji | 1920 | 2012 | 232 | 161 | 0.69 | 678 | 530 | 602 | 0.9 | 550 |
| Chusaku Oyama | 1922 | 2009 | 231 | 172 | 0.74 | 531 | 390 | 563 | 1.1 | 625 |
| Kojiro Kosugi | 1944 | - | 228 | 175 | 0.77 | 427 | 360 | 380 | 0.9 | 395 |
| Joichi Hoshi | 1913 | 1979 | 228 | 186 | 0.82 | 204 | 150 | 239 | 1.2 | 173 |
| Masaaki Yamada | 1929 | 2010 | 221 | 179 | 0.81 | 1,069 | 610 | 1,484 | 1.4 | 1,030 |
| Junkichi Mukai | 1901 | 1995 | 220 | 157 | 0.71 | 1,356 | 800 | 1,531 | 1.1 | 1,760 |
| Keika Kanashima | 1892 | 1974 | 219 | 121 | 0.55 | 308 | 190 | 532 | 1.7 | 250 |
| Nampu Katayama | 1887 | 1980 | 218 | 152 | 0.70 | 273 | 200 | 251 | 0.9 | 270 |
| Tadanori Yokoo | 1936 | - | 216 | 179 | 0.83 | 186 | 70 | 792 | 4.3 | 90 |
| Kibo Kodama | 1898 | 1971 | 213 | 141 | 0.66 | 505 | 320 | 688 | 1.4 | 380 |
| Tatsuo Takayama | 1912 | 2007 | 212 | 175 | 0.83 | 1,150 | 700 | 1,666 | 1.4 | 1,295 |
| Genso Okuda | 1912 | 2003 | 210 | 156 | 0.74 | 1,160 | 420 | 2,424 | 2.1 | 1,405 |
| Tetsuro Komai | 1920 | 1976 | 207 | 171 | 0.83 | 281 | 170 | 346 | 1.2 | 238 |
| Toko Shinoda | 1913 | - | 205 | 158 | 0.77 | 294 | 120 | 582 | 2.0 | 160 |
| Tadahiko Nakayama | 1935 | - | 204 | 155 | 0.76 | 923 | 600 | 1,043 | 1.1 | 1,388 |
| Takehiko Miyanaga | 1919 | 1987 | 202 | 140 | 0.69 | 545 | 400 | 575 | 1.1 | 570 |
| Sanryo Sakai | 1897 | 1969 | 200 | 149 | 0.75 | 181 | 120 | 221 | 1.2 | 130 |
| Hitoshi Komatsu | 1902 | 1989 | 200 | 136 | 0.68 | 306 | 200 | 306 | 1.0 | 250 |
| Zenzaburo Kojima | 1893 | 1962 | 199 | 130 | 0.65 | 1,435 | 960 | 2,004 | 1.4 | 1,380 |
| Chikkyo Ono | 1889 | 1979 | 199 | 143 | 0.72 | 1,143 | 400 | 2,539 | 2.2 | 890 |
| Shoha Ito | 1877 | 1968 | 198 | 142 | 0.72 | 415 | 300 | 466 | 1.1 | 318 |
| Shintaro Suzuki | 1895 | 1989 | 197 | 151 | 0.77 | 383 | 380 | 340 | 0.9 | 365 |
| Kayo Yamaguchi | 1899 | 1984 | 192 | 135 | 0.70 | 895 | 400 | 2,437 | 2.7 | 805 |
| Toshinobu Onosato | 1912 | - | 191 | 140 | 0.73 | 718 | 411 | 1,085 | 1.5 | 676 |
| Keisuke Serizawa | 1895 | 1984 | 191 | 154 | 0.81 | 126 | 75 | 177 | 1.4 | 90 |
| Katsura Funakoshi | 1951 | - | 185 | 147 | 0.79 | 209 | 140 | 200 | 1.0 | 130 |
| Noriko Tamura | 1944 | - | 181 | 154 | 0.85 | 806 | 605 | 820 | 1.0 | 1,040 |
| Tatsuoki Nambata | 1905 | 1997 | 180 | 123 | 0.68 | 585 | 219 | 910 | 1.6 | 490 |
| Nori Shimizu | 1962 | - | 173 | 142 | 0.82 | 384 | 375 | 280 | 0.7 | 410 |
| Iwami Furusawa | 1912 | 2000 | 172 | 139 | 0.81 | 79 | 55 | 71 | 0.9 | 55 |
| Tamiji Kitagawa | 1894 | 1989 | 172 | 130 | 0.76 | 319 | 150 | 443 | 1.4 | 422 |
| Akira Akizuki | 1929 | - | 172 | 117 | 0.68 | 88 | 80 | 54 | 0.6 | 70 |
| Kiyokata Kaburaki | 1878 | 1972 | 171 | 122 | 0.71 | 893 | 410 | 1,108 | 1.2 | 900 |
| Hoshun Yamaguchi | 1893 | 1971 | 170 | 121 | 0.71 | 430 | 240 | 551 | 1.3 | 420 |

| Artist name | Year born | Year died | Works (1) | Works (2) | Ratio | Hammer price (¥1,000) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Median | SD | CV | IQR |
| Yoson Ikeda | 1895 | 1988 | 168 | 93 | 0.55 | 218 | 160 | 196 | 0.9 | 235 |
| Kazu Wakita | 1908 | 2005 | 168 | 117 | 0.70 | 363 | 300 | 298 | 0.8 | 400 |
| Heihachiro Fukuda | 1892 | 1974 | 167 | 121 | 0.72 | 1,427 | 560 | 2,759 | 1.9 | 1,040 |
| Kiyonaga Ito | 1911 | 2001 | 165 | 113 | 0.68 | 706 | 500 | 756 | 1.1 | 620 |
| Yasuo Kuniyoshi | 1889 | 1953 | 160 | 99 | 0.62 | 996 | 170 | 2,640 | 2.7 | 398 |
| Munehiro Nakamura | 1950 | - | 159 | 126 | 0.79 | 359 | 305 | 174 | 0.5 | 208 |
| Rieko Morita | 1955 | - | 156 | 137 | 0.88 | 528 | 90 | 951 | 1.8 | 240 |
| Hiroshi Sugimoto | 1948 | - | 155 | 134 | 0.86 | 870 | 403 | 1,028 | 1.2 | 1,139 |
| Jiro Takamatsu | 1936 | 1998 | 150 | 134 | 0.89 | 1,445 | 230 | 3,505 | 2.4 | 650 |
| Ryusuke Nishimura | 1920 | 2005 | 149 | 114 | 0.77 | 621 | 500 | 625 | 1.0 | 423 |
| Keizo Koyama | 1897 | 1987 | 148 | 111 | 0.75 | 1,643 | 1,150 | 1,638 | 1.0 | 2,458 |
| Naobumi Seimiya | 1917 | 1991 | 147 | 115 | 0.78 | 544 | 420 | 416 | 0.8 | 365 |
| Nobuo Sekine | 1942 | 2019 | 145 | 116 | 0.80 | 389 | 293 | 402 | 1.0 | 399 |
| Jiro Yoshihara | 1905 | 1972 | 143 | 103 | 0.72 | 2,889 | 575 | 9,121 | 3.2 | 1,785 |
| Konosuke Tamura | 1903 | 1986 | 143 | 129 | 0.90 | 266 | 200 | 243 | 0.9 | 265 |
| Chimei Hamada | 1917 | 2018 | 143 | 110 | 0.77 | 279 | 123 | 501 | 1.8 | 178 |
| Kiichiro Hayashi | 1919 | 1999 | 142 | 110 | 0.77 | 412 | 360 | 269 | 0.7 | 240 |
| Yujin Nakaji | 1933 | 2017 | 141 | 97 | 0.69 | 572 | 500 | 367 | 0.6 | 460 |
| Kaoru Yamaguchi | 1907 | 1968 | 140 | 106 | 0.76 | 1,356 | 545 | 2,212 | 1.6 | 1,378 |
| Saburo Saito | 1917 | 1996 | 138 | 112 | 0.81 | 348 | 200 | 384 | 1.1 | 330 |
| Seiji Chokai | 1902 | 1972 | 136 | 87 | 0.64 | 807 | 580 | 998 | 1.2 | 610 |
| Kunio Makino | 1925 | 1986 | 136 | 120 | 0.88 | 1,542 | 1,375 | 1,492 | 1.0 | 2,390 |
| Daijo Aoki | 1891 | 1979 | 134 | 95 | 0.71 | 154 | 120 | 115 | 0.7 | 115 |
| Rei Kamoi | 1928 | 1985 | 133 | 100 | 0.75 | 2,176 | 1,825 | 1,741 | 0.8 | 2,200 |
| Michio Fukuoka | 1949 | - | 132 | 105 | 0.80 | 664 | 600 | 545 | 0.8 | 520 |
| Toichi Kato | 1916 | 1996 | 131 | 99 | 0.76 | 379 | 120 | 599 | 1.6 | 255 |
| Kyujin Yamamoto | 1900 | 1986 | 131 | 98 | 0.75 | 504 | 320 | 527 | 1.0 | 380 |
| Eien Iwahashi | 1903 | 1997 | 130 | 83 | 0.64 | 576 | 400 | 667 | 1.2 | 635 |
| Gakuryo Nakamura | 1890 | 1969 | 127 | 79 | 0.62 | 294 | 160 | 344 | 1.2 | 290 |
| Tekison Uda | 1896 | 1980 | 125 | 84 | 0.67 | 235 | 88 | 724 | 3.1 | 134 |
| Ryo Hirano | 1927 | 1992 | 125 | 107 | 0.86 | 256 | 240 | 220 | 0.9 | 343 |
| Eijin Suzuki | 1948 | - | 124 | 120 | 0.97 | 106 | 85 | 68 | 0.6 | 65 |
| Sotaro Yasui | 1888 | 1955 | 122 | 93 | 0.76 | 2,194 | 240 | 5,585 | 2.5 | 1,395 |
| Chuta Kimura | 1917 | 1987 | 122 | 91 | 0.75 | 640 | 400 | 670 | 1.0 | 460 |
| Noriyuki Ushijima | 1900 | 1997 | 121 | 90 | 0.74 | 1,539 | 1,375 | 996 | 0.6 | 1,150 |
| Shuho Ikegami | 1874 | 1944 | 121 | 73 | 0.60 | 190 | 120 | 217 | 1.1 | 175 |
| Mitsuo Kano | 1933 | - | 119 | 101 | 0.85 | 226 | 100 | 374 | 1.7 | 120 |
| Ryusei Kishida | 1891 | 1929 | 118 | 98 | 0.83 | 3,218 | 430 | 14,477 | 4.5 | 875 |
| Shinsen Tokuoka | 1896 | 1972 | 117 | 73 | 0.62 | 1,228 | 480 | 1,996 | 1.6 | 640 |
| Buzan Kimura | 1876 | 1942 | 117 | 83 | 0.71 | 370 | 150 | 516 | 1.4 | 343 |
| Katsuzo Satomi | 1895 | 1981 | 117 | 90 | 0.77 | 459 | 330 | 524 | 1.1 | 365 |
| Kei Shibusawa | 1949 | 2012 | 115 | 100 | 0.87 | 686 | 490 | 715 | 1.0 | 901 |
| Gaho Hashimoto | 1835 | 1908 | 112 | 77 | 0.69 | 490 | 260 | 797 | 1.6 | 320 |
| Ichiro Fukuzawa | 1898 | 1992 | 112 | 82 | 0.73 | 208 | 160 | 179 | 0.9 | 211 |
| Susumu Maki | 1936 | - | 112 | 79 | 0.71 | 687 | 560 | 584 | 0.9 | 620 |
| Kohei Morita | 1916 | 1994 | 109 | 88 | 0.81 | 466 | 270 | 596 | 1.3 | 546 |
| Ichinen Somiya | 1893 | 1994 | 108 | 82 | 0.76 | 450 | 280 | 511 | 1.1 | 634 |
| Kunio Komatsuzaki | 1931 | 1992 | 107 | 76 | 0.71 | 232 | 80 | 338 | 1.5 | 275 |
| Keiyu Nishimura | 1909 | 2000 | 105 | 91 | 0.87 | 206 | 140 | 195 | 0.9 | 185 |
| Jun Nakao | 1917 | - | 104 | 93 | 0.89 | 320 | 350 | 183 | 0.6 | 270 |
| Hiroshi Kanosue | 1927 | 1991 | 104 | 75 | 0.72 | 1,002 | 650 | 981 | 1.0 | 815 |
| Masayoshi Nakamura | 1924 | 1977 | 103 | 77 | 0.75 | 302 | 160 | 372 | 1.2 | 210 |
| Daido Moriyama | 1938 | - | 100 | 67 | 0.67 | 464 | 300 | 891 | 1.9 | 326 |
| Kagaku Murakami | 1888 | 1939 | 100 | 65 | 0.65 | 3,079 | 1,050 | 6,531 | 2.1 | 2,300 |
| Kojin Kudo | 1915 | 2011 | 99 | 80 | 0.81 | 318 | 280 | 245 | 0.8 | 290 |

| Artist name | Year born | Year died | Works (1) | Works (2) | Ratio | Hammer price (¥1,000) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Median | SD | CV | IQR |
| Manjiro Terauchi | 1890 | 1964 | 99 | 70 | 0.71 | 991 | 800 | 743 | 0.7 | 825 |
| Seiji Nakamura | 1935 | 2011 | 98 | 81 | 0.83 | 490 | 400 | 530 | 1.1 | 460 |
| Kanuemon Asai | 1901 | 1983 | 98 | 64 | 0.65 | 675 | 430 | 772 | 1.1 | 483 |
| Meiji Hashimoto | 1904 | 1991 | 97 | 69 | 0.71 | 348 | 150 | 435 | 1.2 | 350 |
| Umetaro Azechi | 1902 | 1999 | 97 | 83 | 0.86 | 74 | 60 | 60 | 0.8 | 53 |
| Yonezo Shibata | 1926 | 2006 | 97 | 83 | 0.86 | 198 | 100 | 232 | 1.2 | 215 |
| Toshio Tabuchi | 1941 | - | 96 | 66 | 0.69 | 1,186 | 200 | 1,661 | 1.4 | 1,745 |
| Heihachiro Togo | 1848 | 1934 | 96 | 70 | 0.73 | 114 | 70 | 120 | 1.1 | 109 |
| Taisuke Hamada | 1932 | - | 96 | 75 | 0.78 | 377 | 320 | 296 | 0.8 | 385 |
| Keigo Kimura | 1944 | - | 96 | 70 | 0.73 | 623 | 625 | 414 | 0.7 | 575 |
| Shozo Shimada | 1933 | 2016 | 95 | 77 | 0.81 | 304 | 260 | 269 | 0.9 | 270 |
| Akira Kaho | 1927 | 2018 | 92 | 67 | 0.73 | 164 | 120 | 133 | 0.8 | 145 |
| Shohei Matsuda | 1913 | 2004 | 92 | 66 | 0.72 | 536 | 260 | 573 | 1.1 | 690 |
| Kanzan Shimomura | 1873 | 1930 | 91 | 73 | 0.80 | 858 | 580 | 1,532 | 1.8 | 700 |
| Ryohei Miwa | 1929 | 2011 | 91 | 69 | 0.76 | 326 | 310 | 216 | 0.7 | 370 |
| Sumio Kawakami | 1895 | 1972 | 91 | 58 | 0.64 | 95 | 75 | 91 | 1.0 | 67 |
| Keisen Tomita | 1879 | 1936 | 91 | 58 | 0.64 | 107 | 70 | 107 | 1.0 | 80 |
| Kiyoshi Nakashima | 1943 | - | 89 | 71 | 0.80 | 429 | 280 | 461 | 1.1 | 555 |
| Shikanosuke Oka | 1898 | 1978 | 88 | 58 | 0.66 | 4,850 | 2,250 | 6,505 | 1.3 | 7,824 |
| Shiho Sakakibara | 1887 | 1971 | 88 | 61 | 0.69 | 442 | 260 | 511 | 1.2 | 480 |
| Fuku Akino | 1908 | 2001 | 87 | 63 | 0.72 | 586 | 380 | 619 | 1.1 | 355 |
| Hoan Kosugi | 1881 | 1964 | 87 | 66 | 0.76 | 278 | 200 | 266 | 1.0 | 215 |
| Yukihiko Yasuda | 1884 | 1978 | 86 | 59 | 0.69 | 1,027 | 680 | 1,013 | 1.0 | 1,430 |
| Wasaburo Itozono | 1911 | 2001 | 86 | 68 | 0.79 | 446 | 410 | 232 | 0.5 | 250 |
| Makoto Takada | 1913 | 1992 | 85 | 62 | 0.73 | 699 | 580 | 415 | 0.6 | 453 |
| Kunitaro Suda | 1891 | 1961 | 85 | 50 | 0.59 | 1,607 | 360 | 2,728 | 1.7 | 1,755 |
| Kyosuke Chinai | 1948 | - | 85 | 68 | 0.80 | 436 | 345 | 374 | 0.9 | 483 |
| Hyoichi Yamamoto | 1912 | 1999 | 84 | 74 | 0.88 | 281 | 270 | 159 | 0.6 | 203 |
| Toshio Hirakawa | 1924 | 2006 | 84 | 69 | 0.82 | 149 | 130 | 109 | 0.7 | 160 |
| Saburosuke Okada | 1869 | 1939 | 83 | 62 | 0.75 | 2,569 | 1,025 | 4,948 | 1.9 | 2,585 |
| Makoto Masuda | 1920 | 1989 | 83 | 65 | 0.78 | 336 | 340 | 203 | 0.6 | 280 |
| Takeji Fujishima | 1867 | 1943 | 83 | 65 | 0.78 | 1,649 | 660 | 2,414 | 1.5 | 2,020 |
| Naondo Nakamura | 1905 | 1981 | 81 | 58 | 0.72 | 178 | 135 | 148 | 0.8 | 160 |
| Bakusen Tsuchida | 1887 | 1936 | 81 | 64 | 0.79 | 271 | 200 | 271 | 1.0 | 313 |
| Yuji Misu | 1927 | 2010 | 80 | 66 | 0.83 | 622 | 565 | 438 | 0.7 | 488 |
| Yoko Yamamoto | 1952 | - | 79 | 59 | 0.75 | 83 | 70 | 56 | 0.7 | 61 |
| Kenkichi Sugimoto | 1905 | 2004 | 78 | 43 | 0.55 | 401 | 150 | 568 | 1.4 | 390 |
| Kenji Yoshioka | 1906 | 1990 | 77 | 62 | 0.81 | 118 | 85 | 112 | 1.0 | 82 |
| Toshiro Aoki | 1947 | - | 77 | 60 | 0.78 | 1,348 | 1,025 | 1,154 | 0.9 | 663 |
| Suiseki Ohashi | 1865 | 1945 | 77 | 42 | 0.55 | 438 | 355 | 317 | 0.7 | 395 |
| Kokki Miyake | 1874 | 1954 | 76 | 57 | 0.75 | 98 | 70 | 76 | 0.8 | 80 |
| Saburo Aso | 1913 | 2000 | 75 | 58 | 0.77 | 511 | 425 | 404 | 0.8 | 525 |
| Gentaro Koito | 1887 | 1978 | 74 | 42 | 0.57 | 974 | 610 | 972 | 1.0 | 608 |
| Koichi Takeuchi | 1941 | - | 74 | 43 | 0.58 | 554 | 530 | 321 | 0.6 | 475 |
| Miematsu Tanabe | 1897 | 1971 | 74 | 59 | 0.80 | 247 | 250 | 159 | 0.6 | 165 |
| Hiroshi Okutani | 1934 | - | 73 | 57 | 0.78 | 646 | 550 | 456 | 0.7 | 550 |
| Somei Yuki | 1875 | 1957 | 73 | 51 | 0.70 | 129 | 82 | 141 | 1.1 | 105 |
| Sho Ishimoto | 1920 | 2015 | 73 | 55 | 0.75 | 851 | 320 | 992 | 1.2 | 1,160 |
| Kokei Kobayashi | 1883 | 1957 | 72 | 52 | 0.72 | 1,107 | 455 | 1,415 | 1.3 | 1,450 |
| Yataro Noguchi | 1899 | 1976 | 71 | 52 | 0.73 | 321 | 255 | 330 | 1.0 | 305 |
| Usen Ogawa | 1868 | 1938 | 70 | 55 | 0.79 | 202 | 150 | 231 | 1.1 | 131 |
| Misao Yokoyama | 1920 | 1973 | 69 | 56 | 0.81 | 2,347 | 2,000 | 2,426 | 1.0 | 3,205 |
| Gyoshu Hayami | 1894 | 1935 | 68 | 55 | 0.81 | 1,448 | 75 | 4,286 | 3.0 | 450 |
| Sojin Nakahata | 1912 | 1999 | 68 | 47 | 0.69 | 619 | 520 | 605 | 1.0 | 800 |
| Kazuho Hieda | 1920 | - | 68 | 53 | 0.78 | 384 | 320 | 340 | 0.9 | 380 |

| Artist name | Year born | Year died | Works (1) | Works (2) | Ratio | Hammer price (¥1,000) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Median | SD | CV | IQR |
| Hideo Nishiyama | 1911 | 1989 | 66 | 51 | 0.77 | 116 | 80 | 116 | 1.0 | 92 |
| Koichi Nabatame | 1933 | - | 66 | 44 | 0.67 | 566 | 580 | 421 | 0.7 | 575 |
| Harumi Tateishi | 1908 | 1994 | 66 | 54 | 0.82 | 180 | 140 | 169 | 0.9 | 131 |
| Kinosuke Ebihara | 1904 | 1970 | 65 | 44 | 0.68 | 991 | 775 | 1,290 | 1.3 | 1,278 |
| Bakuzan Sakaki | 1926 | 2010 | 65 | 43 | 0.66 | 173 | 150 | 122 | 0.7 | 125 |
| Yoshio Tsuruoka | 1917 | 2007 | 65 | 54 | 0.83 | 343 | 240 | 401 | 1.2 | 255 |
| Eisaku Wada | 1874 | 1959 | 65 | 52 | 0.80 | 1,392 | 1,200 | 1,003 | 0.7 | 985 |
| Seiichi Kasai | 1932 | - | 64 | 54 | 0.84 | 436 | 400 | 229 | 0.5 | 250 |
| Hisako Kajiwara | 1896 | 1988 | 64 | 44 | 0.69 | 160 | 130 | 143 | 0.9 | 163 |
| Keisho Imao | 1902 | 1993 | 64 | 42 | 0.66 | 86 | 70 | 58 | 0.7 | 59 |
| Chikuhaku Suzuki | 1918 | - | 63 | 48 | 0.76 | 225 | 160 | 187 | 0.8 | 243 |
| Sanzo Wada | 1883 | 1967 | 63 | 39 | 0.62 | 87 | 55 | 117 | 1.3 | 80 |
| Sentaro Iwata | 1901 | 1974 | 61 | 49 | 0.80 | 117 | 80 | 94 | 0.8 | 90 |
| Yoshihiro Shimoda | 1940 | - | 60 | 45 | 0.75 | 623 | 600 | 466 | 0.7 | 530 |
| Narashige Koide | 1887 | 1931 | 59 | 44 | 0.75 | 3,263 | 440 | 7,357 | 2.3 | 3,078 |
| Teruo Onuma | 1933 | - | 59 | 48 | 0.81 | 127 | 100 | 104 | 0.8 | 103 |
| Junichi Goto | 1948 | - | 58 | 46 | 0.79 | 200 | 115 | 286 | 1.4 | 141 |
| Tomohide Koizumi | 1944 | - | 58 | 44 | 0.76 | 766 | 625 | 505 | 0.7 | 548 |
| Manshu Kawamura | 1880 | 1942 | 58 | 36 | 0.62 | 149 | 103 | 143 | 1.0 | 119 |
| Seitoku Igarashi | 1937 | - | 55 | 51 | 0.93 | 60 | 45 | 51 | 0.9 | 60 |
| Chuichi Konno | 1915 | 2006 | 53 | 41 | 0.77 | 239 | 190 | 195 | 0.8 | 230 |
| Genjin Sugihara | 1912 | 2009 | 53 | 42 | 0.79 | 88 | 68 | 66 | 0.7 | 50 |
| Shosuke Osawa | 1903 | 1997 | 53 | 52 | 0.98 | 87 | 63 | 76 | 0.9 | 77 |
| Eibin Otsu | 1943 | - | 53 | 47 | 0.89 | 94 | 65 | 100 | 1.1 | 68 |
| Sai Morita | 1898 | 1993 | 49 | 32 | 0.65 | 73 | 70 | 55 | 0.8 | 87 |
| Mutsuo Kawashima | 1940 | - | 47 | 40 | 0.85 | 219 | 140 | 214 | 1.0 | 250 |
| Toshihiko Oya | 1940 | - | 47 | 39 | 0.83 | 178 | 130 | 124 | 0.7 | 160 |
| Masayuki Miyata | 1926 | 1997 | 45 | 39 | 0.87 | 79 | 60 | 64 | 0.8 | 48 |
| Seiichi Hara | 1908 | 1986 | 45 | 36 | 0.80 | 122 | 60 | 184 | 1.5 | 108 |
| Suiun Komuro | 1874 | 1945 | 45 | 41 | 0.91 | 66 | 50 | 50 | 0.8 | 60 |
| Jippo Araki | 1872 | 1944 | 42 | 34 | 0.81 | 97 | 63 | 108 | 1.1 | 80 |
| Satoshi Odagiri | 1943 | - | 42 | 38 | 0.90 | 160 | 115 | 132 | 0.8 | 119 |
| Hideo Hagiwara | 1913 | 2007 | 40 | 30 | 0.75 | 58 | 40 | 60 | 1.0 | 44 |
| Banka Maruyama | 1867 | 1942 | 39 | 29 | 0.74 | 144 | 85 | 138 | 1.0 | 147 |
| Gon Nishimura | 1877 | 1938 | 39 | 29 | 0.74 | 95 | 55 | 87 | 0.9 | 50 |
| Nobutaka Oka | 1932 | - | 38 | 31 | 0.82 | 189 | 150 | 125 | 0.7 | 150 |
| Kotaro Migishi | 1903 | 1934 | 38 | 28 | 0.74 | 1,817 | 1,500 | 1,434 | 0.8 | 1,750 |
| Susumu Kobori | 1904 | 1975 | 37 | 30 | 0.81 | 140 | 115 | 80 | 0.6 | 74 |
| Shimei Terashima | 1892 | 1975 | 28 | 22 | 0.79 | 164 | 100 | 149 | 0.9 | 120 |

## Reference


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