2011s-15

Age-Price Profiles for Canadian Painters at Auction

Douglas J. Hodgson

Série Scientifique
Scientific Series

Montréal
Janvier 2011

CIRANO
Allier savoir et décision

Centre interuniversitaire de recherche en analyse des organisations

CIRANO

Le CIRANO est un organisme sans but lucratif constitué en vertu de la Loi des compagnies du Québec. Le financement de son infrastructure et de ses activités de recherche provient des cotisations de ses organisations-membres, d'une subvention d'infrastructure du Ministère du Développement économique et régional et de la Recherche, de même que des subventions et mandats obtenus par ses équipes de recherche.

CIRANO is a private non-profit organization incorporated under the Québec Companies Act. Its infrastructure and research activities are funded through fees paid by member organizations, an infrastructure grant from the Ministère du Développement économique et régional et de la Recherche, and grants and research mandates obtained by its research teams.

Les partenaires du CIRANO

Partenaire majeur
Ministère du Développement économique, de l'Innovation et de l'Exportation

Partenaires corporatifs
Banque de développement du Canada
Banque du Canada
Banque Laurentienne du Canada
Banque Nationale du Canada
Banque Royale du Canada
Banque Scotia
Bell Canada
BMO Groupe financier
Caisse de dépôt et placement du Québec
Fédération des caisses Desjardins du Québec
Financière Sun Life, Québec
Gaz Métro
Hydro-Québec
Industrie Canada
Investissements PSP
Ministère des Finances du Québec
Power Corporation du Canada
Raymond Chabot Grant Thornton
Rio Tinto
State Street Global Advisors
Transat A.T.
Ville de Montréal

Partenaires universitaires
École Polytechnique de Montréal
HEC Montréal
McGill University
Université Concordia
Université de Montréal
Université de Sherbrooke
Université du Québec
Université du Québec à Montréal
Université Laval

Le CIRANO collabore avec de nombreux centres et chaires de recherche universitaires dont on peut consulter la liste sur son site web.

ISSN 1198-8177

Partenaire financier

Développement économique, Innovation et Exportation
Québec

Age-Price Profiles for Canadian Painters at Auction

Douglas J. Hodgson [*]

Abstract

We conduct an empirical analysis of the effect on the auction price of a Canadian painting of the age of the painter at the time of creation of the painting. We consider several hundred artists, active over the entire history of Canadian art, who are pooled in the estimation of a hedonic regression in which a polynomial function in age enters as a regressor along with several other control variables. We then consider the possibility that the age-price relationship has changed over time by : (a) estimating separate age-price functions for three generational groups of artists - those born before 1880, between 1880 and 1920, and after 1920 and thus coming of age in the world of post-war "contemporary art" ; and (b) estimating a parameterization where the shape of the age-price profile is permitted to change continuously depending on the year of birth of the artist. Our principal result is that artists born more recently tend to "peak" earlier in their careers than those of previous generations. As pertaining to artists born after 1920, this result is consistent with the findings of Galenson (2000) for modern American painters, but we find that the phenemenon applies over longer periods of art history.

Mots clés : Auction, Age-price profiles, Canadian painting, hedonic regression.

[*] Département de sciences économiques, Université du Québec à Montréal, C.P. 8888, succ. Centre-Ville Montreal, Quebec, Canada, hodgson.douglas-james@uqam.ca.

1. INTRODUCTION

It is agreed among obervers of art markets that the price commanded by the painting of a given artist can be highly dependent on the age of the artist at the time of creation of the work, and that the relation between age and price can vary across artists. Working with auction data, one can econometrically estimate the relation, using a hedonic regression in which other observable characteristics of the painting (such as size, genre, etc.) are controlled for. Concepetually, the results of such an analysis can be interpreted within the context of the age-productivity (or experience-productivity) model commonly estimated by labour economists (Mincer (1974)).

This line of enquiry is most closely associated with David Galenson, who, sometimes with co-authors, has undertaken several studies in which age-price profiles are estimated for major artists (see, for example, Galenson (2000, 2001) and Galenson and Weinberg (2000, 2001)) . A related study for the individual case of Picasso is due to Czujack (1997), who found that the most highly valued Picassos at auction tend to be those from the Blue, Rose, and Cubist periods (1902-1915), while the least valuable are those produced after 1944.

The principal focus of the work of Galenson (2000, 2001) and Galenson and Weinberg (2000, 2001) is the possible existence of, and explanations for, changes in age-price profiles for different cohorts whose careers overlap during periods of particular art historical importance. Two examples of such periods are studied – nineteenth and early twentieth century Paris, and post-war New York City. In Paris, art historians describe a revolution in which the prevailing impressionist and post-impressionist styles, associated with such artists as Manet, Cézanne, Monet, and Gauguin, gave way to the fast-moving diversity of styles known as early modernism, as represented by, for example, Matisse, Dufy, Picasso, and Miro. The second period saw the birth of the contemporary New York "Art World", where an earlier generation of abstract expressionists, born before 1920 and including Philip Guston, Jackson Pollock, and Barnett Newman, were succeeded by a cohort characterized by a quickly-evolving diversity of styles, represented by painters such as Joan Mitchell, Andy Warhol, Sol LeWitt, and Philip Pearlstein.

The basic findings in these studies are that, in both historical periods, earlier generations are characterized by an age-price profile well to the right of that of younger generations, that is to say, that the members of earlier generations tend, on average, to "peak" later in their careers than do younger painters. These econometric results are obtained from the estimation of hedonic regressions which include polynomials in painters' ages. Galenson (2000, 2001) and Galenson and Weinberg (2000, 2001) find that these results, obtained from auction prices, are consistent with the judgements of art historians as measured by the age distribution of pictures illustrated in art history textbooks for different artists.

The analysis and interpretations provided for the empirical results obtained in the foregoing papers have not been uncontroversial (see, for example, Ginsburgh and Weyers (2006)), but the empirical results themselves are convincing and, whatever light they may shed on the art history of the periods considered, there is no question that they should be of interest to economists, art collectors, and anyone else who may want to use a hedonic model to arrive at an estimate of the approximate value of a particular art work.

Our objective in the present paper is to investigate the effect of age on auction prices for Canadian painters. In particular, within a hedonic model, we seek to investigate the nature of the contribution of age as a factor in determining the value of a painting. We will begin by estimating a model in which all artists are pooled together and a single age-price profile estimated, but we will then proceed to investigate the utility of segmenting our selection of artists according to period of birth. We do this by first distinguishing three broad "cohorts" of painters, and estimating a different age-price profile for each one, and then by incorporating date of birth directly into the age-price function, so that the estimated function can shift continuously based on year of birth. This latter specification is a novel contribution of this paper.

The auction market for Canadian art is very active, with total annual sales of well over $10 million, and individual works occasionally selling for over $1 million. The art of painting has a long history in Canada, with a continuous tradition dating to the seventeenth century, and with many of the leading historical figures (Riopelle, Borduas, Krieghoff, Carr, Thomson and the Group of Seven) being household names in Canada (see Harper (1977) or Reid (1973, 1988)). It is plausible that with such a lengthy and diverse history, there would be changes over time in the conditions of the art market and of artistic creation that would lead to time

shifts in the shape and location of an estimated aggregate age-price profile. Although the individual nature of artistic creation would suggest the estimation of individual age-price profiles, this is difficult to do for many artists as a number of observed sales sufficient to accurately estimate such a relation is often unavailalble, particularly when one considers that hedonic regressions often have hundreds of regressors (but see Galbraith and Hodgson (2010) for an attempt to mitigate this problem). We thus consider in the present paper the utility of disaggregating at the generational, rather than individual, level.

Without claiming to present or justify an articulated model of the nature of artistic creation, or to making a substantive contribution to thinking on the history of Canadian art, there are certain basic art historical considerations that suggest that broad changes over time may have occurred in the age-price profile in Canadian art. Starting with the more recent period, the phenomena documented by Galenson (2000, 2001) and Galenson and Weinberg (2000) for U.S. modern artists born before and after 1920 could very well be present in Canada. The post-war "art world" is a global one, with the rapidity of travel and communication greatly facilitating the transfer of artistic ideas and standards across borders. The proximity of the major Canadian cities of Montreal and Toronto to the post-war art capital of New York made it all the easier for contemporary Canadian artists to be "plugged in" to current trends. The rapid expansion in the early post-war period of the number of commercial galleries in the major Canadian cities and of the Canadian university system were additional factors enabling and encouraging younger artists to pursue the latest avant-garde trends (see, for example, Borcoman (1969, pp 22-23) or Leclerc (1992)). We would thus expect that in partitioning Canadian artists into groups born before and after 1920, we would observe an age-price profile for the latter group to the left of that of the former group, as in Galenson (2000, 2001) and Galenson and Weinberg (2000). As described below, this is indeed the case.

There are reasons particular to Canada that suggest that a further partition of artists born before 1920 may yield useful results. In particular, it is only after World War I that there emerged in Canada self-defined schools of younger modern painters with specific programmes to revitalize artistic creation in Canada. The best known of these was the Toronto-based Group of Seven, although other such groups were active, such as the Beaver Hall Group and Contemporarty Arts Society in Montreal. These artists generally had a small but existent base of collectors to whom they could sell their paintings to augment income received from teaching or commercial art. Most of the painters in these groups were born in

the 1880's and started exhibiting and selling their best-known work shortly after the end of the war.

If we consider the earlier history of Canadian art, we see more isolated figures who were often trained in Europe, who may have been journeymen, or whose incomes were mostly gained from entirely non-artistic pursuits, and whose client base was very narrow or even non-existent. The best art of such a person would tend to be produced later in life, as it would take more time to acquire the basic skills necessary to produce competent paintings, with lengthy periods of life possibly being completely artistically inactive, and more time further required to try to find a client base and identify a range of subject matter and style that would appeal in a very thin market. One of the most important eighteenth century Canadian painters was the German-born William Berczy (see Allodi (1991)). He was a jack-of-all-trades who lived a very colourful and varied life and only painted on occasion. His best-known painting, one of the early masterpieces of Canadian art, "The Woolsey Family" in the National Gallery, Ottawa, was painted at the age of 65. Cornelius Krieghoff (1815-1872) was active in colonial Montreal and Quebec City in the mid-nineteenth century. In the context of a very thin art market, he had to patiently find his own way in developing a personal style and in forging a client base (see Harper (1979) and Reid (1999)). Even for an artist born as late as 1871, it could be very difficult to find any encouragement or opportunity at all to pursue art as a career. Emily Carr lived most of her life in the city of Victoria, British Columbia, on the Pacific Coast. Victoria was a small city with very little opportunity for an ambitious young artist, and Carr, without a market for her art, essentially abandoned painting for several years, only resuming major artistic activity after the age of 50, when some of her early paintings attracted the attention of collectors and critics in the large eastern cities of Toronto, Montreal, and Ottawa. The work she created in her fifties and sixties, when she had finally found a market for her art, is generally considered to be her best (Thom et al (2006), Shadbolt (1979)).

These considerations lead us to estimate different age-price profiles for artists born before and after 1880. They also suggest that the changes in the market and artistic environments motivating such a break are probably better thought of as being gradual and evolutionary, rather than abrupt and revolutionary, in nature. We will therefore also estimate a new specification that allows the age-price profile to shift continuously in time as a function of the artist's date of birth. As will be seen below, we find with such a model a gradual shift to the left over time in the profile, as would be expected based on the above remarks.

2. DATA AND ECONOMETRIC MODEL

2.1 Data

Records of sales of Canadian paintings at auction from 1968 to 2009 were collected from Campbell (1970-75, 1980), Sotheby's (1975, 1980) and Westbridge (1981-2010). Our data set includes results on sales for painters judged to be of significant interest from the standpoint of Canadian art history, this criterion being satisfied if a painter is mentioned in one of the major histories of Canadian art written by Harper (1977) or Reid (1973, 1988). We consider only oil and acrylic paintings, and only sales for which the auction house provides a secure attribution. For each painting, we recorded, in addition to the identity of the artist, the height and width, the medium and support, the auction house, the date of sale, the genre of the picture, and, when available, the date of execution of the painting. The prices we use are hammer prices as reported in the aforementioned publications. The resulting data set, an expanded version of that used in the study of the investment properties of Canadian paintings by Hodgson and Vorkink (2004), contains 25,760 sales, of which date of execution was available for 10,033[1]. These latter form the sample on which the hedonic regressions reported below are based. We are left with 242 painters for which at least one dated painting is recorded, and they are listed in Appendix 1 in chronological order according to date of birth.

2.2 Econometric Model

We estimate three different specifications of a hedonic regression model, in all of which log price is regressed on the various painting-specific characteristics listed in the preceding subsection, with the fashion in which age enters the regression differing in the three cases.

[1] The data sources used do not provide date of execution information for every painting. This problem is especially bad for the relatively early auctions, for which date of execution is infrequently reported in the publications consulted. Also, certain artists rarely date their work, or only date relatively important works, with lesser works such as sketches being undated. Thus, even in recent sales at upscale auction houses, there may be works for which date of execution is not reported in the auction catalogue, and so will not be reported in our data sources. To get an idea of the magnitude of the problem, we chose at random, as a representative illustration, the catalogue for the 24 November 2006 sale at Heffel's. This is one of Canada's top auction houses, and their glossy, expensive catalogues contain extensive information on the works for sale, including essays by major art historians for cetain lots. Nevertheless, for only 104 of the 153 oil or acrylic works on sale was date of execution reported in the catalogue.

First, age is included through a polynomial function with all painters pooled together, regardless of date of birth. Second, we estimate the same polynomial model, but now with the painters partitioned according to the following three broad cohorts or generations: (1) those born up to 1880, (2) those born after 1880 and up to 1920, and (3) those born after 1920. Separate parameter estimates are computed for each cohort. The third model pools all the painters, but now adds to the polynomial in age the same polynomial, multiplied by the date of birth of the painter. This has the effect of allowing the polynomial function linking age to price to change continuously through time (according to date of birth), rather than to change in two discrete jumps as in the second specification.

Each of the three specifications can be written as special cases of the following general model:

(1) $$y_i = x_i'\beta + g(z_i, \gamma) + u_i,$$

for $i = 1,...,n$ where y_i is the log price for sale *i*, the number of sales is *n* (equal to 10,033 in our case), x_i is a vector of observations of *k* control variables (other than age), β is an unknown *k*-vector of parameters, z_i is the age of the painter at time of execution of painting *i*, *g* is a function whose form will be discussed in more detail below, γ is an unknown parameter vector, and u_i is a zero-mean disturbance, assumed to be independent of the regressors. The 351 regressors contained in the vector *x* include annual time period dummies, dummy variables for painter, auction house, medium and support, and genre, along with height, width, and surface area measures. Our concern in this paper is with the estimation and analysis of *g*, so we treat β as a nuisance parameter (see Hodgson and Vorkink (2004) for a more complete analysis of a hedonic regression similar to the one considered here).

The first specification we consider for g is a fourth-order polynomial in age:

(2) $$g(z_i, \gamma) = \gamma_1 z_i + \gamma_2 z_i^2 + \gamma_3 z_i^3 + \gamma_4 z_i^4,$$

where $\gamma = (\gamma_1, \gamma_2, \gamma_3, \gamma_4)'$. In this version of the model, it is assumed that the parameters of the functional form are the same for all generations of Canadian painters, so that the function

linking price to age is presumed constant across generations. Galenson and Weinberg (2000, 2001) estimate fourth-order polynomials in age for early twentieth century French artists, as well as for postwar American ones.

In the second place, we estimate a fourth-order polynomial in age, where the parameters are permitted to differ for the three cohorts of painters described above. We therefore have

$$(3) \qquad g(z_i,\gamma)=\sum_{j=1}^{3}\left(\gamma_{j1}z_i+\gamma_{j2}z_i^2+\gamma_{j3}z_i^3+\gamma_{j4}z_i^4\right)I\left(i\in gen(j)\right),$$

where $I\left(i\in gen(j)\right)$ is an indicator function equal to one if the painter of painting *i* belongs to generation *j*, and equal to zero otherwise.

Finally, we estimate a quartic function in age, supplemented with date-of-birth effects:

$$(4) \qquad g(z_i,\gamma)=\sum_{j=1}^{4}\left(\gamma_j z_i^j+\gamma_{j+4}z_i^j db_i\right)$$

where db_i is the year of birth of the painter associated with observation i[2].

Under all three specifications, the regression is linear and can be consistently estimated by ordinary least squares (OLS). However, the errors in a model such as this are generally not identically distributed normal (preliminary OLS estimates of the model under specifications (2) and (3) yielded Jarque-Bera (1980) normality statistics of 2313 and 2846, respectively), and so OLS will not be the maximum likelihood estimator and will be asymptotically inefficient. In particular, the presence of heteroskedasticity and non-normality in the errors suggests the use of an estimator that is robust to these departures from the canonical OLS assumptions. One could correct for the presence of heteroskedasticity in estimating the model by weighted least squares, which would be efficient if the weights were correctly estimated and the weighted errors normal. Both assumptions are, however, questionable. One could, for

[2] Our thanks to Bernard Fortin for suggesting the estimation of a model allowing for continuous drift in the parameters of the age-price profile.

example, follow Galenson and Weinberg (2001) in weighting each observation by the standard deviation of realized prices for its painter, but this omits other possible sources of heteroskedasticity, such as the date of sale, as well as any non-normality that may be present. One could, in principle, deal with the first of these problems by weighting the observations by a nonparametric function of the regressors, but this introduces curse of dimensionality problems in the non-parametric estimation.

We opt to estimate all three versions of the regression using the semiparametric adaptive estimator developed by Bickel (1982). This estimator treats the errors as being independently and identically distributed (iid) from a distribution of unknown form, and is fully asymptotically efficient under general conditions. However, Hodgson (2000) shows that Bickel's (1982) estimator is robust to the presence of heteroskedasticity in the errors, and will adapt for the non-normality induced in the unconditional density of the errors by this heteroskedasticity. Furthermore, the usual standard error estimates proposed by Bickel (1982) are also robust. Thus, the adaptive estimator, though not fully asymptotically efficient in the presence of heteroskedasticity, nevertheless has powerful robustness properties, can provide a substantial efficiency gain relative to OLS, and is easy to compute, as described in Appendix 2. For other applications of this estimator to hedonic regressions, see Hodgson, Slade, and Vorkink (2006) and Hodgson and Vorkink (2004).

3. EMPIRICAL RESULTS

We begin by examining our results for the pooled group of all painters before looking at the breakdown by cohort. We can see from the first row of Table 1 that the average age of the painter at time of execution for the 10,033 sold paintings in our sample is just over 50, with a standard deviation of 16. The estimates of the parameters of the fourth-order polynomial in age and associated standard errors are reported in the first row of Table 2. The R-squared is 0.802 and the chi-square statistic for joint significance of the age parameters 408.86. The implied age-price profile is graphed in Figure 1. The function rises rapidly to a peak age of 34, after which it gradually declines in an approximately linear fashion, with a work executed at the age of 60 fetching about 20% less than peak.

The results for the model estimated with artists partitioned by cohort are reported in Tables 1 and 2 and in Figures 2-4. The age distribution of paintings that are sold at auction (Table 1) differs significantly for the most recent generation (mean of 42.3 and standard deviation of 11.3), compared with the earlier ones (respective means of 49.6 and 53.8, with standard deviations of about 16). Although this result could be due in part to bias arising from the fact that some members of this latest cohort were alive and active for all or part of our sample period, it is robust to the joint truncation of the set of artists included to those born before 1935 and of the dates of sale to those after 1995. It suggests a number of hypotheses consistent with the notion that the generation born after 1920 is more likely to do its best work at a relatively early stage of life: (i) a decline in quality, originality, or financial remuneration of an artist's work will tend to lead to a decline in productivity measured by number of works painted; (ii) an early period of frenetic productivity could lead to burnout; (iii) later works, if of lesser quality or historic interest, will be less demanded in the secondary (auction) market.

The differences between the age-price profiles for the different cohorts can be observed in Figures 2-4, which are based on parameter estimates reported in Table 2. This regression had an R-squared of 0.806, and the Wald statistics for joint significance of the age parameters, were, respectively by cohort, 42.17, 414.53, and 180.85. For the pre-1880 cohort (Figure 2), prices increase rapidly with age until about 35, after which they slowly increase to a peak age of 46, and then decline only very gradually thereafter. For the second cohort, born between 1880 and 1920, the function, plotted in Figure 3, peaks at 35 and then declines fairly rapidly, with a fall off of value of nearly 25% between the ages of 35 and 60. A Wald statistic with null hypothesis that the parameters of the first two cohorts are identical rejected strongly at 94.31. Again, the results for the post-1920 cohort are the most unique of the three. Here, we see that prices peak much earlier, at the age of 24, and then drop rapidly, by about 60%, between the ages of 25 and 50. The parameters for the third cohort are significantly different from those for both the first and second, with respective Wald statistics of 89.67 and 170.35.

The results of the estimation of model (4), in which date-of-birth effects are included, are reported in Table 3, and the age-price profile is illustrated in Figures 5-8 for four examples of years of birth, at 35-year intervals from 1815 to 1920. The R-squared is 0.804, and the parameters for the date of birth effects are jointly significant, with a chi-squared statistic of 139.16. We can see from Figures 5-8 a clear shift to the left in the peak age as function of

date of birth, as the peak age for an artist born in 1815 is about 40, for an artist born in 1850 is 37, for an artist born in 1885 is around 30, and for one born in 1920 is 24. We thus observe a clear and continual shift to the left of the age-price profile, consistent with the picture presented in Figures 1-4 and with our a priori expectations.

5. CONCLUDING REMARKS

Our empirical results provide convincing evidence that the age at which a Canadian painter executed a work is an important variable in predicting the sale price at auction of the work Furthermore, we have seen that the nature of the influence of age on valuation depends on the date at which the artist was born. Whether the model is estimated with the set of all artists disaggregated by cohort, or whether in a specification allowing the age-valuation relation to shift continuously over time, we find that the relation tends to shift to the left, so that artists born more recently are found to "peak" earlier in their lives, with valuation beyond the peak declining more precipitously with age for the younger cohorts.

In addition to the inherent value that these findings should have for those with an interest in this particular market, the results raise questions about the nature of the evolution of the conditions of artistic creation in Canada over the centuries that may be of more general interest and that complement the analysis of similar findings in other art markets as presented by Galenson (2000, 2001) and Galenson and Weinberg (2000, 2001). In particular, there seems to be a relation between the thickening of the commercial art market associated with an expansion in the number of commercial art galleries and higher-valued work being done earlier in the careers of artists. In the Canadian case, there is also the associated rapid growth of the urban population as the country evolved from a mainly rural colonial society to a highly urbanized modern nation-state (see Table 4). We can make conjectures as to the nature of the influence upon the conditions of artistic creation of the economic and social evolution referred to here, but a rigorous theoretical and empirical analysis of any such links is left for future work.

ACKNOWLEDGEMENTS

For their helpful remarks, I am grateful to Ruth Dupré, John Galbraith, Tim Worrall, Bernard Fortin, Victor Ginsburgh, the referees, and seminar participants at the 2006 meetings of the SCSE, CEA, and CIRPÉE, the 2007 European Applied Cultural Economic Workshop, the 2008 Southern Economic Association Congress, and the University of Ottawa. I also acknowledge financial support from SSHRC, FQRSC, and RCER.

Table 1 – Average age at time of execution for paintings sold at auction, by cohort

Cohort	Number obs.	Average age	Standard deviation
All	10,033	50.5	16.1
Pre-1880	2578	49.6	16.4
1880-1920	5485	53.8	16.4
Post-1920	1970	42.3	11.3

Table 2 – Hedonic regression: estimates of parameters of fourth-order polynomial in age, by cohort (standard errors in parentheses)

Cohort	Age	Age^2	Age^3	Age^4
All	0.122 (.0287)	-2.97×10^{-3} (8.08×10^{-4})	2.63×10^{-5} (9.63×10^{-6})	-7.48×10^{-8} (4.13×10^{-8})
Pre-1880	0.113 (.0516)	-1.94×10^{-3} (1.40×10^{-3})	1.03×10^{-5} (1.60×10^{-5})	-8.46×10^{-10} (6.48×10^{-8})
1880-1920	0.288 (.0592)	-7.76×10^{-3} (1.82×10^{-3})	8.45×10^{-5} (2.36×10^{-5})	-3.32×10^{-7} (1.10×10^{-7})
Post-1920	0.619 (.153)	-.0234 (5.35×10^{-3})	3.54×10^{-4} (8.03×10^{-5})	-1.89×10^{-6} (4.35×10^{-7})

Table 3 – Hedonic regression: estimates of parameters of quadratic in age for all artists with date-of-birth effects included

Regressor	Estimate	Standard error
Age	4.91	1.84
Age^2	-0.0587	.0506
Age^3	-6.59×10^{-5}	5.93×10^{-4}
Age^4	3.03×10^{-6}	2.51×10^{-6}
D.B. X Age	-2.44×10^{-3}	9.76×10^{-4}
D.B. X Age^2	2.65×10^{-5}	2.70×10^{-5}
D.B. X Age^3	8.75×10^{-8}	3.17×10^{-7}
D.B. X Age^4	-1.83×10^{-9}	1.35×10^{-9}

Table 4 – Total and Urban Population of Canada, 1851-1971

Year	Total (millions)	Urban (millions)
1851	2.44	0.32
1871	3.74	0.72
1891	4.93	1.54
1911	7.22	3.28
1931	10.38	5.57
1951	14.01	8.63
1971	21.57	16.41

Source : Statistics Canada

APPENDIX 1 – LIST OF PAINTERS INCLUDED

(the painters included in our empirical study are listed here in chronological order according to year of birth, the latter being provided in parentheses along with the number of observed sales for each painter)

George Heriot (1766, 2), Robert Field (1769, 1), Antoine Sebastien Plamondon (1804, 4), James Duncan (1805, 1), Robert Whale (1805, 6), George Theodore Berthon (1806, 3), Robert Todd (1809, 1), Daniel Fowler (1810, 1), Paul Kane (1810, 3), Martin Somerville (1810, 2), Otto Jacobi (1812, 81), Cornelius Krieghoff (1815, 161), Theophile Hamel (1817, 3), William Sawyer (1820, 9), William Armstrong (1822, 2), William Cresswell (1822, 20), A.S. Falardeau (1822, 7), Napoleon Bourassa (1827, 1), Henri Perre (1828, 5), Ludger Ruelland (1828, 1), John O'Brien (1831, 2), Charles Caleb Ward (1831, 8), Lucius R. O'Brien (1832, 12), William Raphael (1833, 43), Marmaduke Matthews (1837, 13), John A. Fraser (1838, 6), Thomas Mower Martin (1838, 43), Frederick Arthur Verner (1839, 88), Henry Sandham (1841, 14), John Hammond (1843, 135), Frederic Martlett Bell-Smith (1846, 53), Allan Edson (1846, 19), John C. Forbes (1846, 7), Henri Julien (1846, 1), Robert Gagen (1847, 4), Wyatt Eaton (1849, 2), Robert Harris (1849, 44), William Cruikshank (1849, 2), J.W.L. Forster (1850, 8), William Brymner (1855, 25), Charles Huot (1855, 9), Homer Watson (1855, 30), Percey Woodcock (1855, 7), Horatio Walker (1858, 37), F.S. Coburn (1871, 256), Julian Seavey (1856, 4), Franklin Brownell (1857, 54), William Blair Bruce (1859, 15), Paul Peel (1860, 63), George Reid (1860, 73), Laura Muntz Lyall (1860, 26), J.M. Barnsly (1861, 27), Robert Holmes (1861, 1), William Atkinson (1862, 80), Archibald Browne (1862, 27), Henri Beau (1863, 23), William R. Hope (1863, 2), Carl Ahrens (1863, 16), Ozias Leduc (1864, 13), James Wilson Morrice (1865, 13), H. Ivan Neilson (1865, 2), Maurice Cullen (1866, 72), Joseph Franchere (1866, 10), Curtis Williamson (1867, 7), Ludger Larose (1868, 24), Joseph Saint-Charles (1868, 3), William Beatty (1869, 97), C.W. Jeffreys (1869, 5), Sophie Pemberton (1869, 9), Marc-Aurèle de Foy Suzor-Coté (1869, 134), Georges Delfosse (1869, 10), Emily Carr (1871, 88), Charles Gill (1871, 10), Edmund Morris (1871, 8), Fred Brigden (1871, 6), J.E.H. Macdonald (1873, 267), Tom Thomson (1877, 35), W.J. Wood (1877, 3), W.H. Clapp (1879, 36), W.P. Weston (1879, 105), Helen MacNicoll (1879, 13), John Russell (1879, 15), Clarence Gagnon (1881, 121), Fred Varley (1881, 44), Albert Robinson (1881, 105), A.Y. Jackson (1882, 817), W.J. Phillips (1884, 1), David Milne (1882,

85), Mabel May (1884, 29), Lawren S. Harris (1885, 142), Arthur Lismer (1885, 309), Emily Coonan (1885, 2), John Lyman (1886, 18), Charles H. Scott (1886, 11), Hortense Gordon (1887, 14), Mabel Lockerby (1887, 5), Bertram Brooker (1888, 12), Randolph Hewton (1888, 13), Frank Johnston (1888, 137), Marc-Aurèle Fortin (1888, 78), Frank Carmichael (1890, 54), Lemoine Fitzgerald (1890, 24), Eric Goldberg (1890, 2), Adrien Hebert (1890, 30), Sarah Robertson (1891, 7), Rodolphe Duguay (1891, 24), Edwin Holgate (1892, 63), Aleksandre Bercovitch (1893, 2), Kathleen Morris (1893, 15), Fritz Brandtner (1896, 16), Louise Gadbois (1896, 65), Prudence Heward (1896, 6), Lilias Torrance Newton (1896, 5), Andre Bieler (1896, 50), Ernst Lindner (1897, 8), J.W.G. Macdonald (1897, 46), Anne Savage (1898, 19), A.J. Casson (1898, 475), Paraskeva Clark (1898, 24), Yvonne McKague Housser (1898, 41), Robert W. Pilot (1898, 282), Charles Comfort (1900, 70), Jack Humphrey (1901, 15), Alexandra Luke (1901, 2), Will Ogilvie (1901, 6), Isabel McLaughlin (1903, 17), Carl Schaefer (1903, 33), Jean-Paul Lemieux (1904, 136), Louis Muhlstock (1904, 13), Goodridge Roberts (1904, 150), Pegi Nichol Macleod (1904, 13), Paul-Emile Borduas (1905, 57), William Leroy Stevenson (1905, 12), Illingworth Kerr (1905, 230), Maxwell Bates (1906, 146), Alfred Pellan (1906, 33), Marian Scott (1906, 16), Jori Smith (1907, 54), Henri Masson (1907, 254), Ernst Neumann (1907, 16), B.C. Binning (1909, 22), Jack Bush (1909, 68), Jack Shadbolt (1909, 126), Gordon Webber (1909, 6), Marion Nicholl (1909, 11), Lawren P. Harris (1910, 3), Philip Surrey (1910, 35), Leon Bellefleur (1910, 127), Stanley Cosgrove (1911, 255), Miller Brittain (1912, 7), Kate Graham (1913, 5), E.J. Hughes (1913, 102), John Korner (1913, 8), John Hall (1914, 7), Jean Dallaire (1916, 58), Fernand Leduc (1916, 12), Albert Dumouchel (1916, 11), Walter Yarwood (1917, 8), Louis de Niverville (1917, 2), Jacques de Tonnancour (1917, 50), Gordon Smith (1919, 57), Michael Snow (1919, 5), William Perehudoff (1919, 26), Alex Colville (1920, 12), Gershon Iskowitz (1921, 30), Ray Mead (1921, 14), Clark McDougall (1921, 8), Jack Nichols (1921, 1), Pierre Gauvreau (1922, 13), Robert Varvarande (1922, 5), Jean McEwen (1923, 104), Jean-Paul Riopelle (1923, 326), Bruno Bobak (1923, 13), Donald Jarvis (1923, 6), Marcelle Ferron (1924, 79), Tom Hodgson (1924, 14), Harold Town (1924, 91), Marcel Barbeau (1925, 31), Ronald Bloore (1925, 6), Patterson Ewen (1925, 18), Denis Juneau (1925, 2), Rodolphe de Repentigny (1926, 8), Roy Kiyooka (1926, 4), Kenneth Locchead (1926, 25), Arthur McKay (1926, 4), Kazuo Nakamura (1926, 36), William Ronald (1926, 73), Gerald Scott (1926, 1), Takao Tanabe (1926, 42), Tony Tascona (1926, 2), Dorothy Knowles (1927, 64), Jean-Paul Mousseau (1927, 9), William Kurelek (1927, 61), Jean-Paul Jerome (1928, 20), Francoise Sullivan (1928, 1), Jean Goguen (1928, 2), Hugh Mackenzie (1928, 1), Daphne Odjig (1928, 20), Toni Onley (1928,

63), Louis Belzile (1929, 15), Rita Letendre (1929, 74), Allen Sapp (1929, 111), Suzanne Bergeron (1930, 1), Fernand Toupin (1930, 52), Robert Hedrick (1930, 1), Jack Chambers (1931, 5), Graham Coughtry (1931, 8), Joyce Wieland (1931, 3), Edmund Alleyn (1931, 46), Claude Tousignant (1932, 8), Norval Morriseau (1932, 144), Dennis Burton (1933, 16), John Meredith (1933, 21), Guido Molinari (1933, 18), Ted Godwin (1933, 10), Charles Gagnon (1934, 3), Tony Urquhart (1934, 13), Yves Gaucher (1934, 8), Richard Gorman (1935, 15), Christopher Pratt (1935, 6), Gordon Rayner (1935, 6), Ivan Eyre (1935, 8), Alex Janvier (1935, 18), Mary Pratt (1935, 17), Otto Rogers (1935, 13), Tom Forrestall (1936, 10), Doug Haynes (1936, 10), Christiane Pflug (1936, 1), Greg Curnoe (1936,1), Claude Breeze (1938, 4), Guy Monpetit (1930, 3), Brian Fisher (1939, 1), Jacques Hurtubise (1939, 9), Paul Fournier (1939, 10), Ken Danby (1940, 2), Joseph Drapell (1940, 5), John Boyle (1941, 1), Esther Warkov (1941, 2), Michael Morris (1942, 3), Milly Ristvedt-Handerek (1942,1), Harold Klunder (1943, 3), Ron Martin (1943, 8), Carl Ray (1943, 4), Joice Hall (1943, 2), Michael Forster (1943, 18), David Bolduc (1945, 14), Daniel Solomon (1945, 3), Jackson Beardy (1944, 1), Bruce St. Clair (1945, 2), Ric Evans (1946, 1), Alex Cameron (1947, 1), Erik Gamble (1950, 1)

APPENDIX 2 – BICKEL'S (1982) ADAPTIVE ESTIMATOR

We consider estimation of a linear regression model

$$y_i = w_i'\delta + u_i,$$

where δ is the parameter vector to be estimated. The estimator is efficient under the assumption that the disturbances are iid with a density function $f(u)$ that is symmetric, so that $f(u) = f(-u)$. Using the OLS estimator $\hat{\delta}$, compute the associated residuals

$$\hat{u}_i = y_i - w_i'\hat{\delta}, i = 1,...,n.$$

For each residual $\hat{u}_i$, i=1,…,n, one can use the remaining residuals to compute a kernel estimate of the level of the density f evaluated at $\hat{u}_i$ as follows :

$$\hat{f}_i(\hat{u}_i) = \frac{1}{2(n-1)} \sum_{\substack{j=1 \\ j \neq i}}^{n} \left\{ K\left(\frac{\hat{u}_i + \hat{u}_j}{h} \right) + K\left(\frac{\hat{u}_i - \hat{u}_j}{h} \right) \right\},$$

where K is a kernel function (we use the standard normal density in our empirical application) and h is a bandwidth parameter that converges to zero as the sample size n goes to infinity (in practice, we use the rule-of-thumb plug-in bandwidth mentioned by Silverman (1986, p. 45)). We also have the following estimate of the first derivative of f:

$$\hat{f}_i'(\hat{u}_i) = \frac{1}{h2(n-1)} \sum_{\substack{j=1 \\ j \neq i}}^{n} \left\{ K'\left(\frac{\hat{u}_i + \hat{u}_j}{h} \right) + K'\left(\frac{\hat{u}_i - \hat{u}_j}{h} \right) \right\}.$$

We then have the estimated (negative of the) score of f, evaluated at $\hat{u}_i$:

$$\hat{\psi}_i(\hat{u}_i) = \frac{\hat{f}_i'(\hat{u}_i)}{\hat{f}_i(\hat{u}_i)},$$

where some trimming conditions may need to be specified in the computation of $\hat{\psi}_i$.

The sample score vector and information matrix of the likelihood function can be approximated, respectively, by the following semiparametric estimators:

$$\hat{S}_n = -n^{-1} \sum_{i=1}^{n} w_i \hat{\psi}_i(\hat{u}_i)$$

and

$$\hat{\Phi}_n = \hat{\Omega} n^{-1} \sum_{i=1}^{n} w_i w_i',$$

where $\hat{\Omega} = n^{-1}\sum_{i=1}^{n}\hat{\psi}_i(\hat{u}_i)^2$. The adaptive estimator $\tilde{\delta}$ is then computed using the following one-step Newton-style adjustment of the OLS estimator $\hat{\delta}$:

$$\tilde{\delta} = \hat{\delta} + \hat{\Phi}_n^{-1}\hat{S}_n.$$

Under conditions specified by Bickel (1982), $\tilde{\delta}$ will be consistent and asymptotically normal,

$$\sqrt{n}\left(\tilde{\delta} - \delta\right) \xrightarrow{d} N\left(0, \Phi^{-1}\right),$$

where the asymptotic covariance matrix Φ^{-1} is consistently estimated by $\hat{\Phi}_n^{-1}$.

REFERENCES

Allodi, M. 1991. *Berczy.* National Gallery of Canada.

Bickel, P. 1982. On adaptive estimation. *Annals of Statistics* 10: 647-671.

Borcoman, J. 1969. *Goodridge Roberts.* National Gallery of Canada.

Campbell, H. 1970-1975. *Canadian Art Auction Record 1969-1974*, vols 1-6. Toronto: Canadian Antiques and Fine Arts; and Montreal: Bernard Amtmann.

Campbell, H. 1980. *Canadian Art Auctions, Sales, and Prices, 1976-1978.* Don Mills, Ont.: General.

Czujack, C. 1997. Picasso paintings at auction, 1963-1994. Journal *of Cultural Economics* 21:229-247.

Galbraith, J.W. and Hodgson, D.J. 2010. Dimension reduction and model averaging for estimation of artists' age-valuation profiles. McGill University.

Galenson, D.W. 2000. The careers of modern artists. *Journal of Cultural Economics* 24:87-112.

Galenson, D.W. 2001. *Painting Outside the Lines.* Harvard.

Galenson, D.W., and Weinberg, B.A. 2000. Age and quality of work: The case of modern American painters. *Journal of Political Economy* 108:761-777.

Galenson, D.W., and Weinberg, B.A. 2001. Creating modern art: The changing careers of painters in France from impressionism to cubism. *American Economic Review* 91:1063-1071.

Ginsburgh, V. and Weyers, S. 2006. Creativity and life cycles of artists. *Journal of Cultural Economics* 30:91-107.

Harper, J.R. 1977. Painting *in Canada: A history (2nd ed.).* Univ. of Toronto.

Harper, J.R. 1979. Krieghoff. Univ. of Toronto.

Hodgson, D.J. 2000. Unconditional pseudo-maximum likelihood and adaptive estimation in the presence of conditional heterogeneity of unknown form. *Econometric Reviews* 19:175-206.

Hodgson, D.J., Slade, B.A., and Vorkink, K. 2006. Constructing commercial indices: A semiparametric adaptive estimator approach. *Journal of Real Estate Finance and Economics* 32:151-168.

Hodgson, D.J. and Vorkink, K. 2004. Asset pricing theory and the valuation of Canadian paintings. *Canadian Journal of Economics* 37:629-655.

Jarque, C. and Bera, A. 1980. Efficient tests for normality, homoskedasticity, and serial independence of regression residuals. *Economics Letters* 6:255-259.

Leclerc, D. 1992. *The Crisis of Abstraction in Canada: The 1950s.* National Gallery of Canada.

Mincer, J. 1974. *Schooling, Experience, and Earnings*. Columbia University Press.

Reid, D. 1973. *A Concise History of Canadian Painting*. Toronto: Oxford.

Reid, D. 1988. *A Concise History of Canadian Painting (2nd ed.).* Toronto: Oxford.

Reid, D. 1999. *Krieghoff : Images of Canada.* Toronto: Douglas & McIntyre.

Shadbolt, D. 1979. The Art of Emily Carr. Toronto: Douglas & McIntyre.

Silverman, B.W. 1986. *Density Estimation for Statistics and Data Analysis*. London: Chapman and Hall.

Sotheby's. 1975. *Canadian Art at Auction, 1968-1975*. Toronto: Sotheby's.

Sotheby's. 1980. *Canadian Art at Auction, 1975-1980*. Toronto: Sotheby's.

Thom, I. et al. 2006. Emily Carr : New Perspectives on a Canadian Icon. Toronto: Douglas & McIntyre.

Westbridge, A.R. 1981-2010. *Canadian Art Sales Index, 1977-2009*. Vancouver: Westbridge.

Fig. 1 – Age–Price Profile, All Painters

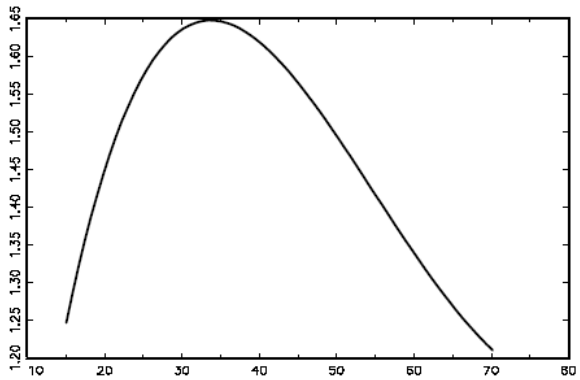

Fig. 2 – Age–Price Profile, pre–1880

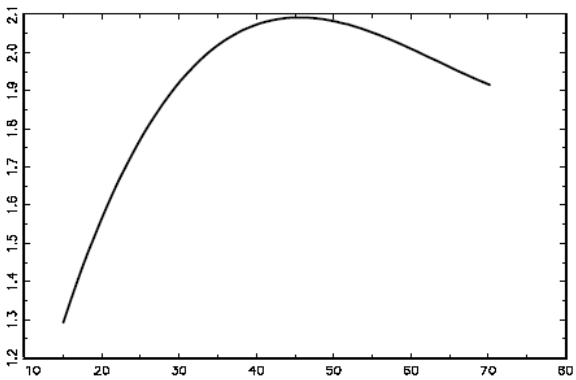

Fig. 3 – Age–Price Profile, 1880–1919

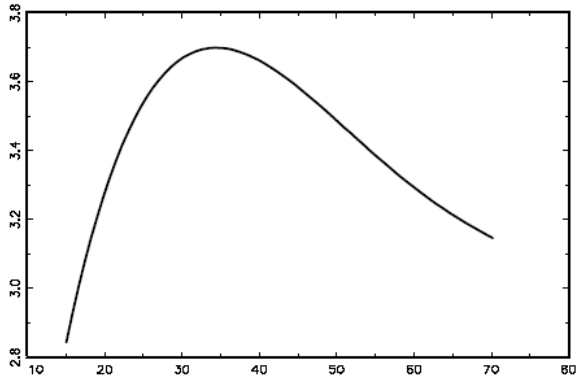

Fig. 4 – Age–Price Profile, post–1920

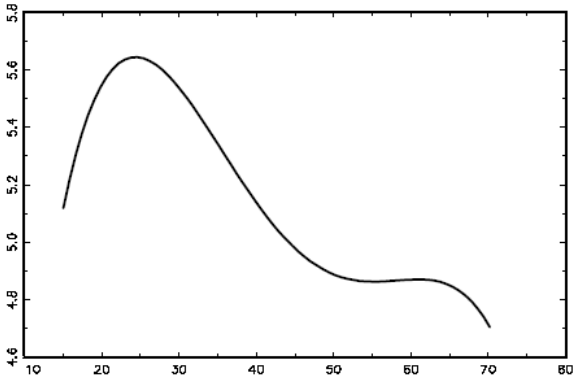

Fig. 5 — Age–Price Profile with Date of Birth Effects (1815)

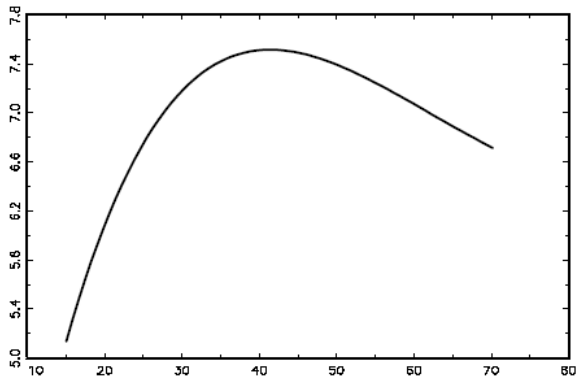

Fig. 6 — Age–Price Profile with Date of Birth Effects (1850)

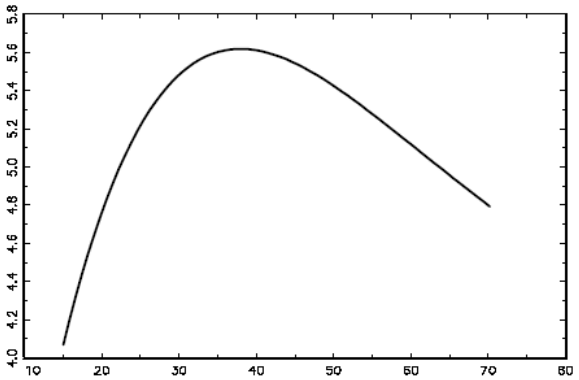

Fig. 7 — Age–Price Profile with Date of Birth Effects (1885)

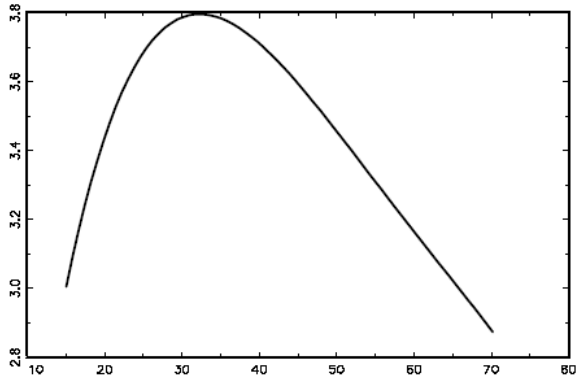

Fig. 8 — Age–Price Profile with Date of Birth Effects (1920)