**METHODOLOGY**

**ANCHORING**

A two-stage regression model for detecting anchoring is specified in Beggs & Graddy (2009). The same model is used to detect anchoring effects in later papers such as Hong et al. (2015), and in general, may be estimated for goods that exhibit unchanging hedonic quality over time – a key assumption of their work. Intuitively, their model identifies anchoring by looking at two sales of an item, say a painting, at different points in time. By controlling for hedonic value at all time points, current price may be regressed on the non-hedonic aspects of past price. This past residual is identified as the anchoring effect.

Hedonic regressions are commonly used to estimate demand for highly heterogeneous items such as art, wine, and real estate as a function of their constituent attributes[[1]](#footnote-1) [[2]](#footnote-2). For example, the value of a painting may depend on its dimensions and authenticity, while a bottle of wine may be appraised based on its age and where it was grown. In the first stage of the model, Beggs & Graddy (2009) regress the sale prices of resold paintings[[3]](#footnote-3) on their hedonic and temporal variables, while also controlling for temporal effects. This yields a hedonic price prediction for each observation of a painting sale. The resulting equation, which both Beggs & Graddy and we use, is given below. We denote the current period as and the previous period as.

For my replication work on the Impressionist and Contemporary datasets, I use the same hedonic variables that Beggs & Graddy used. For Impressionist art this includes painting date, length, width, medium of the artwork, indicators of authenticity (signed, monogrammed, stamped), and artist.[[4]](#footnote-5) For Contemporary art this includes painting date, length, width, medium, and artist. The temporal effects are modelled by half-year time dummies.

In the same manner as Beggs & Graddy, I use the natural log of prices and hedonic price predictions, which allows us to interpret the regression results as relative effects (percent changes). For unsold items, we proxy value with 80% of the low estimate as they do. It is important to note that multiple hedonic price predictions at different times may differ for the same painting, since these are estimated based on the price index. The price index reflects demand for art, which varies over time. The hedonic variables, however, are assumed to remain constant across sales.

In the second stage of the model, Beggs & Graddy specify the following regression, fitted to each unique painting, in order to separate out anchoring from other effects. Their equation (which we also use) is given below.

* is the response variable. Beggs and Graddy fit several regressions where the response represents either the hammer price, an indicator for whether the item sells (which involves a probit transformation), or the presale estimate. In our replication work, we only examine as hammer price.
* is the current hedonic valuation of bidders, i.e. the hedonic price prediction in the current period. To detect anchoring effects, hedonic valuations must be controlled for. Otherwise, one would not be able to separate hedonic and non-hedonic drivers in the current period.
* is the anchoring effect. This specifies how past hammer price, the anchor, differs from, the current hedonic valuations of bidders. Since we have already controlled for the latter, this term measures the extent to which past price impacts current price.
* is the past residual, i.e. non-hedonic inputs into past price. This is necessary to control for

The anchoring effect is captured in the term, which specifies how information from the past price (the anchor) differs the later hedonic price prediction and thus the dependent variable. The last term controls for unobservable non-hedonic effects on price. For example, if the past price was not only a function of the painting’s hedonic characteristics, but was also a function of bidding activity at the time, this will be controlled for in the term. Otherwise, not only reflects the impact by past price on the later hedonic prediction, but also past bidding activity and other non-hedonic factors inputted into. In the case of the dependent variable (for a regression for hammer price), we see that those non-hedonic inputs, usually captured by, would instead be contained in the residuals. One should also note that because hedonic prices may vary over time, is distinct from. Additionally, the intercept represents the value of in the absence of other predictors. For example, if represents hammer (sale) price, then a high intercept could suggest a high average price for paintings across the given market.

<do note that is already accounted for in this model -> collinear >

**IDENTIFYING SUBSTITUTES**

As we discussed earlier and as Beggs & Graddy (2009) note, it is extremely difficult to track down multiple sales of the same item. The same art piece can become a drastically different hedonic object within its lifetime. And, many years or decades may elapse between sales of the same art piece – far too long to reliably measure anchoring biases.

It is reasonable to believe that buyers (and specialists), when bidding on an artwork, make judgments based not only on that artwork’s past sales, but also what similar pieces went for as well. This allows for a much more versatile approach to identifying anchoring effects, or if between different goods, cross-effects – given that we control adequately for hedonic differences. Before measuring similarity, however, we must identify related pieces for the current good, since many other pieces may be entirely irrelevant. Thus, to identify substitutes for the sale of a current art piece, we search through our data for past sales of other pieces with the same artist, medium, and signs of authenticity. I also omit observations where no substitutes were found. This gives us a list of related art sales to consider for the current good. Only then may we proceed to measure similarity and test for anchoring cross-effects, as described below.

**ANCHORING AND SUBSTITUTION**

Here, we build on the two-stage regression model presented earlier.

Suppose, as before, we have our same design matrix and our hammer prices. We run the first hedonic regression as before, except that we are not concerned specifically with resale and simply treat auction date as another explanatory variable.

We next depart from the original model. Denote the sale observation of our current good as and the observation of a single substitute as, such that the hedonic predictions estimated above are, and are the respective hammer prices[[5]](#footnote-6). Then our second regression is:

Here, the subscripts for the past and current sales and are replaced by subscripts for the substitute and current good. The previous regression model assumed that there was no unobserved quality changes in the painting across sales, such that (though hedonic prices could still change). However, in this generalized framework, we assume that characteristics do differ across goods, that is. Thus, we need to control for those hedonic differences by including a measure of substitution in our regression model, which may be constructed from either or. This allows us identify anchoring effects in, as before.

What if a painting has multiple substitutes – the multivariate case? Let a given good have a vector of substitutes. We can write:

Here, and are price and hedonic prediction for a representative substitute. Two goods and may have different numbers of substitutes, which is why for our regression model it is necessary to aggregate them via a function such as the mean or maximum (I use the former). Hence, this multivariate regression tests whether there exists anchoring effects for the sale of the current good with respective to the “average” substitute – a conglomerate of all substitutes together. The marginal effect of on, then, represents how strongly the dependent variable (such as price) is affected by our quality of substitution. As before, the measure of substitution may be calculated from the multivariate or. Finally, if we omit and use the current good’s previous sale instead of its average substitute, this reduces to the original model of Beggs & Graddy.

**MEASURING SUBSTITUTION (SIMILARITY) ACROSS ART PIECES**

In this research, we experiment with two simple measures of substitution between art pieces. The first is derived from the hedonic predictions, and represents unobserved quality differences. The second is formulated from our interviews with art experts and specialists. These do not and cannot perfectly capture differences between artworks, but do provide a starting point for quantitatively measuring art similarity.

**MEASURE #1: SECOND MOMENT OF HEDONIC PRICE DIFFERENCES**

For a current good and other art pieces, which are aggregated into an “average substitute,” one way we can measure substitution is by examining differences between the hedonic price predictions. These correspond to unobserved quality differences. We use the following measure, which is essentially a second moment estimator about the current good’s hedonic prediction[[6]](#footnote-7):

As described before, we work in logs for relative effects, and the negative sign allows a higher (smaller hedonic differences) to correspond to higher substitutability. The squared term is used instead of absolute value so that the estimator also captures the variability of hedonic differences, which corresponds to lower substitutability. This is important because substitutability may differ drastically across goods: it is preferable to have uniformly substitutable goods rather than a polarized mix of good and bad ones.

**MEASURE #2: DOMAIN KNOWLEDGE**

For our second measure of substitution, we draw upon domain knowledge from our expert interviews. We found some of the most commonly mentioned and important determinants of artwork similarity (substitutability) are artist, medium, signs of authenticity, size of the artwork, and how recently the artwork was auctioned. The opinions of our interviewees on more complex factors, such subject matter and artistic style, seemed to be mixed: some said these were key to measuring similarity between pieces, while others looked more to the factors above[[7]](#footnote-8). One thing we were surprised to learn about size in particular was that its importance in determining similarity varies at different price points. For the lower and middle price ranges, people usually purchase art as a decoration, and tend to purchase pieces of similar sizes to display next to each other. As price increases, people tend to value artwork more as an investment, and so the importance of size in determining similarity decreases.

To capture these anecdotal observations about art similarity, we present a second measure of substitution between a current piece and a substitute piece, here formulated as two sale observations at different points in time. This measure of substitution depends on size, hedonic price, and auction date. Artist, authenticity, medium are categorical variables and thus used primarily to filter for substitutes, as we describe later.

Greater differences in size between the two goods correspond to decreased similarity and thus substitutability[[8]](#footnote-9). However, this effect decreases as the hedonic values of the pieces rise. Consistent with the anchoring literature discussed earlier, the farther the anchor (the substitute here) is in the past, the weaker the anchoring effect is. Note that we use hedonic prices to indicate increasing value. This is because can reflect not only but also non-hedonic determinants of price, and furthermore, is the dependent variable to be determined in our main anchoring regression. No possible past anchoring effects are considered with the hedonic prices here: we assume buyers are myopic, as captured in the time difference effect, and assess similarity primarily based on hedonic factors.

The hedonic price predictions enter into both and, but the two measures are considerably different. Hedonic differences are the primary focus of, while for they only serve the implicit purpose of scaling size. The measurealso includes temporal differences, which do not explicitly enter into the hedonic regressions. Hence, we may consider a very broad measure of hedonic similarity, while is a narrower measure formulated from domain knowledge. It is surprising that these two divergent measures yield similar evidence of anchoring effects, and given that we apply these broadly, discover anchoring effects at all. We show this in the next section.

1. Edmonds, Radcliffe G. "A theoretical basis for hedonic regression: A research primer." *Real Estate Economics* 12.1 (1984): 72-85. [↑](#footnote-ref-1)
2. Costanigro, Marco, Jill J. McCluskey, and Ron C. Mittelhammer. "Segmenting the wine market based on price: hedonic regression when different prices mean different products." *Journal of agricultural Economics*58.3 (2007): 454-466. [↑](#footnote-ref-2)
3. The data here consists of all sale observations that correspond to the set of paintings that have been resold multiple times. Beggs & Graddy have painstakingly verified each observation against presale catalogs. Because those are not available, in my replication analysis I make the assumption that duplicate observations in their Impressionist and Contemporary data refer to multiple sales of the same item. [↑](#footnote-ref-3)
4. Besides the artist’s hand-drawn signature, monograms and stamps may also be used to mark an artwork as authentic. A monogram is a stylized symbol of the artist (sometimes an artistic rendering of their initials) that may be put onto a work. Artists may also have a custom stamp for their work, which may include their printed name. [↑](#footnote-ref-5)
5. As with resale, we add the temporal constraint that the sale of a substitute must occur before the sale of the current good – in this context, one can only anchor on the past. [↑](#footnote-ref-6)
6. We do not subtract the other term typically used in calculating variance, since that (squared) first moment term reflects absolute hedonic differences between pieces which we still wish to account for. Hence, our measure captures both spread and mean. [↑](#footnote-ref-7)
7. For further discussion: http://www.jstor.org/stable/pdf/20715780.pdf?acceptTC=true [↑](#footnote-ref-8)
8. We add one in the denominator of the first term to protect against results exploding toward infinity. Empirically, however, this is negligible compared to the magnitude of our hedonic prices. [↑](#footnote-ref-9)