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*Is the World Flat or Round?
Mapping Changes in the Taste
for Art*

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Is the World Flat or Round? Mapping Changes in the Taste for Art

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Abstract

This paper is a preliminary attempt to map the changing tastes for works of art as manifested in the prices of paintings sold at auction. There are two main goals in this work: first, to describe a space in which we can represent the work of different artists; and second, to describe how "cultivated taste" moves around that space. It presents a method of analysing "waves" in popularity, and applies this to data on the prices of works of art during the period 1840-1970. It extends traditional methods of mapping points in n-dimensional constellations onto a plane, showing instead how to locate these points on the surface of a sphere. This can make it easier to explain and interpret some of the observed trends in taste. A result of considerable power and great simplicity is derived: for two products located on the surface of a sphere, the correlation between their prices is equal to the cosine of the angle between them - as measured from the centre of the sphere. The paper - a companion to Cowan's (2001) paper in this series - also draws out some of the relationships between this economic analysis and some leading themes in art history and art theory.

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1. Introduction

Public taste, I believe, as far as it is the encourager and supporter of art, has been the same in all ages; a fitful and vacillating current of vague impression, perpetually liable to change, subject to epidemic desires, and agitated by infectious passion, the slave of fashion, and the fool of fancy.

John Ruskin ²

The main lesson imparted by the test of time is the fickleness of taste whose meanderings defy prediction.

William Baumol ³

This paper is a preliminary attempt to map the changing tastes for works of art as manifested in the prices of paintings sold at auction. There are two main goals in this work: first, to describe a space in which we can represent the work of different artists; and second, to describe how "cultivated taste" moves around that space.

In pursuing the first goal, moreover, we have to confront a further quandary: what is the appropriate shape of the space suitable for this purpose? Is the appropriate world "round" or "flat"? This is an empirical question, which can be assessed by reference to measures of "goodness of fit". But there is also an interesting theoretical interpretation. We shall argue that the answer depends on whether one takes a historicist or a modernist perspective on the development of art. When we turn to the second goal, the quote from Ruskin illustrates why our task will be a difficult one: it is not easy to map a "fitful and vacillating current". Even more, we shall argue that movement in taste around the space of painters is a path dependent process.

That provides the link between this paper and the work of Paul David. One of the many areas in which his work has been very influential is in the economics of path dependence - see for example David (1985, 1986, 1997, 1988, 1992, 1993, 1994, 1997), David and Foray (1994), David *et al* (1998). Antonelli (1997) introduces a special issue of *International Journal of Industrial Organisation* on path dependence, inspired by Paul David's work.

In a very loose sense, path dependence is the idea that "history matters" when we try to understand how markets evolve today. But Paul David has provided us with some much more precise definitions of path dependence, and we shall turn to this later (section 4). The path dependence we observe in this case is a little different from that observed in much of his work. For here, as art historians and theorists have recognised (see section 3), there is both positive and negative feedback: positive feedback from the elite to the aspirants but negative feedback from aspirants to the elite.

The rest of the paper is in 8 sections. Section 2 briefly describes the economic models of taste change, which guide what follows - though these are discussed at greater length in the companion paper by Cowan (2001). Section 3 looks at a few central themes in art theory and history that illuminate our study. Section 4 provides a more

² *Modern Painters*, Volume 1 (1843). Here quoted from *Works of John Ruskin*, Vol. 3, pp. 617-8

³ Baumol (1986, p. 14)

precise definition of *path dependence*. Section 5 compares two leading techniques for mapping products in a common space: the characteristics approach and multidimensional scaling (MDS). Section 6 then examines (in the light of section 3) whether an appropriate space for mapping should be flat or round: precisely, should we work with a (two-dimensional) plane or the surface of a (three-dimensional) sphere? Section 7 states precise results for mapping from price correlations to points on a plane or on the surface of a sphere. Section 8 presents some preliminary calculations, which illustrate in a rough way how tastes have changed over a hundred-year period. Section 9 concludes.

2. Social Theories and Economic Models of Taste

This paper aims only to *map* changes in taste, and not to *explain* why they come about. The companion paper by Robin Cowan (2001) offers a model of changing tastes towards works of art. However, to help motivate the paper, here is a brief sketch of one possible process leading to changes in taste.

For a long time, we have known that the character of demand for prestige goods, including works of art, is rather different from the elementary neo-classical picture of demand. Veblen (1899) described how the newly wealthy indulged in conspicuous consumption - that is, the visible consumption of things that other people do not have. So long as these items of conspicuous consumption are not owned by others from whom one wishes to distinguish oneself (Bourdieu, 1984), then they serve their purpose well. But when others who aspire to share the consumption activities of the elite start to catch up, then it is time for the elite to move on to other forms of conspicuous consumption.

Cowan et al (1997, 1998) have developed a model of demand driven by the conflicting desires of association, distinction and aspiration. The consumer may seek to associate in consumption with some groups, may seek distinction in consumption from some other groups, and all the while is aspiring to share some consumption activities with an elite. In this model, demand exhibits waves: to begin with, a particular good may be in demand from the elite, but then demand shifts down-market, and the elite desert the good. Under some circumstances, these waves can repeat themselves. This model generates rich and complex patterns in the consumption of particular goods.

The companion paper by Cowan (2001) shows how models of this sort may be applied to understanding changing tastes towards works of art. In this last study, cycles in relative popularity are a natural outcome when the products are arrayed around a circle.

Although some other social scientists believe that economics has relatively little to say about such historical patterns in demand, the opposite is true. There is indeed a large economics literature on association, distinction and aspiration in demand. We do not attempt to review that literature here, but have done so elsewhere (Swann, 1999; Swann, 2001b). See also McPherson (1987) for a very useful overview. Some of the most important recent contributions are by Becker (1996), Bianchi (ed. 1998), Dosi *et al* (1999), Frank (1985). Moreover, following an influential paper by Baumol

(1986), an interesting and substantial literature has grown up recently on the economics of the arts and culture, including: Cozzi (1998), essays in De Marchi and Goodwin (eds. 1999), Frey (1997, 2000), Frey and Pommerehne (1989), essays in Ginsburgh and Menger (eds. 1996), Grampp (1989), McCain (1981), and Throsby (2001).

Nor does this paper try to describe how painters have reacted to changes in taste. Elsewhere, we have studied how the nature of consumer demand for distinction goods might influence the product design strategies of producers (Swann, 2001a). It is certainly true that some of the painters in our sample painted primarily for the market at the time, and as a result some of their works do not appeal today. By contrast, Van Gogh only sold one painting during his lifetime, but his popularity has grown monotonically since his death.

3. Some Themes in Art History and Theory

Ruskin's remark, quoted at the start of the paper, highlights the volatility of taste. In view of that, it would not make much sense to assume that "a fitful and vacillating current of vague impression, perpetually liable to change" can be approximated by a constant! But Ruskin was talking about taste over all forms of art. Individual episodes are less chaotic but show curious cycles of popularity. As Maurice Rhiems (1961), the art dealer and historian shows us, the fluctuating fortunes of art in different times can be quite entertaining:

It is amusing to see how objects which once were useful, in time cease to be so and later become collector's pieces for the future. In 1935, a woman who started an antique shop in Paris was laughed at for dressing her window with hideous objects from the period 1900 to 1920. At first only the passers-by were amused, but with the years this shop has become world-famous, selling wonderful period bibelots now worth their weight in gold. What has happened in the meantime? The shop is still unchanged, so are the *objets d'art*; but now they are no longer part of our immediate life and we can look at them in a different light. (Rheims, 1961, p. xiv)

But it can also be cutting:

Fashion is a sorcerer's charm or talisman changing the masterpieces of today into the laughing-stock of tomorrow. (Rheims, 1961, p. 133)

Why do these changes in taste come about? It is unlikely that there could ever be one explanation that accounts for all cases, but some examples are suggestive. Take the history of the Pre-Raphaelite group of painters. Quentin Bell (1984) discusses the fall in popularity of the Pre-Raphaelites in the 1920s. Part of their error was to abuse their position as the establishment, and fail to understand innovations elsewhere:

The Pre-Raphaelites, who by the end of the century had become established figures, were among the first to condemn the innovations of the French ... (Bell, 1984, p. 14)

In turn, the 'Bloomsbury Group' (notably Bell's father, Clive Bell, 1927) were influential in turning the tide against the Pre-Raphaelites:

The Bloomsbury set laughed at the Pre-Raphaelites. To them it seemed that 'everything of importance in the second half of the 19th Century had happened in France.' (Barnes, 1998, p. 113)

In addition, Bell recognised that part of the reason for their fall was that the 'wrong' patrons had bought their work:

From the very first these painters found their market among those whom contemporaries would have considered an ignorant and philistine clientele, the 'self-made' men and manufacturers of the North. (Bell, 1984, p. 16)

In that respect, Bell takes a view very similar to that in the economic models of distinction and aspiration described in the last section. He is even closer when he goes on to describe how reproductions of Pre-Raphaelite paintings became commonplace on middle class, *aspirational*, walls:

We all want to exhibit a cultivated taste, we all want to be enlisted in the cultural elite and of course in so doing we deprive the elite of its elitist character; that which had been distinguished becomes in the truest sense vulgar and the public is ready for something else; it is thus I would suggest that the wheel of fashion is made to revolve. (Bell, 1984, p. 16)

While the Pre-Raphaelites became unpopular from the 1920s, and this can be seen in prices paid at auction (see below), the wheel of fashion came round again in the latter part of the 20th century. Barnes (1998, p. 115) notes that attitudes started to change in the 1960s, and 1970s, and that the Tate Gallery exhibition on Pre-Raphaelites in 1984 was one of the most popular ever mounted by the Gallery.

Art theorists also stress how innovators in art can dispel the unattractive associations of the current establishment. Gombrich (1963a) summarises what he calls (with a little irony) the "treasured legend of the modern movement":

What is called loosely 'modern art' sprang indeed from a protest against the lie in the soul, a revulsion from false values. When new classes of patrons acquired unexpected wealth and were bent on ostentation, cheap vulgarity stifled our cities and choked our drawing rooms. Sentimental trash was taken for Great Art. This sickened the heart of the true artists who went on their lonely and perilous way in the face of public neglect and derision. (Gombrich, 1963a, p. 145)

Others went further and argued that true modernity was a negation of all that is past - not just the current establishment:

To be modern, design did not just have to be new, it had to be free of any reference to the decorative styles of the past (Marcus, 1998, p. 7)

Some, by contrast, recognised that negation of the present establishment could lead to a rediscovery of past styles. So, for example, while Malraux (1954) describes a concept of perpetual revolution in art, of the artist as a 'defiant animal' and hence a theory of changing styles of (and tastes for) of art, he nevertheless recognises a potential connection with the distant past. Gombrich (1963b) summarises Malraux's position very succinctly:

In the past this art ... served religion and by doing so it defied the temptations of mere sensuous pleasure; it rejected the agreeable for the sake of 'higher' values ... Modern art came into being as a protest against the commercial pseudo-art of prettiness. It is this element of negation that establishes its kinship with the religious art of the past, which we value more for what it is *not* than for what it is. (Gombrich, 1963b, p. 83).

Gombrich recognises however the fundamental paradox that today's' revolutionaries in art become tomorrow's establishment:

True, modern art will not be able to 'outlive its victory intact'. As an act of defiance it will wither away when it becomes dominant. (Gombrich, 1963b, p. 83)

Historicism, the practice of borrowing from the more distant past (even that untainted by recent associations) was an anathema to true modernists:

Ever since the middle of the previous century, reformers had condemned design's dependence on historicism (and its handmaiden, ornamentation), and the progress of modern design could be measured by the extent to which the mining of historic styles was supplanted by the creation of new, anonymous, and universal forms, forms that looked to the future instead of the past. (Marcus, 1998, p. 7)

But it was widely accepted, especially in the 19th century:

In the 1990s we have grown used to revivals coming around at shorter and shorter intervals ... eclecticism, however, has a much longer history. Christopher Wren reworked the medieval past in his Tom Tower at Oxford, while in the 18th century architects and designers borrowed extensively from Egyptian, Greek, Roman and Chinese sources. It was the 19th century, however, that made Historicism its own, and this obsession for the past is reflected in the large numbers of design source books published on the subject. (McDermott, 1992, p. 120-121)

The history of what was popular and unpopular at particular times in the past shapes what is popular and unpopular today. Using the term, "path dependence" in an informal way, we can say that the history of taste is path dependent. Some of the manifestations of path dependence that have drawn greatest attention in the literature occur when there is positive feedback only, leading perhaps to 'lock in'. Here, in contrast, there is a mix of positive *and* negative feedback.

4. Path Dependence

In some parts of the literature, the term "path dependent" has been used in a rather casual fashion. David (1997, p.13) helps us to be much more precise. Path dependence is a dynamic property of allocative processes. It can be defined with reference to either: (a) the relationship between process dynamics and outcome(s) to which it converges; or (b) the limiting probability distribution of the stochastic process under consideration.

To understand the true meaning of path-dependence, it is easiest perhaps to start by defining *path independence*. A *path independent* process is one whose dynamics guarantee that it will converge to a unique, globally stable equilibrium. Or, in the case of stochastic systems, where the outcome has an invariant stationary asymptotic probability distribution. Stochastic systems with this latter property are *ergodic*. That means they are able to shake off the influence of their past.

David (1997) then offers a "negative definition" of path dependence:

Processes that are non-ergodic, and thus unable to shake free of their history, are said to yield path dependent outcomes. (David, 1997, p. 13)

Working on from this, he can provide a "positive definition":

A path dependent stochastic process is one whose asymptotic distribution evolves as a consequence (function) of the process' own history. (David, 1997, p. 14)

In short, there are three key points about path dependence (David, 1997, pp. 18-19):

- Path dependence is a property of stochastic dynamic systems
- It is natural to interpret a path dependent process as a contingent branching process
- The definition of path dependence is independent of any issues of economic efficiency or inefficiency

From this point of view, there seems little doubt that the evolution of tastes and prices in the market for art is truly a path dependent process - even if not all the models that could be invoked to analyse these are strictly path dependent.

5. Characteristics and Multidimensional Scaling

We can now return to the primary aim of the paper: to map the changing tastes for works of art as manifested in the prices of paintings sold at auction.

Whenever economists seek to represent different products in a common space, the natural starting point is the characteristics approach, developed in the modern literature by Gorman (1980), Ironmonger (1972) and Lancaster (1971). But what characteristics are needed to give an adequate representation of objects so subtle as works of art? Here Bacharach's (1990) work on commodities and language is helpful. We can judge the necessary characteristics from the things people say about these objects. But in the case of works of art, people have said a great deal. For example, Wildenstein's (1996) catalogue of paintings by Monet runs to 4 volumes and over 1500 pages. It would seem to be a difficult task indeed to capture all this in a set of characteristics scores!

Nevertheless, both economists and art historians have tried to capture the essence of good art in a few characteristics. As De Marchi (1999, p. 6) notes, Adam Smith argued that with objects of "art", we derive pleasure from four characteristics:

- Form
- Colour
- Rarity
- Ingenuity of design and manufacture

Equally, the 19th century art and social critic, John Ruskin, said that there were four essential characteristics of great art (Ruskin, 1856; *Works*, Vol. 5 pp 48-63):

- Choice of Noble Subject
- Love of Beauty
- Sincerity
- Invention (Imagination)

And, amongst classical writers on this theme, perhaps the greatest advances were made by De Piles, who again identified four characteristics of art (De Piles, 1708, here quoted from De Marchi, 1999, pp. 8-10):

- Design
- Colouring
- Composition
- Expression

De Piles, indeed, attempted to rank the work of 56 different painters using his own estimates of their scores on these four characteristics. And in the modern literature, the hedonic technique has been applied to works of art (Chanel et al, 1996).

However, in this paper, we shall take a different approach. We seek to identify an *implicit taste space* by reference to observed trends in the prices of works of art. The basic logic of our approach is this. If the prices of works by two painters are closely correlated over time, then we assume that these painters are located close together in the taste space. If, on the contrary, the prices of works by two painters are negatively correlated, then we assume that these painters are located far apart in the taste space.

A variety of techniques exist to enable us to map from an $n \times n$ matrix of correlations between objects into a two-dimensional (or higher dimensional) representation of those objects. These include: principal components, factor analysis and multi-dimensional scaling. Such methods give a ready way of illustrating the similarities and differences between different entities - whether they are nations, companies, products, or even consumers. For a wide range of empirical data sets in economics, and other business studies, two components capture a large share of the total variance.

However, these statistical techniques are often used in a rather ad hoc way, which does not describe the precise microeconomics of how correlations in price map into proximity in taste space. That mapping is set out in detail below.

Accordingly, in what follows, we assume that prices are *sufficient statistics* for describing the evolution of tastes in the art market. In reality, they are not. The art historian has much to tell us about influences which change tastes, that are not captured in prices. Even stronger, this paper assumes in effect that a *matrix of correlation coefficients* between the prices of different artists' work is a sufficient set of statistics. This is somewhat stronger, because it does not make use of the more detailed trends in popularity of different artists.

Are these assumptions too strong? In the second edition of *The Principles of Economics*, Marshall provided an interesting insight into why prices might not give a wholly accurate measure of taste:

And therefore the price at which such a thing is sold will depend very much on whether rich persons with a fancy for that particular thing happen to be present at its sale. If not, it will probably be bought by dealers who reckon on being able to sell it at a profit; and the variations in the price for which the same picture sells at successive auctions, great as they are, would be greater still if it were not for the

steadying influence of professional and semi-professional purchasers. The "equilibrium price" for such sales is very much a matter of accident. (A. Marshall, here quoted from White, 1999, p. 79)⁴

Indeed, since our data source (Reitlinger, 1961, 1970) simply records the auction prices of works (and also some prices relating to private sales), we do not know how many potential buyers were "in the market" for a particular work at any time.

However, Ruskin believed that price was a reasonable measure of the artist's rank:

Of course a thousand modifying circumstances interfere with the action of the general rule; but, taking one case with another, we shall very constantly find the price which the picture commands in the market a pretty fair standard of the artist's rank of intellect. (Ruskin 1843; *Works*, Vol. 3, pp. 617-8)

The technique developed below refers to the "height of taste". We mean by this that location on our space of tastes and artists where demand is strongest. We shall assume throughout that at any time the artist whose work comes closest to the "height of taste" will "enjoy" the highest prices. This is an important, if strong, assumption in what follows.

6. Flat or Round? Modernism or Historicism?

Before starting to construct our map of painters, there is one further issue that needs attention. Should the space be flat or round? It is conventional in Multidimensional Scaling and Principal Components to use a linear or planar representation of the data. But there is an implicit but rarely explored assumption behind this procedure, which could be described as the "transitivity of distance". This is an inherent property of planar representations but would not be found, for example, in a spherical projection.⁵ But it is possible that goods exhibiting cycles in popularity may be better represented by circular or spherical projections.

Ultimately, this is an empirical question. And in what follows we shall create both planar and spherical representations. However, the ideas from art history and art theory summarised in Section 3 also give us an important lead here. To achieve the modernist goal that design has, "to be free of any reference to the decorative styles of the past" (Marcus, 1998), it is necessary to locate painters in an *unbounded* plane. If there are any bounds to this space, it is impossible for design to be innovative and continually to evade any reference to the past. Sooner or later the artist will be forced back into a part of the space that has been occupied by earlier artists.

On the other hand, if one accepts that a degree of historicism is an inevitability, then a bounded space will suffice. In that case, we may wish to distinguish between two types of historicism:

⁴ As White notes, this paragraph was abbreviated in later editions.

⁵ To explain this, consider the travel analogy. Suppose we take a train journey from London to Edinburgh via York. Since York is north-west of London and Edinburgh is north-west of York then the distance from London to Edinburgh exceeds the distance from London to York. This transitivity works on a local scale, but it does not work on a global scale. Thus, for example, to fly from London to Tokyo is a journey of 9,600 km to the east, and to fly from Tokyo to New York is a further journey of 10,800 km to the east. But this does *not* imply that the distance from London to New York is greater than the distance from London to Tokyo. Indeed, at 5,600 km that is the smallest distance of the three. So on this global sphere, distance rankings are not transitive.

- *Distant past historicism*: it is legitimate to use the styles of the *distant* past, but not those of the recent past
- *Recent past historicism*: it is legitimate to use the styles of the *recent* past, but not those of the distant past

Assume that the movement of the "height of taste" around the space of artists is continuous and smooth. If artists and tastes are represented on a real line, then when the height of taste hits the boundary of the space, tastes must move in the reverse direction, and this will entail *recent past historicism*. On the other hand, if artists and tastes are represented on a circle, then the height of taste can continue to cycle in one direction (say clockwise) without reversal: this will entail distant past historicism.

When we move from lines and circles up to planes and spheres, some more subtle possibilities emerge. But if distant past historicism is the more common than recent past historicism (and the references cited in Section 3 suggest it is), then a spherical projection may be more useful for the purposes of this paper.

7. Technical Details

This section presents techniques for mapping from a correlation matrix representing the similarities and differences between products to a planar spherical representation of the positions of those products. The reason we choose to represent products on the surface of a sphere and not on the perimeter of a circle is simply so that two degrees of freedom (or two *components*) are obtained - rather than one. A result of considerable power and great simplicity is derived: for two products located on the surface of a sphere, the correlation between their prices is equal to the *cosine* of the angle between them - as measured from the centre of the sphere.

A variety of standard data reduction methods (principal components, multi-dimensional scaling) take a matrix of distances (or similarities) between entities and project these entities onto a plane. Points close together imply that the entities are similar while points far apart imply that the entities are dissimilar.

But as indicated above, there are some disadvantages from projecting onto a plane. In particular, if the "height of fashion" moves around in a continuous fashion, it implies a particular and perhaps restricted pattern of fashion cycles. By contrast, there are some attractions in locating points on the surface of a sphere for in that case a rather different pattern of cycles is available.

In this section we show how to map from a matrix of correlations into planar and spherical projections. But in each case, we start with the easier case of a line and a circle - because these help us to grasp the intuition of what is happening.

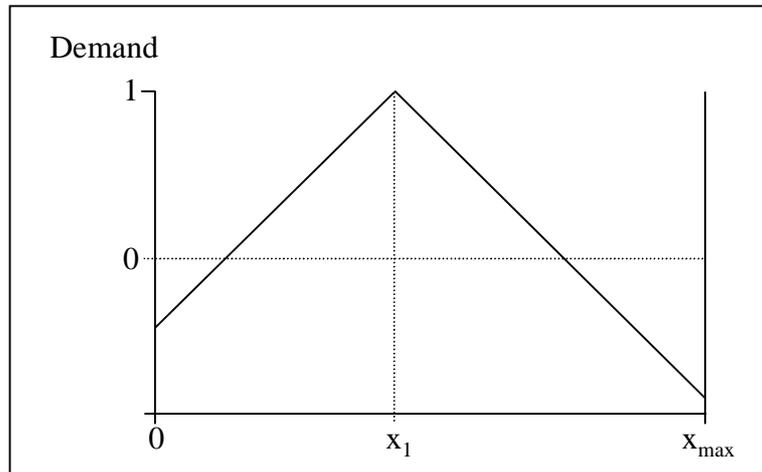
7.1 Line

Assume that each artist is located at some point along a line $(0, x_{\max})$. The "height of taste" is defined as x^* , and the strength of demand at any other point (x_i) along the line is defined as:

$$S(x_i, x^*) = 1 - |x^* - x_i| \quad (1)$$

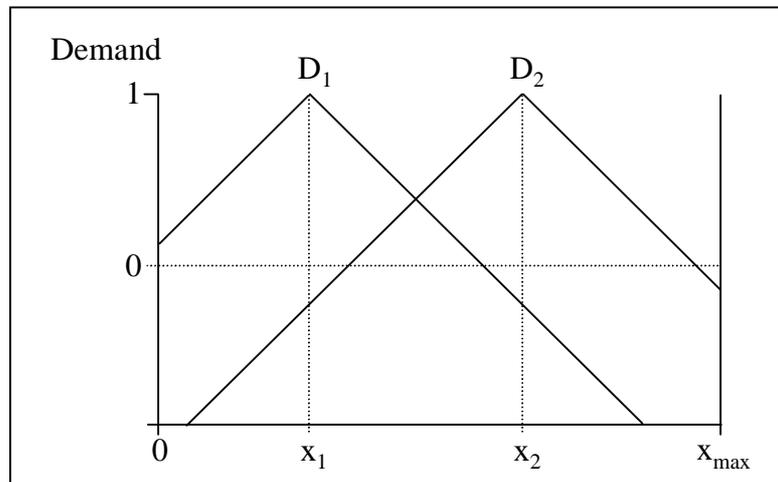
As Figure 1 shows, the signal is at a peak when $x^*=x_i$, and drops away on either side.

Figure 1



We can use this simple model to compute the correlation between demand prices for artists located at different points along the line. To see this, consider Figure 2:

Figure 2



Swann (2001c) shows a very simple and convenient result. Under some assumptions, we can define the correlation between these demand prices as follows:

$$\rho_{12} = \frac{[x_1 - (x_2 - x_1) + (x_{\max} - x_2)]}{x_{\max}} = 1 - \frac{2(x_2 - x_1)}{x_{\max}} \quad (2)$$

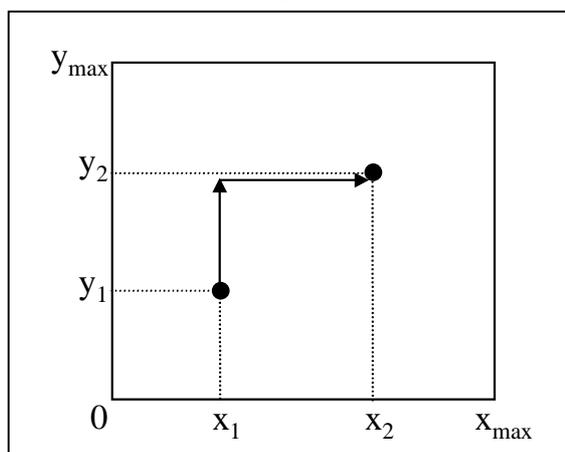
The basic intuition of this result is as follows. We can split Figure 2 into three areas. From 0 to x_1 , the correlation between demand prices is 1; from x_1 to x_2 that correlation is -1; and from x_2 to x_{\max} that correlation is again 1.

In short, there is a natural mapping from positions to correlations: when x_1 and x_2 are located close together, the correlation between their demand prices is close to 1; when they are located far apart, at either end of the painter spectrum, then , the correlation between their demand prices approaches -1.

7.2 Plane

Extending the previous result to a plane is messy rather than difficult. To make it as simple as possible, it is helpful to use a grid measure of distance -rather than an Euclidean measure.

Figure 3



Thus, the distance between any two points (x_1, y_1) and (x_2, y_2) is defined as:

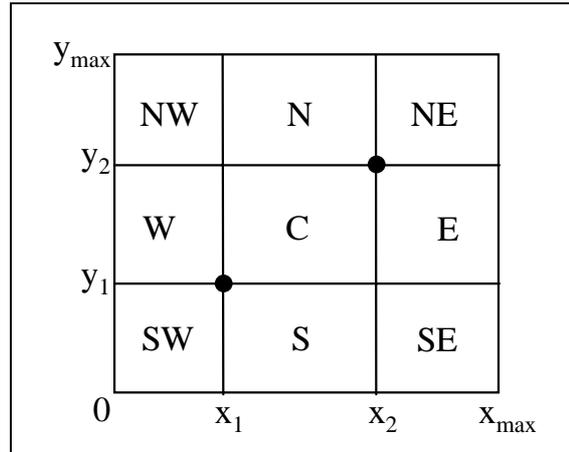
$$L = |x_1 - x_2| + |y_1 - y_2| \quad (3)$$

And as above, we assume that when the height of taste is (x^*, y^*) , then the demand at point (x_1, y_1) is given by:

$$S = 1 - L = 1 - |x_1 - x^*| + |y_1 - y^*| \quad (4)$$

Swann (2001c) shows that the correlation between demand for 1 and demand for 2 can be calculated by the following procedure. Split the plane into nine zones as shown. (Note that this can be done wherever the two points lie. If $y_1=y_2$ then the central horizontal band W-C-E disappears; if $y_2=0$ then the lower horizontal band disappears; and so on).

Figure 4



Swann (2001c) shows that under some conditions, the overall correlation between 1 and 2 over the entire plane can be computed as:

$$corr_{12} = \sum_1^9 a(i) \rho_{12}(i) \quad (5)$$

where $a(i)$ is the area of zone i and ρ_{12} is the correlation between demand for 1 and demand for 2 in zone i . These zone areas and zone correlations are given in the table below:

Table 1

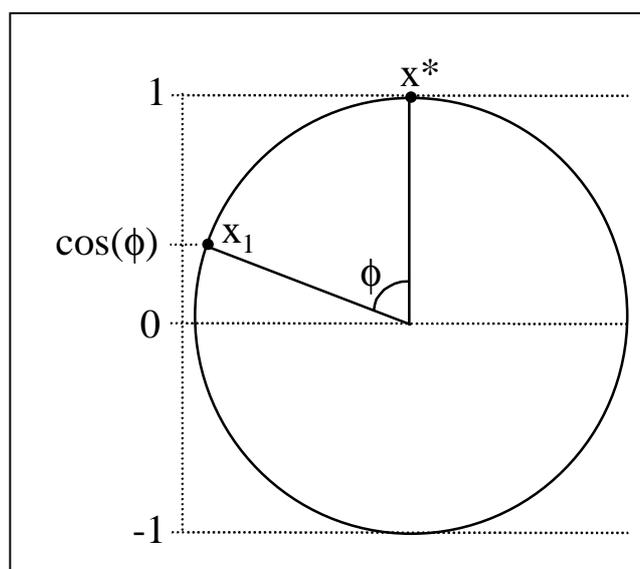
Zone <i>i</i>	Area $a(i)$	Correlation₁₂ $\rho_{12}(i)$
NW	$(y_{\max} - y_2) \cdot x_1$	+1
N	$(y_{\max} - y_2) \cdot (x_2 - x_1)$	$[(y_{\max} - y_2) - (x_2 - x_1)] / [(y_{\max} - y_2) + (x_2 - x_1)]$
NE	$(y_{\max} - y_2) \cdot (x_{\max} - x_2)$	+1
W	$(y_2 - y_1) \cdot x_1$	$[x_1 - (y_2 - y_1)] / [x_1 + (y_2 - y_1)]$
C	$(y_2 - y_1) \cdot (x_2 - x_1)$	-1
E	$(y_2 - y_1) \cdot (x_{\max} - x_2)$	$[(x_{\max} - x_2) - (y_2 - y_1)] / [(x_{\max} - x_2) + (y_2 - y_1)]$
SW	$y_1 \cdot x_1$	+1
S	$y_1 \cdot (x_2 - x_1)$	$[y_1 - (x_2 - x_1)] / [y_1 + (x_2 - x_1)]$
SE	$y_1 \cdot (x_{\max} - x_2)$	+1

Once again, if artists are clustered together in a particular part of the plane, then there is a strong positive correlation in their demand prices. By contrast, if they are located at opposite corners of the plane, then this correlation will be strong and negative.

7.3 Circle

While superficially it may look harder to project points onto a circle than a line (and on the surface of a sphere than on a plane), in fact it is in some respects easier. We shall see that a very simple result obtains: the correlation between the demand for and price of work by two different artists is given by the angle between those two artists as located on the circle and viewed from the centre of the circle. Consider Figure 5:

Figure 5



Suppose that a particular artist is located at point x_1 on the circle, and that at a particular time and date, the most popular artist or "height of taste" is at point x^* . As in the case of the line or plane, we need a function relating demand or demand price for x_1 to x^* .

Here we adopt a slightly different convention to that used in the case of the line or plane. We liken the question to that of computing the brightness of daylight at different places on the globe. Suppose that demand is a signal transmitted from the dotted line at the top of the diagram (which is tangent to the circle at x^* and which passes through 1 on the vertical axis). The intensity of demand felt at any other point on the circle depends on the vertical distance from the transmitter line to that point on the circle.

From the diagram, it is readily apparent that this vertical distance depends on the angle between x_1 and x^* . As drawn, the perpendicular distance from transmitter line to x_1 is $1 - \cos(\phi)$. Hence, if we measure the strength of the signal at x_1 on a scale from -1 to 1, then that strength of signal is given by $\cos(\phi)$. This is reasonable. When the angle between x_1 and x^* is small, so that our chosen artist is close to the "height of taste", then demand is very strong: as $\phi \rightarrow 0$, $\cos(\phi) \rightarrow 1$. By contrast, when the angle ϕ is large, suggesting our chosen artist is far from the "height of taste", then demand is small.

Now, using this framework, we can obtain a remarkably simple and powerful result about the correlation between demand prices for different artists. Take two artists, 1 and 2, located at points x_1 and x_2 on the circumference of the circle. Suppose that the angle between each artist and the vertical (as drawn in the previous figure) is denoted by ϕ_1 and ϕ_2 respectively. Suppose also that the angle between the location of the "height of taste" at any date and the vertical is given by ϕ^* . [Note that in the diagram, $\phi^*=0$.] Then, the strength of demand for the work of painters 1 and 2 is simply defined by $\cos(\phi_1-\phi^*)$ and $\cos(\phi_2-\phi^*)$, respectively.

From this we can obtain the following expression for the covariance of demand prices for 1 and 2. Assume that the "height of taste" might in the fullness of time occur above any point on the circle, and with equal probability. This means that we can assume that the density of ϕ^* is constant over the range $-\pi$ to π . We obtain the covariance by integrating from $-\pi$ to π as shown:

$$\begin{aligned} \text{cov}_{12} &= \frac{1}{2\pi} \int_{-\pi}^{\pi} \cos(\phi_1 - \phi^*) \cos(\phi_2 - \phi^*) d\phi^* \\ &\quad - \frac{1}{2\pi} \int_{-\pi}^{\pi} \cos(\phi_1 - \phi^*) d\phi^* \cdot \frac{1}{2\pi} \int_{-\pi}^{\pi} \cos(\phi_2 - \phi^*) d\phi^* \end{aligned} \quad (6)$$

In fact this expression can be simplified considerably by using two results. First, when k is an *integer* (positive or negative) and because $\sin(a+k\pi) = \sin(a-k\pi)$:

$$\int_{-\pi}^{\pi} \cos(a + k\phi^*) d\phi^* = \frac{1}{k} [\sin(a + k\pi) - \sin(a - k\pi)] = 0 \quad (7)$$

Second, Ayers (1987, p. 143, eqn. 9) shows that:

$$\cos(x) \cos(y) = \frac{1}{2} [\cos(x - y) + \cos(x + y)] \quad (8)$$

Applying the first result to equation (6) we see that the second row of that expression is simply zero. Moreover, using the second result, we see that the first line of equation (6) simplifies to:

$$\text{cov}_{12} = \frac{1}{4\pi} \int_{-\pi}^{\pi} \cos(\phi_1 - \phi_2) \cdot \frac{1}{4\pi} \int_{-\pi}^{\pi} \cos(\phi_1 + \phi_2 - 2\phi^*) d\phi^* = \frac{\cos(\phi_1 - \phi_2)}{2} \quad (9)$$

Now, we can use equation (9) to derive the variance of demand for 1 (or 2):

$$\text{var}_1 = \frac{\cos(\phi_1 - \phi_1)}{2} = \frac{1}{2} \quad (10)$$

From which it is clear that the simple correlation between the demand prices of 1 and 2 is given by:

$$\rho_{12} = \frac{\cos(\phi_1 - \phi_2)/2}{\sqrt{(1/2) \cdot (1/2)}} = \cos(\phi_1 - \phi_2) \quad (11)$$

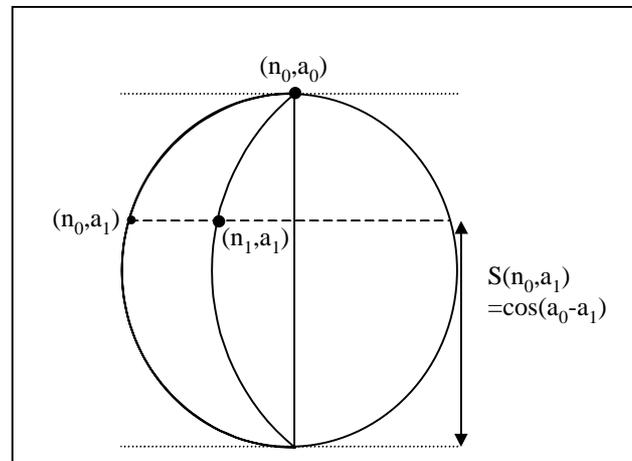
In short, the formula describing the demand intensity for one artist when another is the "height of taste" also defines the correlation between demand prices for the work of different artists. This simple but powerful result plays a central role in what follows.

7.4 Sphere

An equivalent result obtains in the case of the sphere, but the proof is rather more cumbersome. It is also helpful to use a slightly different notation. Suppose that we follow cartographical principles and identify any point on a sphere by its *latitude* (a) and *longitude* (n).

Start by assuming that the "height of taste" is located at the "North Pole" - that is, where latitude = 90°N (or $+90^\circ$, or $\pi/2$). In this case the result from the previous section carries over in a straightforward way. To see this, examine Figure 6:

Figure 6



As in the case of the circle, a radiating plane is tangent to the sphere at the point (n_0, a_0) , where $a_0 = 90^\circ$, which defines the "height of taste". The strength of demand signal at another point is defined by the vertical distance between the radiating plane and that other point. Now, as is clear from the diagram, when the "height of taste" is at the North Pole, then the strength of demand anywhere else depends only on the latitude at that other point. The diagram shows two points (n_0, a_1) and (n_1, a_1) on the same latitude a_1 , and it is readily apparent that the demand strength is the same at both: $\cos(a_0 - a_1)$.

This convenient result does not apply when the "height of taste" is not at the North Pole. Then a more complex formula applies. This asymmetry does not imply any imperfection in the sphere - rather it results from a fundamental asymmetry in the treatment of longitude and latitude in cartography: latitude is defined between -90° and $+90^\circ$ while longitude is defined between -180° and $+180^\circ$.

Figure 7

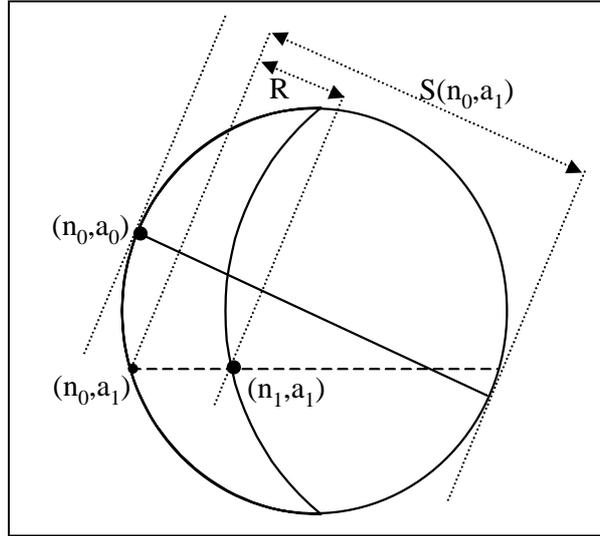


Figure 7 shows the more general case. Here the "height of taste" is at (n_0, a_0) and we wish to compute the strength of demand at another point (n_1, a_1) . It is easiest to do this in two stages. First, define another point (n_0, a_1) which is located on the same longitude as the height of "taste" and the same latitude as the other artist. Compute the strength of the demand signal at (n_0, a_1) by the perpendicular distance between the "radiating plane" tangent to the sphere at (n_0, a_0) and this intermediate point (n_0, a_1) . The strength of demand at (n_0, a_1) is given by $S(n_0, a_1)$. Then, second, compute the perpendicular distance between this intermediate point and the final point (n_1, a_1) . This second distance is defined by R in the diagram. The strength of the signal at (n_1, a_1) can then be computed as: $S(n_0, a_1) - R$.

The first stage is easy. Because (n_0, a_0) and (n_0, a_1) are on the same longitude, then we can use the result of the previous section to compute the strength of signal at (n_0, a_1) . It is simply given by $\cos(a_0 - a_1)$.

The second stage is a bit harder. First, compute the horizontal distance from (n_0, a_1) and (n_1, a_1) along the horizontal (and dotted) latitude line. This can be calculated as follows. The horizontal girth of the sphere at latitude a_1 is given by $2\cos(a_1)$. At the equator ($a_1=0$), the horizontal girth is at its maximum (equal to the diameter of the sphere, which is 2). Away from the equator, the girth is smaller. The horizontal distance between (n_0, a_1) and (n_1, a_1) however, is only a proportion of this girth, equal to:

$$2 \cos(a_1) \cdot \frac{[1 - \cos(n_0 - n_1)]}{2} = \cos(a_1) \cdot [1 - \cos(n_0 - n_1)] \quad (12)$$

Moreover, this horizontal distance between (n_0, a_1) and (n_1, a_1) overstates the distance when measured perpendicular to the "radiating plane" (R). To obtain R, we need to multiply the horizontal distance by $\cos(a_0)$.

Hence the strength of demand at (n_1, a_1) when the "height of taste" is at (n_0, a_0) is defined by:

$$S(n_1, a_1) = \cos(a_0 - a_1) + \cos(a_0)\cos(a_1) \cdot [1 - \cos(n_0 - n_1)] \quad (13)$$

By putting $a_0 = 90^\circ$, we can see that this formula handles the special case where the "height of taste" is at the North Pole - and where the strength of demand is simply $\cos(a_0 - a_1)$.

Once again, it can be shown that this formula for the strength of demand can also be used to compute the correlation between demand prices of two different artists. The proof is very cumbersome but the basic idea is as follows. Once again, define two different artists 1 and 2 by the longitude/latitude co-ordinates: (n_1, a_1) and (n_2, a_2) . Again, assume that the "height of taste" could be found with equal probability above any point on the surface of the sphere. Then we can show (Swann, 2001) that the correlation between the demand prices of 1 and 2 is given by:

$$corr_{12} = \cos(a_1 - a_2) + \cos(a_1)\cos(a_2) \cdot [1 - \cos(n_1 - n_2)] \quad (14)$$

Finally, we can - as a special case of the sphere - locate points on a hemisphere. This is done simply by limiting the longitude to the range $\{-\pi/2, +\pi/2\}$.

8. Some Illustrative Results

The main data for this study come from Reitlinger's (1961, 1970) studies of the auction prices of works of art. In addition, we have generated an approximate price deflator using data from Mitchell (1980) and Mitchell and Deane (1971). In particular, we have focussed on the auction prices of oil paintings by some of the major artists on the 17th, 18th, 19th and 20th centuries. We should add, of course, that some of the artists commanding high prices in the past have fallen right out of favour in the twentieth century. Indeed, that is one of the phenomena that this study has set out to explore. Accordingly, the criterion for inclusion is that the artist commanded relatively high prices (in real terms) at some point of the evolution of the art market between 1800-1970, even if his/her work is not highly priced now.

Guerzoni (1995) has discussed some of the shortcomings of these data. The raw data are not in an ideal form for econometric analysis. This is no reflection on the *accuracy* of the data. Indeed, since these are for the most part, auction prices, where the agreed sums are recorded, then the data are very accurate. A few prices are estimated by Reitlinger, but this is not a serious source of error.

Rather, the problems with these data reflect two main factors. The first is the non-homogeneity of works of art. Clearly different works are unlikely to be of equal merit. Some are small paintings, others are large canvasses. While art historians have documented these paintings in great details, we did not (as discussed above) think it practical to attempt to turn these qualitative descriptions into a list of characteristics or to construct a hedonic analysis of art prices. At most, we have tried to reduce the degree of variance in art prices by restricting our attention to oil paintings, neglecting most watercolours or prints, and neglecting the smaller works or studies. Also, where 2 or 3 paintings were sold as a lot we have attributed the total price paid between the constituent parts of the bundle.

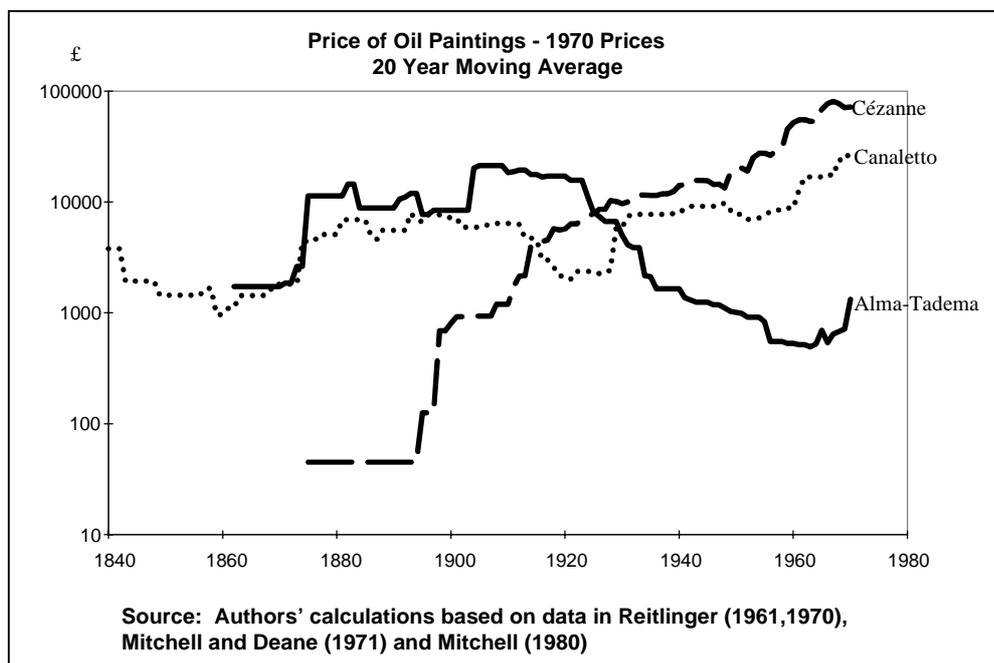
Second, while the volume of art traded increased markedly in the post-war period - and in particular during the 1960s, this is still a fairly thin market. Amongst the great old masters, indeed, few works of significance came up for auction in recent years. As a result, it has not been practical to include a number of old masters in our sample - as there is just too little data, and what sales there are do not represent their great works. Moreover, sales are infrequent and unevenly spaced.

While some econometricians might wish to delve into the peculiar time-series properties of these data, we have chosen instead to perform a very simple analysis of these data, in three steps. First, we have constructed an average price for each artist in each year as follows. We take a 20-year moving average covering all the items sold in the last 20 years. Naturally, this smoothes the raw data considerably.

Second, we have deflated these prices by a general price index derived from Mitchell (1980) and Mitchell and Deane (1971). A little splicing was required to make the index continuous back to 1840, and while it is far from perfect, it is adequate for our immediate purposes. Some have argued that it would be even more interesting to deflate by an art price index, so that one can look simply at relativities within the art market, and abstract from the secular upwards trend in art prices during (for example) the 1960s. Eventually, we may be able to do that, but it would require a more comprehensive set of prices that we have analysed so far.

Third, we have computed a simple correlation coefficient between the price series for each painter. In practice, it is unlikely that a simple correlation coefficient is a sufficient statistic for all the analysis we might want to do here. For example, some artists have shown price cycles with relatively low periodicity, while others have exhibited perhaps one major cycle in a hundred years or more. Figure 8 illustrates this for three artists, chosen more or less at random, but who do happen to show some very different time-series properties.

Figure 8



However, for the preliminary analysis in this paper, we shall work just with these correlation coefficients using data on the prices of works by 20 artists (listed in Appendix 1) for up to 130 years.

Econometric Methods

With the correlation matrices computed as described in the previous section, we have applied the methods of Section 7 to create some preliminary artist maps. Of course, as noted above, this is by no means a new procedure since there is a very well established tradition of using principal components (or multidimensional scaling) to construct such maps. However, the analysis of Section 7 helps to bring out more precisely the way in which product locations in a characteristics space map into demand price correlations. And it is only with that precision that we can hope to discriminate between planar and spherical projections as a means of representing these data.

The basic procedure is straightforward. For any set of co-ordinates for all the artists in our sample, we can compute the matrix of implied correlations between them. We can then compare that to the actual and compute a matrix of residuals. We then add up the absolute values of these residuals across each element in the correlation matrix to obtain a sum of absolute residuals. The aim of our optimisation algorithm, then, is to choose the set of co-ordinates which minimises this sum of absolute residuals.

The minimand is of course a highly non-linear function of the co-ordinates. But we can apply the Lasdon-Waren GRG2 (Generalised Reduced Gradient) non-linear optimisation code to solve this. The problem can be seen as an exercise in

mathematical programming: we have to minimise the sum of absolute residuals with upper and lower limits on all the co-ordinates. For the planar representation, we assume that all artist co-ordinates are between 0 and 1 on both axes. For the spherical representation, the latitude must be between $-\pi/2$ and $\pi/2$ while the longitude must be between $-\pi$ and π .

Results

The sum of absolute residuals for the 400 elements of the correlation matrix comes to 23.5 for the planar representation and 17.4 for the spherical representation. This could suggest that the spherical representation is slightly preferable, but we are cautious about making such a claim. The results described here are preliminary and we cannot be certain that we have reached the global optimum in each case. These statistics correspond to a mean absolute error of 4 percentage points in the spherical representation and 6 percentage points in the planar representation. These figures are quite acceptable.

Figures 9 and 10 show, respectively, the co-ordinates obtained for the planar and spherical representations. They are actually strikingly similar. In Figure 9 we have superimposed a dotted circle, within the plane, and it is striking how most artists cluster around this circle. Indeed, this suggests that were we to constrain the artists to lie on a circle and not on a sphere then that constraint would not do too much damage to the data. By contrast, it is clearly inappropriate to constrain the artists to a (one-dimensional) line.

We can also use these charts to interpret the main trends in the prices of these artists during the period 1840-1970. In the 19th Century and at the start of the 20th Century, the artists (Landseer, Collins, Meissonier, Alma-Tadema) in the top left hand part of these charts were at the "height of taste". During the early and middle part of the 20th century, the "height of taste" was moving in an anti-clockwise fashion, with a strong revival in the prices of Nattier and Hals. The first of the impressionists in the bottom right (Renoir) was also the first to enjoy a rapid growth in prices early 20th Century, while the prices of artists further to the right took off later (van Gogh and Bonnard).

In short, the "height of taste" has - over a hundred years or so - completed rather more than half an anticlockwise circuit from top left to bottom right. Where next?

The results here probably don't bring out the full advantage of the spherical projection over the planar. Indeed, in the best solution obtained to date, no painter is located on the back of the sphere: the front hemisphere fits everybody in comfort. This work is continuing, and when we complete computations for a much larger number of artists, it is likely that the algorithm will need to spread out the artists over a wider area, and some will locate on the back of the sphere.

Figure 9: Planar Map of 20 Artists

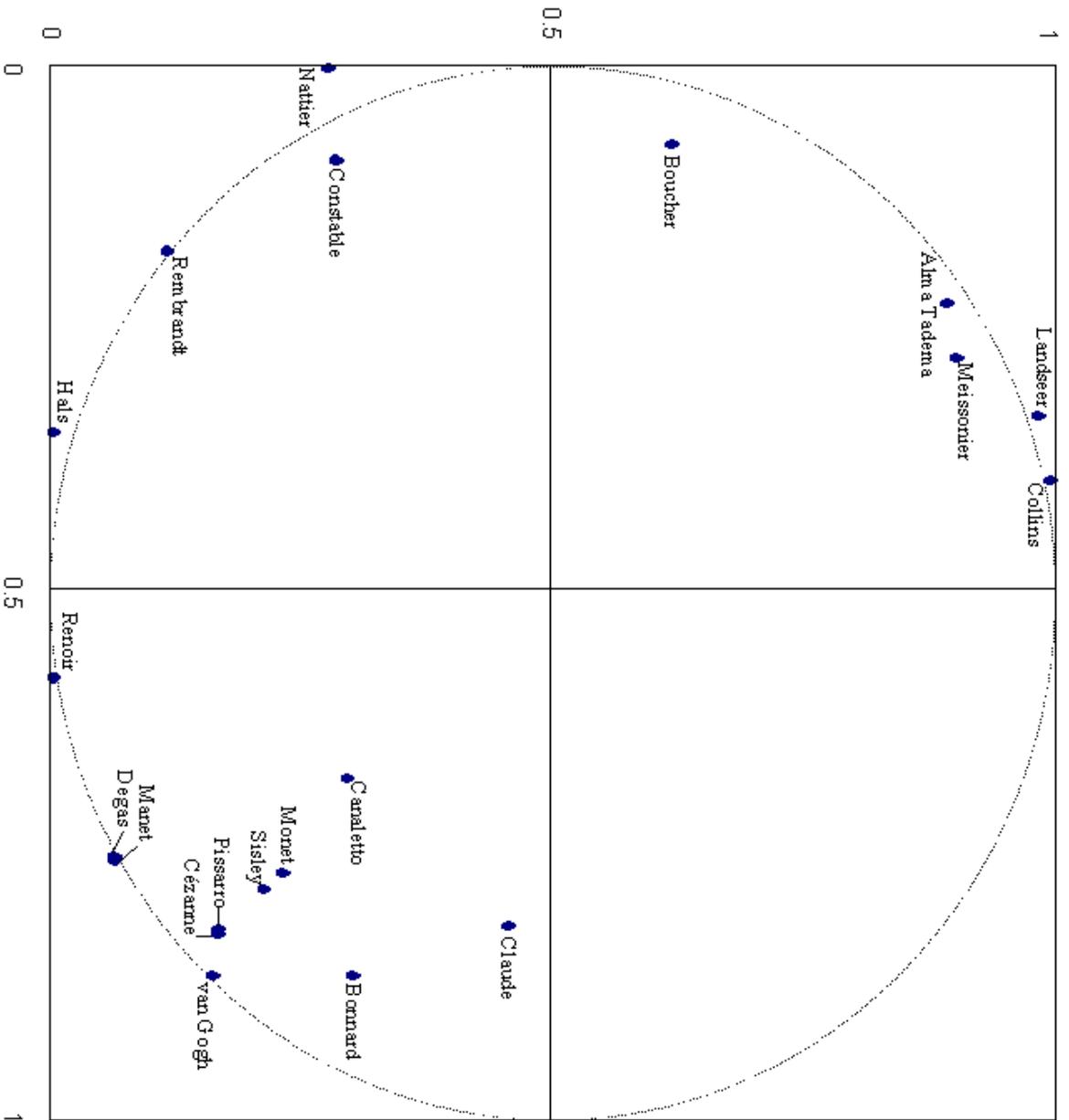
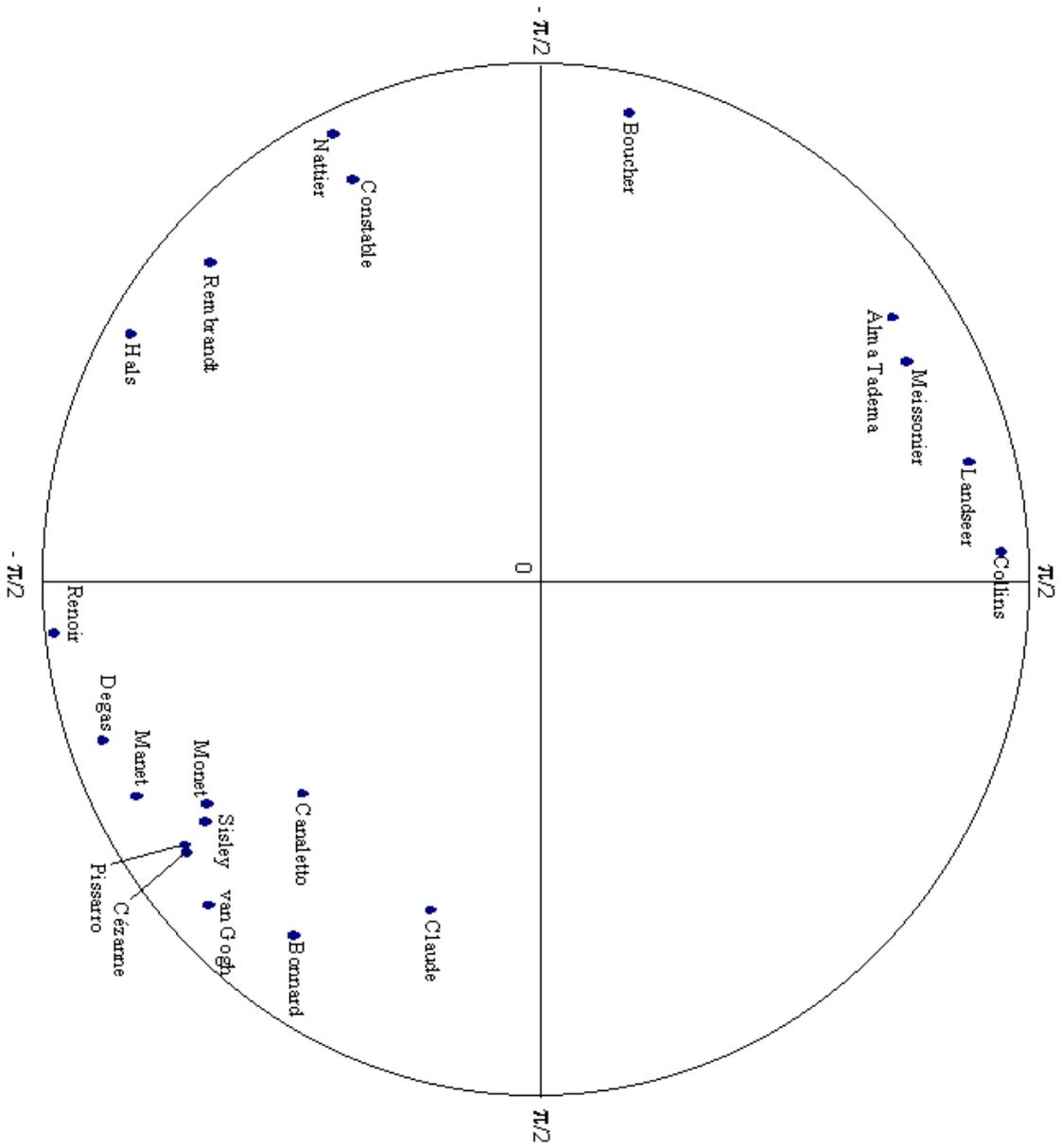


Figure 10: Spherical Map of 20 Artists



9. Conclusions

The aim of this work is to construct a map of artists and to illustrate how tastes evolve within that map. We have seen that there is an interesting similarity between some of the economic models of evolving tastes and what art historians and art theorists have written about the evolution of art. Moreover, we have seen that the evolution of tastes is clearly a path dependent process, in the sense of the term defined by Paul David. Rather than constructing a characteristics space for works of art, the paper constructs an *implicit space* of painters derived from the correlations between prices of different painters' work. We discuss whether a planar representation or a spherical representation would be preferable. We suggest that the modernist ideal, that new art be divorced from any reference to the past, requires an unbounded planar representation. We also distinguish between two types of historicism: distant past historicism and recent past historicism. The former fits more comfortably with a spherical representation while the latter fits best with a planar representation.

The main theoretical results of the paper are to show exact methods for deriving planar and spherical representations of artists from a correlation matrix of prices. The spherical representation offers a result of striking power and similarity. For two artists located on a circle, the correlation between the prices of their work is shown to equal the cosine of the angle between them - and an analogous result applies to the spherical case. These methods are applied to a representative sample of data on the prices of work by 20 artists, taken from the period 1840-1970. The maps generated show these painters arrayed over three-quarters of a hemisphere, and the "height of taste" has - over a hundred years or so - moved top left to bottom right.

This work is still ongoing. But the techniques presented here offer an interesting way to map artists, so that we can better understand the path dependent nature of tastes in art, and the associated waves in popularity of different artists.

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Appendix 1
List of Artists Analysed in this Study

Alma-Tadema, Lawrence: 1836-1913
Bonnard, Pierre: 1867-1947
Boucher, François: 1704-1770
Canaletto, Antonio: 1697-1768
Cézanne, Paul: 1839-1906
Claude Le Lorrain (or Claude Gellée): 1600-1682
Collins, William: 1788-1847
Constable, John: 1776-1837
Degas, Edgar: 1839-1917
Hals, Frans: 1584-1666
Landseer, Edward: 1802-1873
Manet, Edouard: 1832-1883
Meissonier, Ernest: 1815-1891
Monet, Claude: 1840-1926
Nattier, Jean-Marc: 1685-1766
Pissarro, Camille: 1831-1903
Rembrandt van Ryn: 1606-1669
Renoir, Pierre Auguste: 1841-1919
Sisley, Alfred: 1840-1899
van Gogh, Vincent: 1853-1890

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