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Speaking of Graphics

Chapter 4

Playfair and Lineal Arithmetics

William Playfair can be rightly considered as the one who, more than 200 years ago, laid the foundation for the art and science of statistical diagrams. More recently, the memory of Playfair's pioneering work has been revived by Edward Tufte [1]. Many of the elements of Tufte's theory of statistical diagrams are illustrated by means of reproductions from Playfair's work. When it is considered that the early diagrams had to be engraved on copper plates and sometimes colored by hand, one can only wonder how so much quality could have been produced with such scarce and primitive means.

William Playfair is best described as a pamphletist, a kind of independent journalist who tried to earn a living from publications on matters of current economical and political interest. He was a great admirer of his contemporary Adam Smith [2]. Although he had not received academic training, Playfair did not shy of publicly attacking and criticizing the economical and political system of his days. To this effect he chose to use diagrams as a vehicle for expressing his ideas in defense of the monarchy and advocating the strength of England. Hence we can draw a parallel with the work of Florence Nightingale that was to appear 70 years later and to which we will refer in a subsequent chapter [3]. Where Nightingale tried to gain support for her sanitary reform and looked for alliances to promote her plans, Playfair seems to have been less tactful and diplomatic. As a result he does not seem to have won many friends for his cause. Most of his enterprises failed, and he reportedly died in disgraceful circumstances. The historical background to Playfair's work, however, is so colorful and surprising, that it is worth to be related here. What follows

is the story of William Playfair as it transpires from his own writings and from scarce primary sources.

4.1 Life and work of Playfair

William Playfair was born in 1759 in Scotland at Benvie close to Dundee, the son of a clergyman. His elder brother was John Playfair (1748-1819), a mathematician and geologist, who became professor of natural philosophy at Edinburgh. The latter is still known for the English edition of the Elements of Euclid's Geometry. The influence of his 11-years older brother John is related by William as follows [4]: 'At a very early period of my life, my brother, who, in a most exemplary manner, maintained and evaluated the family his father left, made me keep a register of a thermometer, expressing the variation by lines on a divided scale. He thought me to know, that, whatever can be expressed in numbers, may be expressed by lines.'

The use of line diagrams to express the relationship between two variables, more specifically the evolution of a physical quantity with time, was already described by Nicole Oresme in the late scholastic period around 1350 [5]. It has been formalised by René Descartes (1638) as part of his coordinate geometry [6]. One can assume that in Playfair's time line diagrams were already well-established in mathematics and physics, as evidenced by the work of the Swiss-German physicist J.M. Lambert. The latter derived the rate of evaporation of water as a function of temperature from the simultaneous recording of the height of a capillary column of water and of the ambient temperature, both as a function of time [7]. Playfair's innovation seems to lie in the application of the graphical method to economical and sociological quantities, such as the revenues of the

state, prices of commodities, imports and exports to and from various countries, number of inhabitants, size of armies, extents of land, etc. The vast majority of the diagrams that Playfair has produced are time series, showing the variation of a quantity with time.

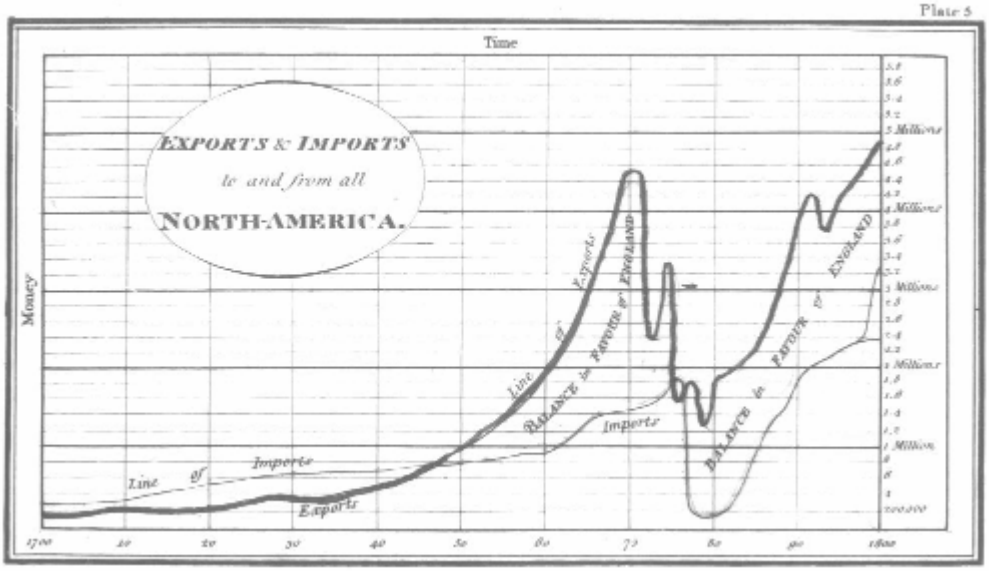

Figure 4.1. Plate 5 from 'The Commercial and Political Atlas' of 1801 showing exports and imports of England to and from North America throughout the 18th century.

William Playfair started to work as an apprentice with Andrew Meikle, the inventory of the threshing machine. In 1780, at the age of 21, William Playfair was employed in Birmingham as a draftsman by Boulton and Watt. It is not known to what extent this early industrial occupation has influenced his later life.

Six years later, in 1786, Playfair published his master piece, entitled 'The Commercial and Political Atlas' [8]. As the subtitle indicates, this charming little booklet '...represents at a single view, by means of copper plate charts, the most important public accounts of revenues, expenditures, debts and commerce of England'. It truly deserves the name of Atlas,

which he borrowed from Gerard Mercator's famous collection of geographical charts [9].

After the first publication of his Atlas in 1786, according to his own account, he left for France in 1787 [10]: 'When I went to France in 1787, I found several copies there ... [one of which] was presented to the King, who being well acquainted with the study of geometry, understood it readily and expressed great satisfaction.' Subsequently, in 1789 'The political and economical Atlas' was translated in French and, on this occasion, Playfair obtained an exclusive royal privilege for his invention and its 'manufacture'. He was also invited to attend a session of the Académie des Sciences at the Louvre where his work was presented. It is perhaps not surprising that the royal support and interest from the king of France for his early work turned Playfair into an adversary of the French Revolution that was soon to break out. It is alleged that he took active part in the early uprisings and that for this he was expelled from France in 1790 by the revolutionary government.

Upon his return in England he published a vehement pamphlet against the French revolutionaries, especially the Jacobinist fraction [11]. Shortly thereafter in 1796, he opposed those in England who were in favor of making peace with France because of the staggering cost of the war, the heavy burden of taxation and the increasing national debt that resulted from it [12]. Surely, he meant to apply his invention to matters of immediate consequence: 'If our English pseudopatriots are determined to exhibit to our enemies, our increasing debts, ... I surely may be permitted to shew, at one single view, that our resources overtop our burthens.' One may wonder whether his exhortations had any effect on the course of

events. What is certain, however, is that Playfair won for himself abroad the label of 'enemy of France' for many years to come.

The turning of the century marked a fruitful period in Playfair's life. In this period appeared 'Lineal Arithmetics' (1798), 'The statistical Breviary' (1801), the revised and extended edition of 'The political and economical Atlas' (1801), ' An Inquiry into the permanent Causes of the Decline and Fall of powerful and wealthy Nations' (1805), already cited, and several other works. At that time he was fully aware of the uniqueness and originality of his geometrical approach to matters of commence and finance which he had commenced 15 years ago. His 'Statistical Breviary' is remarkable for the multivariate description of the political and economical situation of Europe in the 18th century [13]. In one single diagram he combined revenues, population and surface of the main countries, which can be considered as the forerunner of multivariate diagrams.

Playfair tried to explain his method to his contemporaries using applications from the economical and political context of his days, such as the rising debt of the nation, the high level of revenues exacted from the population and the ongoing war with France. He earned some international recognition and was praised by Alexander von Humboldt (1769-1859), a famous German geographer and meteorologist. From a technical point of view, his charts had reached a high degree of perfection and craftsmanship, as Tufte remarked, quite above that of his earlier work [1]. Playfair realized that diagrams are objects of thought and imagination, with a language of their own. He also understood the multivariate aspect of the world of finance and economy that he wanted to explain visually and

he realized that it is mandatory to see multiple variables at the same time. In 1814, the year of the defeat and abdication of Napoleon, Playfair was back in Paris, where he became editor of 'Galignari's Messenger'. Four years later, in 1818, he is convicted to three months of imprisonment for defamation. He returned to London, where he died in 1823, reportedly in misery and poverty, after 64 years of a turbulent and prolific life. The British Library general catalog lists 34 of his works.

4.2 The Commercial and Political Atlas

Playfair's Commercial and Political Atlas presents a succession of charts, mostly time-series, some of them hand-colored and each faced by a page providing a brief political and economical interpretation of the main features of the opposing diagram. The Atlas must have attracted some attention from the public, as it was reprinted the year after in 1867. A third revised and updated edition became available in 1801, 15 years after the first publication. A splendid and now almost classic example from the third edition is the chart of 'Exports and Imports to and from all North America', covering the period from 1700 to 1800 [14] and which is shown in Fig. 4.1. Note that this time series extends until the year before that of its publication. A feat that is rarely accomplished today in the publication of national accounts and census data which usually take several years before they are committed to print. As to the source of the data, Playfair testifies that [15]: '... they are taken from the accounts laid down every year before the House of Commons, therefore may be regarded upon as the best that are to be produced.' Most of his data had been recorded by Act of Parliament in the Custom-House Books and in the Public Accounts from the Journals of the House of Commons. They were there for everybody to peruse, but, Playfair seemed to be the first to present them in a, at that time, novel graphic format.

What could have been Playfair's motivation for doing so? In the preface to his Atlas, he states: '... a man who has carefully investigated a printed table finds, when done, that he has only a very faint and partial idea of what he has read, and that like a figure imprinted on sand it is soon totally

erased and defaced.' One should note the highly pictorial and imaging style which is characteristic for the pamphletist he will become in later life. He also defended his 'applications of the principles of geometry to matters of finance' as follows [15]: '... it is necessary to produce novelty, but above all to aim at facility in communicating information, for the desire of obtaining it has diminished in proportion as disgust and satiety have increased.' The above statement reveals the other darker side of Playfair, who often offers bold statements when logical and mathematical arguments would have served better. This aspect of his character has contributed to his later troubles and misfortune. Nevertheless, the following passage from his Atlas sounds almost prophetic when projected against the present-day background of the European continent: 'A great change is now operating in Europe and though it is impossible to guess in what it will most likely terminate, yet it is very certain that it will neither in a political nor a moral view return to its former situation. The minds of men, the boundaries of nations, their laws and relation with each other, are all in a state of change, and commerce must feel the consequences of those events of which it has been a principal cause.'

Playfair was convinced that history is reflected (or 'painted to the eye') in the charts and that it can be reconstructed graphically from socio-economical data [15]: 'The author presumes to think that the mode of painting to the eye the transaction of past times, is a considerable step in making that investigation easy ...'. In his 'Statistical Breviary' of 1801 he maintains that [13]: 'of all the senses, the eye gives the liveliest and most accurate idea of whatever is susceptible of being represented by it. ... For no study is less alluring or more dry and tedious than statistics, unless the mind and imagination are set to work.' He also took great care in

explaining the reading rules of his charts [15]: '... it remains only for me to request that those who do not, at first sight, understand the manner of interpreting the Charts, will read with attention the few lines of direction ... after which they will find all the difficulties entirely vanish ...' In his 'Lineal Arithmetics' of 1798 he compares the charts with musical scores [16]: '... the bottom line is divided into space representing years, and the right hand line into sums of money, exactly in the manner of music that is printed.'

4.3 History as reflected in commercial charts

Figure 4.2. Boston tea party (1773). American colonists disguised as Indian natives throw shiploads overboard, an incident which precedes the commencement of the American revolution.

In the chart of trade with North America during the entire 18th century (Fig. 4.1), Playfair identified several phases in the commercial and political relationship between Great Britain and North America [15]. In the early part of the time series, the trade relationship is typical for that between a colony and its motherland. Exports from England were relatively low and paid for by imported goods of what the colony produced. The balance between Exports and Imports weighed against England until about 1746 when it rapidly became in favor of England, which was evidence for the increasing wealth in the colonies. This phase reached a peak value in 1770. From that point on, speculative oscillations took place. When prospects in the colonies looked promising, credit was easily granted by

the banks to traders, and as readily withdrawn when the colonies failed to pay for delivery. The nonlinear and chaotic behavior of the socio-economic variables was in fact tell-tale signs for irreversible processes, for catastrophic changes and creation of new order. The first dip in the line of exports occurred in 1773, the year of the Boston tea party, when angry colonists, disguised as Indian natives, seize three ships in the harbor of Boston and throw the freight overboard (Fig. 4.2). Shortly thereafter the balance of trade reversed against England in 1775, the year of the commencement of the American Revolution, when George Washington took command of the armies of the 13 united colonial states. One year later, however, the balance was restored in favor of England and the normal course of business resumed after 1781, the year of the victory by allied American and French troops at Yorktown, which announced the conclusion of the war of independence. (Note that there is perhaps a slip of the engraver on this chart in the rightmost part of the line of imports. We will assume that the upper branch of the bifurcation is the correct one.) A peculiarity of the 1801 version of the trade chart for North America is the lack of quantitative agreement with the original one of 1786. The latter, which covers the period from 1770 to 1782, agrees in its general proportions with the corresponding part of the more extended chart in the revised edition of 1801. There are obvious discrepancies, however. For example, the export value in 1774 is read as 3.85 million pounds in the earliest version, and as 3.25 million pounds 15 years later. In the first version, exports decreased between 1780 and 1782, while they started to raise in the later one. Since Playfair rarely included tabulated data with his diagrams, it is difficult to decide which one is more correct. Sometimes it is argued that the joint publication of tabulated data and its graphic representation is redundant. Tables and diagrams, however, serve

different purposes. They are perceived and processed in different ways by the mind, and therefore are best presented together within the same publication, and as closely as possible.

A shortcoming of the diagram in Fig. 4.1 is the use of current monetary values rather than the corresponding real (factor) values, adjusted for inflation. The effect of inflation may have exaggerated the steeply rising curves of import and export in this time series. Playfair was aware of this effect, since he included in the same Atlas a chart showing the evolution of the national debt using deflated figures. The sign of the balance of trade would have been the same, however, with or without adjusted figures. Playfair's chart of Fig. 4.1, however, deserves the label of graphical excellence bestowed upon by Edward Tufte, because of its historical significance and on the merits of its technical qualities, among which the unobtrusive grid lines, variable line thickness and clear legends. The quality also includes an element of proportion, which according to Playfair refers to the form and shape of the curves in his chart. This proportion results from the simultaneous viewing of the curves showing the progression of import and export with time.

Playfair had a holistic and multivariate vision of his charts [15]: '... it gives a simple, accurate and permanent idea, by giving form and shape to a number of separate ideas, which are otherwise abstract and unconnected. In a numerical table there are many distinct ideas given, and to be remembered, ... This mode unites proportion, progression and quantity, and consequently one act of memory.' The term proportion is to be understood here as the shape of a curve such as it is perceived by the mind, and similar to the shape (or Gestalt) which we remember of

persons, animals and so on. In this sense, Playfair speaks of his charts as objects of thought and imagination, endowed with the property of proportion (from the shape of the curves), progression (with time) and quantity (in terms of monetary value). The analogy with the shapes of continents and seas on maps in a geographic Atlas is compelling. A similar holistic position has been taken already around 1350 by Nicole Oresme, who proposed that objects are endowed with particular shapes defined by the evolution of their physical quantities (temperature, velocity, etc.) with time [17]. Tufte commented on the chart [18]: 'To Playfair graphics were preferable to tables because it showed the shape of the data in a comparative perspective.' The modes of comparison of the chart are, on the one hand, across successive points in time and, on the other hand, between export and import. Playfair stated that : 'On the whole this chart exhibits ... a very strong and curious contrast.' We will expand the concept of contrast in the forthcoming chapters on multivariate graphics, in which we will show that contrasts can be defined as deviations from what is expected. The presence of strong contrasts induces an element of surprise.

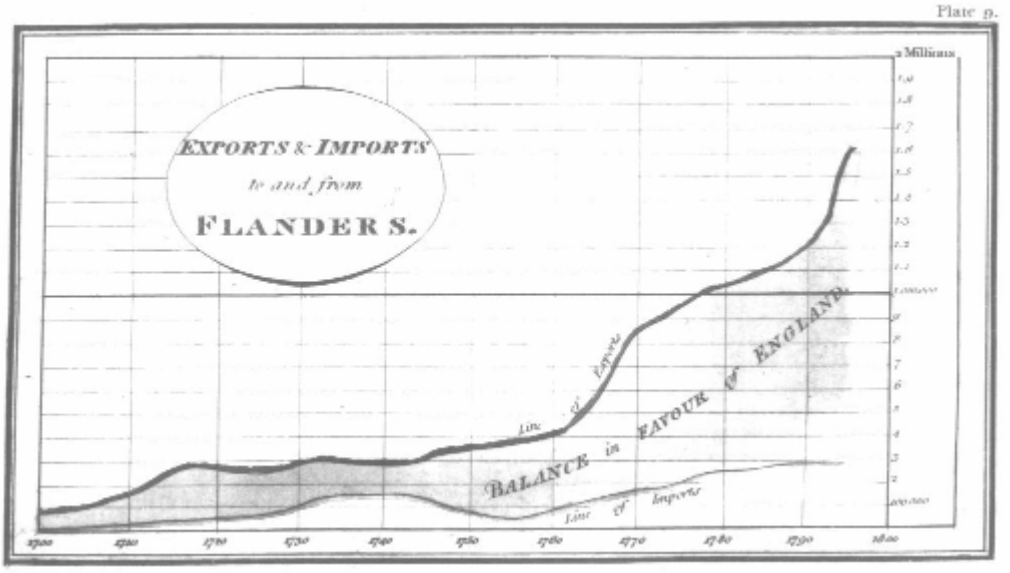

Figure 4.3. Plate 9 from 'The Commercial and Political Atlas' of 1801 representing exports and imports of England to and from Flanders during the 18th century.

Thus far we have emphasized two additional qualities of statistical graphics, namely allowance for comparison of shapes and ability to show interesting and strong contrasts. A remarkable feature of the Commercial and Political Atlas is its systematic and repetitive lay-out which allows for comparison of shapes and for detection of contrasts across successive charts. For comparison we reproduce in Fig. 4.3 the chart which shows the exports and imports of England to and from Flanders during the 18th century [19]. Playfair comments on the page which faces the chart on the rising exports from England during the later decades of the time series : 'The excellence of our hardwares, and many woven stuffs, have been the occasion of this late increase and balance in our favour.' The comparatively low import from Flanders elicits some rather dry remarks which betray the pamphletist: '... they have no natural productions to furnish us with to any considerable amount, at least not such as we want ... . There are other markets near at home, and better than England, for whatever Flanders has to spare.' Then he proceeds in a slightly

admonishing and moralizing tone: 'Such a trade as this is of more real advantage than one of a much greater amount to America, which cannot pay for anything soon, and often does not at all; and which opens a wide field of deception. Yet such is the disposition of men, that we value what is speculative and precarious, more than what is safe and beneficial. The support and protection of our trade to Flanders ought to be a matter of public attention, as it is of great public advantage.' One needs only to compare Figs. 4.1 and 4.3 to become convinced of the truth of Playfair's statement. Although the absolute level of exports to America was around 1800 about 3 times larger than that to Flanders, the balance in favor to England appears to have been almost equal (1.6 millions for America versus an extrapolated 1.4 millions for Flanders). If one were to account for the losses incurred by England during the American war of independence, the contrast would be even more striking. Clearly, the Atlas is to be read as a large mosaic, all charts combining into one large shape, much like in a matrix of scatter plots.

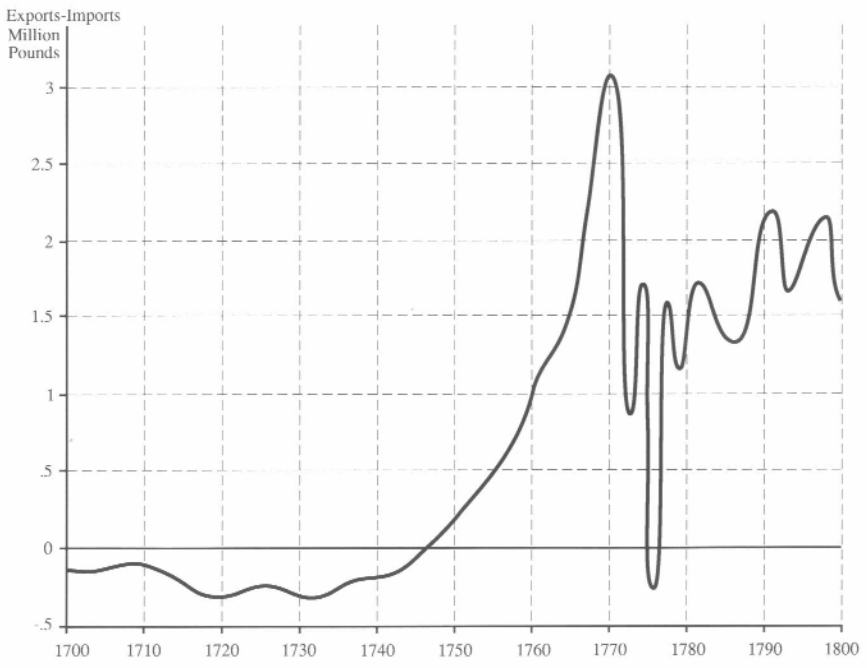

Figure 4.4. Difference chart representing the balance of trade between England and North America during the whole of the 18th century. The chart has been obtained from measurements made on the individual curves of Fig. 4.1.

4.4 Lineal Arithmics applied to the commercial charts

William Cleveland has drawn attention to a problem that occurs when one is requested to judge vertical distances between two time series, such as the balance between exports and imports as a function of time [20]. His observation has been illustrated by means of a chart from Playfair's Atlas representing exports and imports between England and India. In some cases the eye is not capable of picking up large differences between exports and imports, especially when there are abrupt changes in exports, imports or both. A so-called difference chart, representing the difference between exports and imports against corresponding years, is more suitable for the detection of interesting details of the balance of trade, than the original amount chart. This observation can be confirmed by means of the difference chart in Fig. 4.4 which we derived from measurements made on the original curves of exports and imports of England to and from North America in Fig. 4.1. Surprisingly, we observe from 1773 onwards a more regular pattern of oscillations on the difference chart than would be expected from looking at the original curves. Note the deep troughs around 1773 (Boston tea party) and 1775 (commencement of the war). The oscillations of the trade difference during the later decades can be easily overlooked in the original chart, because of the rapid rise of exports and imports in those years.

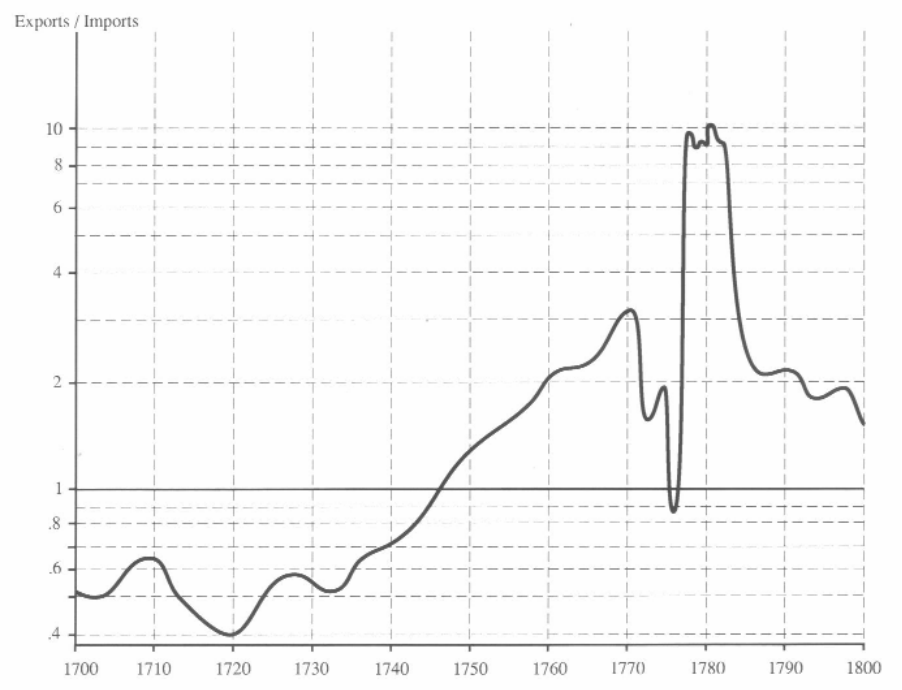

Figure 4.5. Log-ratio chart representing the logarithm of the ratio of exports to imports for the trade between England and North America during the 18th century. The chart has been constructed from measurements on the individual export and import curves of Fig.4.1.

We propose here an alternative to the difference chart in which the ratio of exports to imports is plotted on a logarithmic scale as a function of time. Such a 'log ratio chart' shows relative changes that are independent of the unit of measurement. Hence, it does not suffer from the effect of inflation, which in Playfair's charts prevents a truthful comparison of monetary quantities at different points in time. Log ratio charts can only be obtained from measurements that are defined on so-called ratio scales which possess a natural zero, such as is the case with weight, length, time, amount of money, etc. Logarithms allow to cover a broader range of variation of the scale by giving more emphasis to the smaller values and by reducing the impact of the larger ones. In the case of a time series, the slopes of the tangents of the log ratio curve reveal relative rates of change, in our case the percentage annual increase of the exports to

imports ratio [21]. The log-ratio chart of Fig. 4.5 has been obtained from measurements on the individual curves of Fig. 4.1 representing exports and imports between England and North America. Notice that ratios in excess of one correspond with a positive balance of trade, ratios less than one indicate a negative balance. The logarithmic transformation is more amply discussed in the chapters on multivariate data analysis.

If we look at Fig. 4.5 we observe a rather steady (almost linear) increase of the exports/imports ratio over half a century between 1720 and 1770. The annual percentage increase of the exports/imports ratio over this period can be obtained from the expression:

$$100 \times (((4.52 \times 0.53) / (1.44 \times 0.21))^{1/50} - 1) = 4.2 \text{ \% / year}$$

where the numbers have been read off from Playfair's chart (Fig. 4.1). Such a near-constant rate of increase of the exports to imports ratio is almost impossible to detect visually from the original chart of Fig. 4.1 because of the crossing of the curves of export and import in 1746. The two salient dips in the log ratio curve at 1773 and 1775 mark the events that were identified before on the difference chart of Fig. 4.3 . A prominent feature of the curve is the towering export/import ratio between 1775 and 1784, the period of the revolution. This phenomenon may reflect the blockade of imports from North America by French allies during the war. From 1785 onwards, a steady decline of the export/import ratio is observed. As both imports and exports rise rapidly after the revolution to values never obtained before (Fig. 4.1), and as the balance between them remains more or less the same (Fig. 4.4), their ratio must decline (Fig. 4.5).

Although a log-ratio chart is probably harder to interpret than the amount and difference charts, its proportion (or shape) yields interesting additional information. In the chapters on multivariate analysis we will insist on the importance of log ratios for the determination of contrasts in measurements that possess a natural zero. We only recall here a basic relationship between the difference of the logarithms of two positive quantities a and b and the log ratio of them:

$$\log a - \log b = \log (a / b)$$

which holds for any base of logarithms.

The relationship states that the distance between two points on a logarithmic scale is proportional to the log-ratio of the corresponding values. A comparison of a log-ratio with its 'expected' value produces a contrast. (In this context, the expected value can be derived from averaging over some part of the series or from an appropriately chosen reference value.) If we take the 1770 value of the export/import ratio in Fig. 4.5 as a reference, then we observe a strong negative contrast in 1773 and 1775, strong positive contrasts from 1776 to 1782 and progressively increasing negative contrasts from 1786 to the end of the series.

When the ratio of a to b is close to unity (in which case a is not much different from b), it can be shown that the log-ratios are proportional to the relative difference between a and b:

$$\ln (a / b) = \ln (1 + (a - b) / b) \approx (a - b) / b$$

where the symbol ≈ means approximately equal and where ln denotes natural logarithms (with base e = 2.71828…). The approximation is better to the extent that the ratio a/b approaches unity. Hence, in the case of small fluctuations, the log ratio chart reduces to a relative difference chart.

4.5 The legacy of Playfair for graphicacy

How did history treat the legacy of William Playfair? As it appears, he was mostly remembered in the years after his death by those who thought unkindly of him. The Larousse Dictionary of the 19th century provided in 1874 a detailed amount of his entrepreneurial misfortunes and of his political quarrels, without any reference to his statistical charts. In the 1932 edition of the same dictionary, one only learns that he wrote numerous pamphlets and led '... une existence agitée et misérable', which hardly needs translation. The 1963 edition no longer provided a reference to William Playfair [22]. La Grande Encyclopédie of 1900 provided an extensive biography of Playfair, enumerating his failures and ill fate. Some of his statistical works are mentioned here, however, including the Atlas and the Breviary [23]. The Encyclopaedia Britannica of 1911 and 1985 does not mention William Playfair. At least one eminent scholar and statistician of the late 19th century did justice to William Playfair. Karl Pearson, when being professor of mathematics and mechanics at University College in London, introduced William Playfair in his Gresham Lectures of 1892. These lectures were held 12 times a year and were destined to the general public [24]. In the statistical graphics lecture, Playfair was mentioned as the father of the geometry of statistics and a detailed exposition of Playfair's approach was provided. Pearson also contrasted the English geometrical method of statistics with the French approach of these days which put emphasis on probability calculus [25]. The lessons at Gresham College also referred to Charles Minard's famous flow diagram and to M. Ibry's graphical train schedules (cited by Etienne Marey), which are classics revived recently by Edward Tufte [26]. In the

works of Minard and Marey one also finds casual references to the graphic charts of Playfair. A thorough discussion of Playfair's contribution to statistical graphics has been published in 1935 and 1938 by H.G. Funkhouser [27]. The latter essay points to the first pioneers of political economy in England, whose work preceded that of Playfair by 100 years, namely Charles Davenant and William Petty [28], although it is not certain to what extent these writers had a direct influence on him. More recent recognition of Playfair's work is given by Erica Royston [29]. In the Oxford Companion of the Decorative Arts, Playfair is described as the founder of the diagrammatic technique. In this rather surprising connotation between science and art, diagrams are introduced as a visual shorthand by which familial information can be shown in an original way, such as to stimulate thinking as well as aid in understanding [30]. Finally, Playfair's work has been put into eminent perspective as an example of statistical chart making by Edward Tufte [1]. Nowadays, no serious essay on statistical charting or on graphic information display can afford not to mention the pioneering work by Playfair [31].

If William Playfair had been more of a scholar and less of a pamphletist, perhaps his work would have been accepted more readily in the learned journals and books of his time. It would lack then, however, the sharpness and conviction of the self-taught inventor, the missionary and the prophet. Maybe he failed in his short term ambition to convince the world of the utility of lineal arithmetics, i.e., geometry applied to accounts. He certainly never reached the height and depth of Adam Smith whom he admired and emulated. Nor was attention paid to his work by later political economists, such as John Stuart Mill, Karl Marx, John Meynard Keynes and others. Nevertheless, Playfair laid down the first foundation of a theory of

statistical diagrams which are as compelling today as they were in his time. We only recall two of his basic observations [32] : 'Men of high rank, or active business, can only pay attention to general outlines ...' and 'on inspecting any of these charts attentively, a distinct impression will be made, to remain unimpaired for a time ...'. It is the irony of history then that he is cited today more often than his older and learned brother John, who took care of him and to whom he owed his first lessons in statistical charting of thermometer readings.

Notes

[1] Edward R. Tufte, The visual Display of quantitative Information. Graphics Press, Cheshire, Conn, 1983.

[2] Adam Smith, Inquiry into the Nature and Causes of the Wealth of Nations. 1776. There probably never was any direct contact between Adam Smith and William Playfair, although the latter wrote a preface to the 1805 edition of the 'Inquiry'.

[3] In the chapter on Florence Nightingale we emphasize the role of statistical graphics in her struggle to reform the sanitary conditions in army hospitals in the aftermath of the Crimean war of 1854-1855.

[4] William Playfair, An Inquiry into the permanent Causes of the Decline and Fall of Powerful Nations. London, 1805.
Note the similarity of the title with that of Adam Smith's 'Inquiry into the Nature and Causes of the Wealth of Nations'.

[5] Nicole Oresme (Nicolas d'Oresme), Tractatus de Latitudinibus Formarum (Scientia Latitudinum Formarum). Around 1350, first printed in Padua in 1482, translated into English by Grant in 1966.
The horizontal and vertical axes of Oresme's diagram are called longitudes and latitudes, by analogy with geographic maps. For a discussion of the work of N. Oresme:
Anneliese Maier, An der Grenze von Scholastik und Naturwissenschaft. Storia e Letteratura, Roma, 1952, pp. 356-384.

[6] René Descartes, Discours de la Méthode pour bien conduire sa Raison et pour chercher la Vérité dans les Sciences. Jan Maire, Leyden, 1637.
With applications of the method in : La Dioptrique, les Météores et la Géométrie.
The conventional use of x and y to represent the coordinates along the horizontal and vertical axes of a bivariate diagram derive from Descartes' work in his Géométrie. See also the chapter on Descartes in this book.

[7] Johann Heinrich Lambert, Essai d'Hygrométrie ou sur la Mesure de l'Humidité. Mémoires des Sciences et Belles Lettres, 1769. From: Laura Tilling, Early experimental graphs. British Journal for the History of Science, 8, 193-213, 1975. Cited by: E.R. Tufte, The Visual Display of quantitative Information. Opus cit., pp. 45-46.
In Lambert's work the slope of the tangent to the curve representing the height of a water column as a function of time is plotted as a function of temperature. This application is exemplary for the level of graphic analysis in the 18th century.

[8] William Playfair, The Commercial and Political Atlas, representing by means of stained Copper-plate Charts, the Exports, Imports and general

Trade of England . First edition, London, 1786. Second edition, J. Stockdale, London, 1787.
The subtitle of the second edition differs slightly from that of the first edition and is quoted in the text. Third and revised edition, T. Burton, Lincoln's Inn Fields, London, 1801. This edition represents 'the progress of ... England during the whole eighteenth century.'
French translation: Tableaux d'Arithmétique linéaire du Commerce, des Finances, et de la Dette nationale de l'Angleterre. Traduit par H. Jansen, Paris, 1789.

[9] Atlas refers to an ancient king of Etruria who was reputed for his wisdom, not to the Titan who, according to Greek mythology, was sentenced to carry the world on his shoulders for having stormed the heavens. See also the chapter on Mercator and Wright in this book.

[10] William Playfair, The Commercial and Political Atlas. Opus cit., 1801.

[11] William Playfair, The History of Jacobinism, its Crimes, Cruelties and Perfidies, from the Commencement of the French Revolution to the Death of Robespierre. London, 1795.

[12] William Playfair, For the Use of the Enemies of England, A real Statement of the Finances and Resources of Great Britain. London, 1796.

[13] William Playfair, The Statistical Breviary, shewing, on a Principle entirely new, the Sources of every State and Kingdom in Europe; illustrating with stained Copper-Plate Charts, representing the physical powers of each distinct Nation with Ease and Perspicuity. London, 1801.
The 'Breviary' is a graphical interpretation of statistical data presented in the 'Statistical Tables' of J.G. Boetticher of Koenigsberg, which Playfair translated and prefaced:
J.G. Boetticher, Statistical Tables; exhibiting a View of all the States of Europe, showing with great Accuracy, their Population, Military and Marine Strength, Revenue and Expenditure, Form of Government, etc., Number of Houses and Inhabitants, historical Occurrences (translated by W. Playfair). J. Stockdale, London, 1800.

[14] Plate 5 is from W. Playfair, The Commercial and Political Atlas, third edition. Opus cit., 1801. In the original version, the lines of exports and imports are colored in red and yellow, respectively.

[15] William Playfair, The Commercial and Political Atlas. Opus cit., 1801.
The Boston tea party took place on December 16, 1773. Figure 4.2 shows an engraving by Daniel Chodowiecki produced in 1784. From:
Washington, De Groten aller Tijden (The Great of all Times). Amsterdam Boek, Amsterdam, 1972, p.22 (in Dutch)

[16] William Playfair, Lineal Arithmetics applied to shew the Progress of England during the present Century. London, 1798.

[17] Nicole Oresme, Tractatus de Uniformitate et Difformitate Formarum. Around 1350.
According to Oresme, the distinct 'shapes' of a free-falling body and of a propelled projectile are characterized by their velocity-time diagrams.
Anneliese Maier, Die Vorläufer Galileis im 14. Jahrhundert. Studien zur Naturphilosophie der Spätscholastik, Storia e Letteratura, Roma, 1949.
Ernst Borchert, Die Lehre von der Bewegung bei Nicolaus Oresme. Beiträge zur Geschichte der Philosophie und Theologie des Mittelalters, Band XXXI, Heft 3, Münster, 1934.

[18] Edward R. Tufte, The visual Display of quantitative Information. Opus cit.

[19] Plate 9 is from William Playfair, The Commercial and Political Atlas. Opus cit., 1801.

[20] William S. Cleveland and Robert Mc Gill, Graphical perception : Theory, experimentation, and application to the development of graphical methods. Journal of the Am. Stat. Ass. (JASA), 79, 531-554, 1984.
The chart of exports and imports between England and India is from the 1786 edition of 'The Commercial and Political Atlas.'

[21] Irving Fisher, The ratio-chart for plotting statistics, Publ. of the Am. Stat. Ass., 15, 577-601, 1916-17.

[22] Larousse, Dictionnaire du XIX Siècle. Paris, 1874, 1932 and 1963.
The 1874 edition contains a detailed biography of William Playfair, mainly referring to his failing business enterprises and political activity. It is mentioned that he founded a bank in Paris in 1790 and, after failing, returned to London where he opened a jewellery shop. The 1963 only contains a reference to his brother John, the Scottish mathematician and geologist.

[23] La Grande Encyclopédie. Inventaire raisonné des Sciences, des Lettres et des Arts. Paris, 1900.

[24] Egon S. Pearson, Karl Pearson, an Appreciation of some Aspects of his Life and Work. Cambridge University Press, Cambridge, Engl., 1938.
The contents of the Gresham Lectures have been published in extended form in:
Karl Pearson, The Grammar of Science. J.M. Dent, London, 1937 (First published in 1892).
Karl Pearson was Galton Professor of Eugenics at University College in London from 1911 to 1933 and founded the department of 'applied statistics', a term coined by Florence Nightingale. See also the chapters on Florence Nightingale and on Karl Pearson in this book.

[25] The controversy between French and Anglo-American approaches to statistical graphics still transpires today. An illustration thereof is found in multivariate analysis of contingency tables, which confronts proponents of

Correspondence Analysis with those of log-linear methods. While the former method has been developed and used mainly in France, the latter has been inspired by Anglo-American statisticians. See also the relevant chapters on multivariate methods in this book.

[26] Edward R. Tufte, The visual Display of quantitative Information. Opus cit.
Train schedules have first been constructed in the form of distance-time diagrams by the French engineer M. Ibry. They have been reproduced by E.J. Marey, a physiologist who earned fame for first describing the movement of men and horses by means of a special photographic technique which he developed:
Etienne J. Marey, La Méthode graphique dans les Sciences expérimentales et principalement en Physiologie et en Médicine. G. Masson, Paris, 1878.
A famous flow diagram by Charles Minard represents the campaign of 1812-13 of Napoleon in Russia and the progressive annihilation of the 'Grande Armée': Charles J. Minard, Tableaux graphiques et Cartes figuratives de M.Minard. Bibliothèque de l'Ecole Nationale des Ponts et Chaussées, Paris.

[27] H. Gray Funkhouser and H.M. Walker, Playfair and his charts. Economic History, 3, 103-109, 1935.
H. Gray Funkhouser, Historical development of the graphic representation of statistical data. Osiris, 3, 269-404, 1938.
Attention to Funkhouser's essays has been drawn by :
Howard Wainer, How to display data badly. The American Statistician, 38, 137-147, 1984.
The author praises Playfair's charts of exports and imports of England to and from all parts of the world during the 18th century.

[28] Charles Davenant, Discourses on the public Revenues and on the Trade of England. London, 1698.
Sir William Petty, Essays on political Arithmetic. London, 1699.

[29] Erica Royston, A note on the history of graphical presentation of data. In : Studies in the History of Statistical Probability. (Egon S. Pearson and Maurice G. Kendall, Eds.), Griffin, London, 1970, pp. 173-184.

[30] Harold Osborne (Ed.), The Oxford Companion to the decorative Arts. Clarendon Press, Oxford, 1975, pp. 293-297.
In this passage the work of W. Playfair is said to be more fully developed by Otto Neurath. A statement with which we cannot fully agree, as follows from the chapter which is devoted to Neurath and the Vienna method of picture statistics. In fact, Neurath rejected the use of histograms and line charts.

[31] See for example a more recent work on the design of information displays:
Peter Wildbur, Information graphics. Trefoil Publ., London, 1989.

The book also includes illustrations from the work of Gerard Mercator, Florence Nightingale and Otto Neurath, which are covered more extensively in this book. A review of design methods from statistical graphics was prepared by :
Stephen E. Fienberg, Graphical methods in statistics. The American Statistician, 33, 165-178, 1979.

[32] William Playfair, The Commercial and Political Atlas. Opus cit., 1786.

Biographical Notes

1759 Born at Benvie, close to Dundee, the son of a clergyman. Brother of John Playfair (1748-1819), geologist and mathematician, professor of natural philosophy at Edinburgh.
Apprentice with Andrew Meikle, inventor of the threshing machine.

1780 Draftsman for M. Boulton and J. Watt in Birmingham.

1786 'Commercial and Political Atlas' (with new editions in 1787, 1801).

1787 Leaves England for France.

1788 French translation of the 'Atlas'. Obtains royal patent for his invention.

1789 Takes side for the royalists in the early events of the French revolution.

1790 Expelled from France.

1795 'The History of Jacobinism, its Crimes, Cruelties and Perfidies from the Commencement of the French Revolution to the Death of Robespierre.'

1796 'For the Use of the Enemies of England. A real statement of the finances and resources of Great Britain.'

1798 'Lineal Arithmetics, applied to shew the Progress of England during the present Century.'

1801 'The statistical Breviary, shewing the Resources of every State and Kingdom of Europe' using data compiled by J.G. Boetticher.

1805 'An Inquiry into the Permanent Causes of the Decline and Fall of Powerful and Wealthy Nations..., designed to shew how the Prosperity of the British Empire may be prolonged.'
'A Statistical Account of the United States of America', a translation and illustration of an original French publication by D.F. Donnant.
'Life of Dr. Smith', an introduction to the 1801 edition of 'Inquiry into the Nature and Causes of the Wealths of

Nations', first published in 1776 by Adam Smith (1723-1790).

1814 'Political Portraits'

Returns to France. Editor of 'Galignari's Messenger' in Paris.

1818 Convicted to three months of imprisonment for defamation. Returns to London.

1819 'France as it is.'

1821 'A Letter on our Agricultural Distress, their Causes and Remedies.'

1823 Dies in London, reportedly in misery and poverty.
