



Using Excel to Illustrate Hannah and Kay's Concentration Axioms

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Abstract

Most courses in industrial economics/industrial organisation cover the measurement of industry concentration. In a classic paper Hannah and Kay (1977) propose a set of desirable criteria against which any of the numerous concentration measures may be judged. We describe how these criteria can be illustrated for students for several of the most popular measures using an Excel spreadsheet and an exercise sheet developed by the authors and freely available from the HEA Economics Network website.

JEL classification: A22, B41, C88, L11

1. Introduction

Most courses in industrial economics/industrial organisation typically discuss the issue of how to measure the extent of industrial/market concentration. This is fundamental to discussion of the structure-conduct-performance (SCP) paradigm and of empirical studies in relation to topics such as advertising and R&D, and also to an appreciation of the approach adopted by the competition authorities¹ to addressing the welfare implications of monopoly power and its regulation.

There are however, many alternative measures of concentration extant (see Table 1 below), and the question naturally arises as to whether one measure is 'superior' to another and hence should be preferred. Of course, in some instances the choice may be determined by data considerations (availability, decomposability) or with reference to relevant theory (Saving, 1970; Cowling and Waterson, 1976; see also Sleuwaegen and Dehandschutter, 1986). In a classic paper, Hannah and Kay (1977) instead propose an axiomatic approach – that is, a set of desirable criteria a 'good' concentration measure should possess² (see below). Some of the textbooks provide illustrations of different market share distributions and how these impact on the main measures of concentration, and accordingly discuss some of their strengths and weaknesses, including in relation to the criteria (see for example Ferguson and Ferguson, 1994; Lipczynski, Wilson and Goddard, 2009). However, while the criteria themselves are straightforward, and the above illustrations are useful, students do not always find it easy to relate these criteria to specific concentration measures, and hence to appreciate which are most likely to fail against particular criteria. The present paper describes how a simple Excel spreadsheet and guided simulation exercise may be used to illustrate some of the issues arising from the axiomatic approach for several of the most commonly used concentration measures. Both of these resources are freely available from the Economics Network website (http://www.economicsnetwork.ac.uk/archive/latreille_concentration).

¹ In the UK aspects of this function are fulfilled by the Office for Fair Trading and the Competition Commission.

² While the most popular, this is not the only set of criteria extant – see Marfels (1971) and Hause (1977) for alternatives, the latter also showing how several of the measures are related.

The remainder of the paper is set out as follows. In the next section 2 we briefly describe the main measures of concentration in the literature, followed by an outline of the Hannah-Kay axioms. We then outline the resources available focusing on the Excel spreadsheet, its interface and capabilities, while the final section 5 concludes.

2. Measures of concentration

As is well-known, there are two main types of concentration measure extant:

'Absolute' measures, which essentially use information on both the number of firms (N) and the variance of firm sizes (σ^2);

Relative measures (or inequality representations), which use information on σ^2 only.

The main statistical measures in the literature are summarised in Table 1 below, which also sets out special cases where appropriate. These measures (and one or two others) are discussed in more detail in Curry and George (1983), who examine some of their strengths and weaknesses. We do not repeat this discussion here: suffice it to say that, as is well-known, the widely used concentration ratio and the 'relative' measures more commonly fail the axioms than many of the others. These authors also provide a useful account of some of the other conceptual problems associated with measuring concentration such as the appropriate definition of the 'industry'/'market', the treatment of exports and imports, and of multi-product firms, etc. (from which we abstract in our simulations described below).

Table 1: Summary of the main statistical measures of concentration

Measure	Formula	Special cases
Absolute measures:		
Concentration ratio (x-firms)	$CR_x = \sum_{i=1}^x S_i$	
Hirschman-Herfindahl index ³	$H = \sum_{i=1}^N S_i^2$	
Numbers equivalent Herfindahl index	$H_{NE} = \frac{1}{H}$	
(First order) Entropy	$E = -\sum_{i=1}^N S_i \log S_i$	
Relative entropy	$RE = \frac{E}{\log N}$	
Hannah-Kay index	$HK(\alpha) = \sum_{i=1}^N S_i^\alpha$	$\alpha = 2: HK = H$
Hannah-Kay numbers equivalent index	$HK_{NE}(\alpha) = \left(\sum_{i=1}^N S_i^\alpha \right)^{\frac{1}{1-\alpha}}$	$\alpha = 2: HK = H_{NE}$ $\alpha \rightarrow 1: \log(HK) \rightarrow E$
Rosenbluth/Hall-Tideman index	$RHT = \frac{1}{2 \sum_{i=1}^N i S_i - 1}$	
Relative measures:		
Gini coefficient	$G = \frac{N+1 - 2 \sum_{i=1}^N i S_i}{N}$	$G = 1 - \frac{1}{N(RHT)}$
Variance of logs of firm size	$V = \frac{1}{N} \sum_{i=1}^N (\log S_i)^2 - \frac{1}{N^2} \left(\sum_{i=1}^N \log S_i \right)^2$	$S_i = \frac{1}{N} (\forall i): V = H$

Notes: S_i is the market share of firm i and x is the number of firms defining a particular index (often the x largest firms). The (first order) entropy measure is usually calculated with base 2.

³ Note that this measure is sometimes expressed using market share percentages rather than proportions, and is then typically denoted by HHI. This form of the index is used by the US Department of Justice in guidelines for evaluating mergers, where HHI values below 1000 are seen as indicating relatively 'low' concentration, 1000–1800 'moderate' concentration, and those in excess of 1800 'high' concentration.

3. The Hannah-Kay axioms

The seven criteria proposed by Hannah and Kay (1977) for evaluating measures of concentration are reported in several of the main industrial economics texts and are as follows (of which the first four are generally regarded as being the most important):

1. If the concentration curve⁴ for one industry/market lies everywhere above that for another industry, then the former should rank as being more concentrated (the 'concentration curve ranking criterion').⁵
2. The transfer of sales from smaller to larger firms should increase measured concentration (the 'sales transfer principle').
3. The entry of new firms of a size below that of the incumbent average should reduce measured concentration, while the exit of firms below that threshold should increase measured concentration (the 'entry condition').
4. Mergers should result in an increase in measured concentration (the 'merger condition').
5. Random brand switching (by consumers) should reduce measured concentration.
6. A smaller scale of entry should have less effect on measured concentration than a larger scale of entry.
7. Random factors in the growth of firms should increase measured concentration ('Gibrat's Law').
8. Not all measures satisfy all of these criteria, and in practice most are highly correlated with each other. Nonetheless, several of the measures fail to meet many of the criteria, something the simulations described in the exercise accompanying the spreadsheet are designed to illustrate.

4. The Excel spreadsheet and simulation exercise

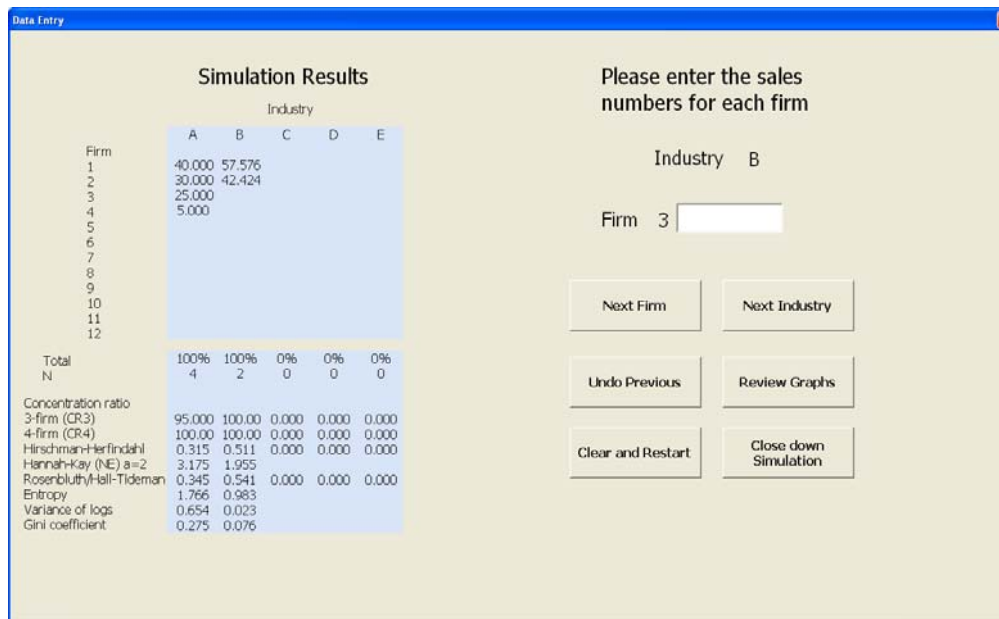
The Excel spreadsheet freely available from the Economics Network website (http://www.economicsnetwork.ac.uk/archive/latreille_concentration)⁶ allows the user to enter data on market sales by firm for up to 12 firms and up to five industries/markets (see Figure 1 which shows a screen capture of the data entry/results screen). These are automatically converted to market shares and various of the main measures of industrial concentration calculated by the program.

⁴ A concentration curve plots cumulative market share on the vertical against the number of firms ranked from largest to smallest on the horizontal.

⁵ Where the curves intersect, the ranking of industries/ markets will depend on the weight accorded to large/small firms.

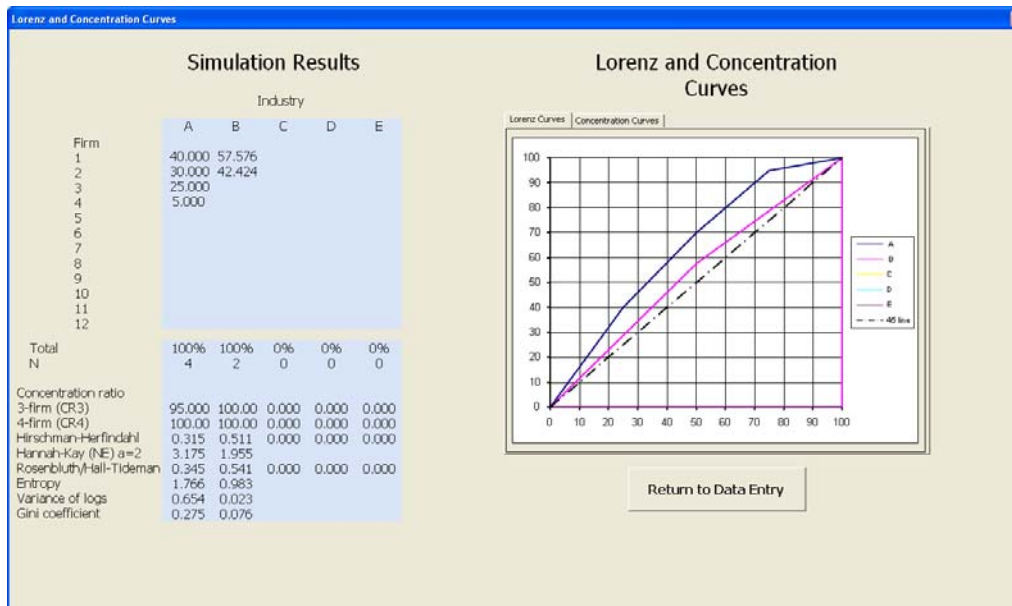
⁶ The website also contains a short technical guide to using the spreadsheet, dealing for example with macros in Excel.

Figure 1 The data entry/simulation results screen



Once the data have been entered for each of the firms in a particular industry, clicking 'Next Industry' then allows data for the next industry to be entered. For each industry entered, the spreadsheet not only calculates the values of each of the concentration measures listed in Table 1 as noted, but also draws the associated Lorenz curve for each industry/market, the latter being obtained by clicking the 'Review Graphs' button (see Figure 2). This facilitates both statistical and graphical comparisons of the chosen markets.

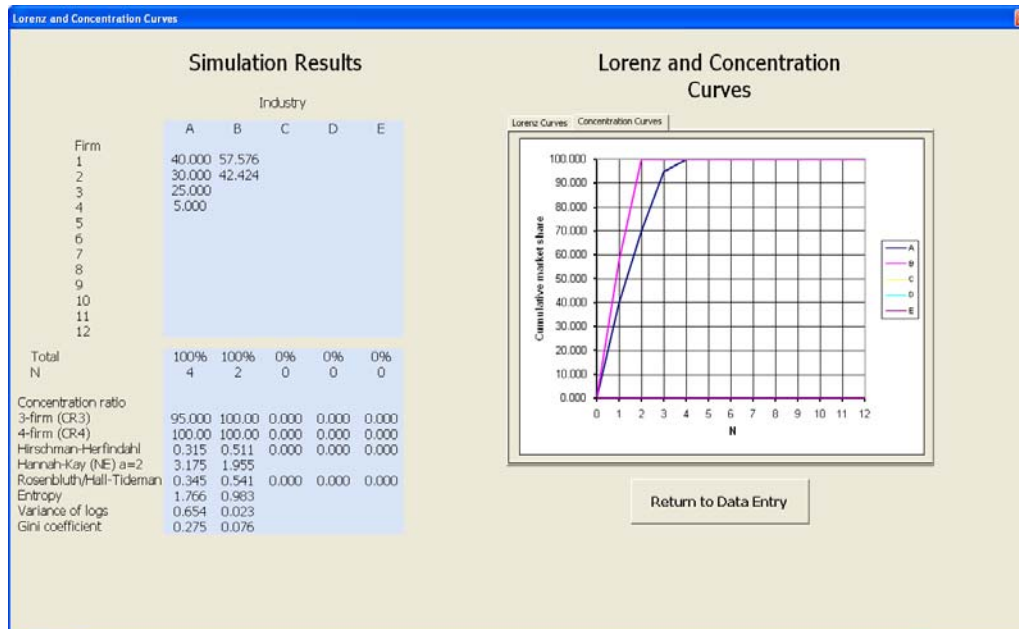
Figure 2 Lorenz curves



The simulation is further programmed to chart the accompanying concentration curves associated with each industry/market on a single diagram (see Figure 3), which are obtained by clicking the relevant tab

in 'Review Graphs' and thereby enables a straightforward comparison of two or more industries on this basis. This enables ready examination of the first of the Hannah-Kay criteria.

Figure 3 Concentration curves



In addition to the spreadsheet and user guide, as noted, the materials on the Network website also include a short exercise sheet describing a set of suggested simulations designed to illustrate each of the Hannah-Kay axioms and enabling students to explore which measures are more likely to fail a particular criterion. This can be used as a self-contained exercise for students to complete in their own time, and/or as the basis of class (or even on-line forum/wiki) discussion. Staff and students can, of course, also experiment with their own values for market shares, for example verifying those in their chosen course text.⁷ The key point is that students get a better feel for how different market share distributions are encapsulated in the various measures of concentration, and which measures are likely to prove problematic in terms of particular criteria.

5. Conclusions

This short paper describes a set of resources freely available from the Economics Network's website that can be used to explore how different market share distributions are summarised by each of the main measures of industrial concentration extant, and how these measures perform in the context of the axiomatic criteria proposed by Hannah and Kay (1977). We believe this active learning tool is likely to give students an improved understanding of some of the strengths and limitations of a range of the commonly used statistical measures, and hence of their value in underpinning policy/regulation.

⁷ An interesting aside is that the software sometimes produces different values from those in some of the popular textbooks, for example due to the use of different bases in calculating logarithms. This too can be deployed as a useful discussion point.

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Appendix

1. Industry Concentration and the Hannah-Kay axioms: a Simulation Exercise

The following simulations are suggestions based on Table 3.1 of Ferguson and Ferguson (1994) and also Lipczynski, Wilson and Goddard (2009) that are designed to illustrate the performance of some of the standard industry concentration measures in terms of the Hannah-Kay (1977) axioms.⁸ In each case, the simulations can be undertaken using the Excel spreadsheet provided.

⁸ The seven criteria are as follows (the first four being regarded as the more important):

1. If the concentration curve for one industry lies everywhere above that for another industry, then the former should rank as being more concentrated; where curves intersect, the ranking depends on the weight accorded to large/small firms (the 'concentration curve ranking criterion').
2. The transfer of sales from smaller to larger firms should increase measured concentration (the 'sales transfer principle').
3. The entry of new firms of size below that of the incumbent average should reduce measured concentration, while the exit of firms below that threshold should increase measured concentration (the 'entry condition').
4. Mergers should result in an increase in measured concentration (the 'merger condition').
5. Random brand switching should reduce concentration (since more consumers leave large firms to go to

The simulations consider the axioms in turn (letters in [] brackets refer to the industry in Ferguson and Ferguson); in each case compare the results from varying the market shares as suggested against the baseline results. At the end of each simulation, clear and reset before proceeding to the next simulation.

Of course you do not need to stick to the illustrations above, and are welcome to vary the market shares in other ways to see the effect on the various measures.

Simulation 1: Concentration curve ranking criterion

For this axiom, compare an industry [E] where the firms have sales of 4000, 3000, 2500 and 500 with a second industry [G] where the sales are 3800, 2800, 1300, 1000, 500, plus six firms each with sales of 100. Begin by comparing the concentration curves for these two industries by clicking on the 'Review graphs' button. Do the concentration curves cross? Which curve is higher and therefore ranked as more concentrated?

Now compare the data on the concentration measures in the bottom panel of the data sheet. Which measures are consistent with the rankings of the two industries as shown by the concentration curve and which are not (and therefore fail this axiom)? Suggest why.

Simulation 2: Sales transfer principle

For this axiom, consider an industry where the firms' sales are 4000, 3000, 1500, 1000 and 500 [F]. Compare this with an industry where half the sales of the smallest firm are now transferred to the fourth largest firm. What happens to the various measures of concentration? Which rise (in accordance with the axiom) and which do not (and thus fail it)? In the case of the failures, consider why.

Simulation 3: Entry condition

For this axiom, consider the first industry in Simulation 1 [E]. The average size (market share) of the firms in this industry is 25% ($100\% \div 4$ firms). Suppose a new entrant joins this industry taking 5% of each existing firm's sales (i.e. $0.05 \times 4000 = 200$ from Firm 1, $0.05 \times 3000 = 150$ from Firm 2, $0.05 \times 2500 = 125$ from Firm 3 and $0.05 \times 500 = 25$ from Firm 4), making a total market share for the entrant of 5% (<25% average market share for the industry prior to entry). The ranked sales are now: 3800, 2850, 2375, 500 (the new firm) and 475. Compare the concentration measures before and after entry. Is it true that the relative measures are most likely to fail? Which measures seem most sensitive to this entry?

Simulation 4a: Merger condition

For this axiom, consider merging the top two firms in the second of the markets in Simulation 1 [G], so that sales are now, in descending order: 6600, 1300, 1000, 500 and six firms with 100 (now 10 firms in total as compared with 11 pre-merger). Compare the concentration measures with the original values. Do all the measures satisfy the criterion in this case?

smaller firms than vice versa).

6. A smaller scale of entry should have less effect on measured concentration than a larger scale of entry.
7. Random factors in the growth of firms should increase measured concentration (Gibrat's Law).

Simulation 4b: Merger condition

What happens if the merger is instead between the fifth and sixth largest firms originally, so that sales are now 3800, 2800, 1300, 1000, 600 and then five firms with 100 each? Which measures now appear to fail? Why is there a difference between the results of simulations 4a and 4b?

Simulation 5: Random brand switching

Starting from the sales figures in simulation 1 [E], suppose 30% of each firm's customers in the next period now switch randomly to other suppliers. This means that the largest firm loses sales of $0.3 \times 4000 = 1200$, the second largest $0.3 \times 3000 = 900$ and so on giving 750 and 150 respectively for the remaining two firms. This means that the total volume of sales switching is 3000. Suppose also that the largest firm *acquires* an equal share of the sales switching from other firms, i.e. $\frac{1}{3} \times 1800 = 600$, while the next largest acquires an equal share of the sales switching from firms 1, 3 and 4, i.e. $\frac{1}{3} \times 2100 = 700$. The third and fourth largest firms will similarly acquire sales of 750 and 950. The firms' new sales are therefore now: $4000 - 1200 + 600 = 3400$; $3000 - 900 + 700 = 2800$; $2500 - 750 + 750 = 2500$; and $500 - 150 + 950 = 1300$ respectively. Do all the measures satisfy this criterion, i.e. does measured concentration fall? Comment.

Simulation 6: Scale of entry

Compare the concentration values in simulation 3 with a larger scale of entry where instead of taking 5% of each firm's existing market share, the entrant now takes 10% (i.e. $0.1 \times 40\%$ from Firm 1, etc.) so that it emerges with a 10% market share. Do the concentration measures reflect that the scale of entry here is larger? Which measures do not and so appear to fail this criterion?

Simulation 7: Random growth factors (Gibrat's Law)

The following considers the operation of Gibrat's Law using the data from Lipczynski, Wilson and Goddard (2009) Table 9.1. The basic idea is that in each period, a firm has a 50:50 chance of either doubling in size or halving. The key is to watch what happens to measured concentration. Start with eight firms all with sales equal to 100. Then compare with a second period (use the new industry feature in the spreadsheet to compare the two) in which four firms double their sales while the remaining four see their sales halved (so four firms have sales of 200 while four have sales of 50). In the next period, allow half of the firms of each size to double their sales, while the remainder halve their sales (so sales are now 400, 400, 100, 100, 100, 100, 25 and 25). In the final period, repeat this so sales are 800, 200, 200, 200, 50, 50, 50 and 12.5. What happens to the measures? Do any not pass the criterion in this case?⁹

The evaluation

Do any measures appear to satisfy *all* of the above criteria, at least for the examples considered? Which fail most often and thus appear less suitable as measures of concentration? Why do the numbers for some of the measures differ from those in the books?

Of course you do not need to stick to the illustrations above, and are welcome to vary the market shares in other ways to see the effect on the various measures.

⁹ Students interested in following up on this topic are referred to section 9.3 in Lipczynski, Wilson and Goddard (2009) to consider some extensions to this very simple example and see a summary of some of the extensive empirical literature in relation to Gibrat's Law (also known as the 'Law of Proportionate Effect').

2. User Guide: Industry Concentration Simulations

It is best to download and save this application before you begin. Depending on your settings, the application may not work in your web browser.

Starting the application

Note: It is possible that your Excel security settings are set too high to run the application, so you should check your macro security settings before opening the file.

In order to undo this in Excel 2003:

Open Excel and click on "Tools" in the menu bar.

Select "macro", and then from the drop down box select "security".

Make sure the setting is no higher than medium.

In order to undo this in Excel 2007:

Before opening the file, open Excel and click on the "Developer" tab in the ribbon. (If this is not showing, click the Microsoft Office Button (top left corner), and select Excel Options. On the Popular tab, click the Show Developer tab in the Ribbon check box.)

Click Macro Security and select Enable all macros. You can ignore the warning about this being potentially unsafe – the macros used in the simulations are safe – but you should reset the security level once you have finished.

When you are ready to start the game double click to open the Industry Concentration Simulations (Excel) file. If requested, click 'enable macros'.

The game should begin on start-up. If the application does not start, press "Ctrl g".

You will be welcomed by an opening screen which will close after five seconds. A welcome screen will then open.

Using the application

The Welcome Screen:

Click the "Begin Simulation" button when you are ready to start the simulation.

The Data Entry Screen:

From this screen you can enter the sales figures for each firm in a particular industry. You will start with Firm 1 in Industry A. Enter the sales figures for Firm 1; then click "Next Firm". You can now enter the sales figures for Firm 2. The percentage of the industry that each firm takes up is automatically calculated and shown in the table on the left-hand side. As you enter more data you will see the concentration ratios changing at the bottom of the table. You can enter data for a maximum of 12 firms. (If you attempt to enter data for more than 12 firms, you will see an error message.) Once you are happy with the number of firms in Industry A, click "Next Industry". You will now be able to enter data for Industry B. You can enter data for a maximum of five industries. If at any time you wish to view the Lorenz and Concentration curves, click "Review Graphs".

The Lorenz and Concentration Curves Screen.

From this screen you can review the Lorenz Curves and Concentration Curves. Select the graph you wish to view by clicking on the appropriate tab. To return to the Data Entry Screen, click "Return to Data Entry".

Restart or Close Down.

If you wish to restart the simulation and enter different data, click "Clear and Restart". This will clear all the data you have entered and take you back to the beginning of the simulation. If you are finished with the simulation, click "Close Down Simulation". The application will shut down and you will be returned to your desktop.

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