Signal detection and decision making

ROSS GAYLER provides a few notes on the topic of ROC, discussed by Paul Hutchinson (*JASSA*, Spring 2006)

Many business problems can be construed as "trying to take the right action at the right time". The simplest case of this involves a binary decision to take or not take a specific action. The decision is driven by the available evidence, which is usually unreliable. For example: buy stock if you believe the price will go up, audit these figures if you believe they are inaccurate, decline to give credit if you believe that this applicant will default.

This suggests that many business problems could be analysed in terms of decision-making based on unreliable evidence. The Theory of Signal Detection (TSD) is a theoretical model of decision-making that is well suited to this purpose. TSD models the analysis of unreliable evidence as equivalent to detecting a faint signal in a background of noise. Most importantly, it separates out the detection process (assessing the likelihood that the signal is actually present) from the response process (deciding to take the action). This separation is important because the response process can depend strongly on the costs and benefits of the actions taken, while the underlying detection process is left unchanged.

The possible scenarios can be categorised in a 2x2 table (signal present/absent versus action taken/not taken). The four cells of this contingency table are conventionally called Hit, Miss, False Alarm, and Correct Rejection and can be observed directly if the true status of the signal is known. If Hits are strongly rewarded and there is no cost attached to the other cells, a rational decision-maker would choose to take the action on every occasion. Conversely, if Correct Rejection is heavily rewarded, a rational decision maker would choose not to take the action on every occasion. Intermediate levels of reward would lead to intermediate patterns of decision-making behaviour. Thus, a signal detector of fixed discriminating capability can generate a whole family of contingency tables depending on the payoffs.

The family of contingency tables generated from one signal detector can be summarised in a graph known as the ROC curve. The shape of the curve indicates the sensitivity of the detector and the position on the curve indicates the response bias of the decision-making process. This separation of sensitivity from response bias allows us to form a clearer view of the ability to detect signals in unreliable evidence.

TSD was originally developed in the 1950s in the context of communications engineering. However, it rapidly spread into other areas (for example, interpretation of x-ray images, military monitoring, and information retrieval) as a theoretical tool for comparing the performance of detectors. Some aspects of TSD are now widely known. For example, the area under the ROC curve is a commonly used measure of sensitivity. However, many analytical practitioners are aware only of this one aspect. This narrowness of view is a shame because TSD has surprising connections to many apparently disparate concepts.
I have addressed this issue in the context of credit scoring by presenting a tutorial paper on signal detection for credit scoring practitioners at the 1999 Credit Scoring and Credit Control conference in Edinburgh, Scotland.

This presentation is available online at www.vedaadvantage.com/whitepaper. It covers the historical development of TSD; the underlying theoretical model; and the breakdown of decision processes into sensitivity and response bias. It also covers various measures of sensitivity of the detection process and how they may be calculated from observable data. This includes a discussion of the ROC curve and sensitivity measures based on the ROC curve. This leads into a discussion of linearising the ROC curve (a topic that has been covered in greater detail by Paul Hutchinson in the Spring 2006 issue of *JASSA*). The linearised ROC curve is used to demonstrate the relationship of TSD to logistic regression.

Because TSD is related to many aspects of statistical analysis of decision-making it supplies a very useful integrative framework. Anyone who uses ROC measures of sensitivity or who is interested in assessing the predictive power of models will benefit from having a reasonable acquaintance with TSD.

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Dr Gayler studied computer science and psychology, and his early psychological research extending the Theory of Signal Detection has been applicable to credit scoring. He is currently collaborating with colleagues at Monash University on an identity fraud detection project and recently spent a month working as a guest researcher at the Quantitative Financial Risk Management Centre, Imperial College London. J