APPLICATION OF STATISTICS IN THE BUSINESS WORLD

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It is an honor to be invited to speak at the Fifth International Conference on the Teaching of Statistics. I would like to share with you some thoughts on the application of statistics in the business world, and I shall use a few actual cases including the Hang Seng Index as illustrations.

I believe most of you know the casino game of roulette. In each round of the game, a small ball falls at random into one of the thirty-seven numbered compartments of a revolving wheel. Bets can be placed on a single number or a set of numbers, including numbers having common attributes. The payout of a winning bet on a single number is thirty-six for one but the chance of winning is actually one out of thirty-seven. The payout of a winning bet on the odd or even attribute of the drawn number is one for one but the chance of winning is eighteen out of thirty-seven. Obviously, these payout rates are lower than the probability of the outcomes.

For roulette players, statistics is useful but not helpful. As each round of the game is statistically independent of the previous rounds, its outcome is a random variable. The only certainty is that the mathematical expectation of the payoff of the game in the long run is zero, simply because the payout rates are always in favor of the casino. This is also true of all other casino games.

Markets and people are the concerns of business. Their behaviors often display patterns and trends, and therefore are not totally unpredictable. It is this partial predictability that makes the application of statistics more useful and meaningful in the business world than in the casinos.

The higher the predictability of the outcome, the more statistics is applicable. For instance, time series analysis is more usefully applied to the consumer price index than the stock price index because retail prices have repetitive seasonal patterns whereas stock prices have erratic cycles.

STATISTICS FOR DECISION-MAKING

Business decisions are much more complex than gambling bets. They aim at the maximization of output, or minimization of input, or optimization of the outcome in the light of the changing market environment, changing consumer preferences and intensifying competition. As the science of inference, statistics is helpful in these respects.

Sometimes decisions are made under certainty where the outcomes of the strategic options are fully predictable. They essentially deal with the management of resources, such as inventory control, where the issue in question is to optimize the available resources to achieve the best possible outcome. These are classic mathematical programming problems.

Sometimes decisions are made under partial uncertainty where knowledge of the outcomes under different strategic options is incomplete. A classical case is acceptance testing in quality control where the decision is to accept or reject the batch in question, and this is a problem for pre-posterior analysis.

Sometimes decisions are made under risk where only the likelihood of the outcomes of various strategic options is known. They are typical problems of risk and return in investment, where the issue in question is to optimize the payoff. The usefulness of statistical methods depends very much on the validity of the quantification of risk with the “variance”.

Sometimes decisions are made under conflicts where competitors are both rational and sophisticated. The issue in question is to outperform the rivals. The development of game theory is to generalize the actions and reactions of competitors and the related payoffs with mathematical models. Although the real life situation is much more complex, hypothetical games help managers to systematically analyze the possible interactive moves of competitors against their marketing or product strategies.

As a Chinese proverb says, “Know yourself and your opponents in order to win each and every battle”. When Hang Seng Bank bid for the site of our new headquarters in a public auction in 1987, we were regarded as the most aggressive bidder as the site was adjacent to our old headquarters. Our major problem was to avoid paying an excessive premium over the market price. As it was too complex for classical competitive bidding models to resolve, we used the rational decision approach instead.

We started with the forecast valuations of a top grade office building on that site to be completed in three years' time under different scenarios of property price trend, ie, optimistic, likely and pessimistic. From these forecast valuations, we worked back the implied land price after deducting development costs, financial costs and developer's profit. As we were a user-developer and banker, we could outbid others by a margin up to the sum of the financial costs and developer's profit. We knew where we would stand. We then identified the likely rivals, studied their market views and analyzed their bidding behaviors. We also knew where our rivals would stand. On this basis, we formulated different strategies against the aggressive, rational and conservative bidders. However, it turned out to be a different game at the auction. We actually bid against an unknown rival and, with a bit of luck, won at a price still within our budget.

STATISTICS FOR MARKET RESEARCH

Market research is perhaps the most common area of statistics application in business. It aims at identifying any gap between customer needs and the products and services being provided in the mass market. There are two broad approaches. The quantitative approach deals more with customer profile, behavior and preference while the qualitative approach deals more with customer attitude and perception.

No matter which approach is employed, the representativeness of the data or information collected is vital to the reliability of the survey results. As it is mostly impractical to survey the entire target population, a representative sample will have to be drawn up.

The fundamentals of survey sampling are randomness and sufficiency, so that any inference from the sample may be projected to the population as a whole and the possible deviation from the true picture arising from the use of a sample may be objectively assessed. As the magnitude of the sampling error is inversely related to the sample size but the survey cost increases with the sample size, the benefit of increasing the sample size is subject to the law of diminishing returns. The dilemma is the trade-off between cost and precision under time and budget constraints.

However, the main cause for concern in practice is non-sampling errors. Substitutions for non-contacts or refusals are often necessary. Systematic selection rather than random selection of respondents is often inevitable in practice. Moreover, interviewer bias cannot be totally eliminated in data collection.

Non-sampling errors cannot be avoided but they can be managed. The handling of non-responses in household expenditure surveys (HES) in Hong Kong is an illustration. The HES is for deriving the weights of the components of the consumer price index. As participating households had to keep a detailed expenditure diary for four weeks, the response rate was around 50% only. This gave rise to two questions. Firstly, how could we improve the response rate and in turn the accuracy of the results? Secondly, would the results be distorted by non-responses? The answer to the first question was to double the sample size and reduce the survey cycle to two weeks. The response rate improved to over 60%. The answer to the second question was to identify the demographic and economic characteristics of the non-responses and make comparisons with those of the participants. Statistical tests showed that any distortion would be insignificant. I shall not elaborate on the details.

Apart from classical hypothesis testing like chi-square and F-statistic, more sophisticated quantitative methods have been developed to measure and analyse consumer satisfaction, perception and preferences. Multiple regression analysis is used to identify the contributing factors to consumer demand and the elasticity of demand. Factor analysis is used to deduce the conceptual and beneficial dimensions underlying the expressed measures of product perception and preference. Cluster analysis is used to deduce homogenous groups from the data set for identification of potential market segments as well as competitors. Conjoint analysis deals with the trade-off in consumer preferences, and identifies the determinant attributes of brand choices.

As human behavior is abstract in nature, the use of mathematical models is at best a generalisation and an approximation of the real life situation. The reliability of these models in practice depends much on the quality of the data input and the validity of the underlying assumptions in the application.

STATISTICS FOR FORECASTING

Theories in multiple regression and time series analysis have provided a well-developed mathematical framework for business forecasting. In practice, a mathematical model consisting of a set of multiple regression equations is developed from history. Apart from classic technical assumptions on the variables used, such as randomness and

linear relationships, there are a number of practical presumptions for statistical forecasting to be effectively applied. Firstly, both the target variables and explanatory variables are discretely measurable. Secondly, causal relationships in variable sets are logical in a real life situation. Thirdly, such relationships will persist into the future.

In real life, however, the economic environment is changing. So are consumer tastes and behaviors. These could upset the demand-supply relationships built up over the years. As such, causal relations between variables shift continuously over time. The result is that the future usually bears a closer relationship with the immediate past than the distant past. As forecasting models are often built on rather long time series, their prediction ability is often impaired.

The econometric model of the Hong Kong economy is a case in point. All the models in use by the Government, academic institutions or financial institutions are trade-based and use the expenditure approach to Gross Domestic Product (GDP). A typical model is constructed on the basis of an exporting city-state economy, with the bulk of the exports being domestically manufactured from imported raw materials.

The model starts with the exports of Hong Kong manufactures, which are determined by the import demands of major markets and the price competitiveness of the goods. Price competitiveness depends in turn on the exchange value of the Hong Kong dollar, domestic labour costs and imported material costs. Domestic labour costs are affected by labour supply and inflation.

The net income from exports will generate demands for capital investments or reinvestments as well as consumption throughout the economy. In turn, these domestic demands will determine the retained imports of capital and consumer goods.

Statistically, all these models have strong explanatory relevance in relation to the past performance of the Hong Kong economy. They meet all the stringent statistical tests for a theoretically perfect regression analysis for time series. However, their predictive power has not been impressive. For the years 1976 to 1996, the deviations of the annual forecasts, both official and private, averaged 2.25 percentage points from the actual annual GDP growth rates of 0.4% to 16.2%. In relative terms, the deviations of the official forecasts, for instance, ranged from an over-estimate of almost 200% for 1982 to an under-estimate of 58% for 1986. While the deviations in the 1970s and 1980s were largely explainable by the forecasting errors in external trade, the situation in the 1990s has been more complex.

The past 20 years witnessed two phases of structural changes in the Hong Kong economy. With the embarkation of economic reforms in 1978, China reopened its doors to foreign trade and investment. In the next 10 years, Hong Kong revived its traditional role as an entrepot, with the share of re-exports in total external sales rising from 25% in 1978 to 48% in 1987. The decade also saw the massive relocation of Hong Kong manufacturing plants to the nearby Pearl River delta area on cost and resources considerations, thereby effectively paving the way for Hong Kong's future reintegration with the Chinese economy.

From 1988 to 1997, the Hong Kong economy evolved from being manufacturing-based to service-based. The share of re-exports further expanded to 86% of total exports and transshipments tripled in the last five years to the equivalent of 25% of onshore trade. Meanwhile, employment in the manufacturing sector fell from some 900,000 in 1980 to 309,000 in 1997 and the figure is still declining. The contribution of the manufacturing sector to the GDP dropped from 24% to 7% during the period. Moreover, according to gross national product (GNP) statistics, income from abroad, mainly from investments, accounted for 35% of GNP in recent years. Hong Kong has been changing its role from a manufacturer to a global merchandiser and investor. In this light, the paradox is that these classic trade-based models are highly explanatory of the past performance but poorly predictive of the future growth trend of the Hong Kong economy.

THEORY AND PRACTICE

Like any science subject, the theory of statistics is meant for a perfect or ideal world, which hardly exists in reality. In the application of statistics in business, there is always a gap between theory and practice. The construction of stock market indices is a good example and I shall illustrate by using the Hang Seng Index.

The Hang Seng Index is the *de facto* indicator of the Hong Kong stock market's performance. To global investors, it is as well-known as the Dow Jones Industrials Average of New York, FTSE-100 Index of London and Nikkei-225 Average of Tokyo.

Technically speaking, the Hang Seng Index is a base period, market capitalization weighted stock price index, comprising 33 constituent stocks. The market value or capitalization of a stock is calculated by multiplying its unit market price by the number of shares issued.

As it is a price index, adjustments are made in the calculation for capital changes such as bonus issues, stock splits or new issues, which would affect the basis of pricing, so that the day-to-day price comparison of the constituents is consistent and undistorted by such capital changes.

There are practical and conceptual advantages in using a sample of stocks to replicate the overall performance of the market. Practically, this will avoid the inclusion of inactive stocks and small capitalization stocks. Thinly-traded stocks are less responsive to market sentiments, and incidentally they are mostly small capitalization stocks. Theoretically, their exclusion would also reduce the auto-correlation of the Index.

Conceptually, the Hang Seng Index is an investment portfolio of 33 constituent stocks. Had an investor tracked the Index with an identical investment portfolio from its base date of 31 July 1964, the market value of this portfolio would have increased by 107 times by the end of 1997. During the 33-and-a-half year period, the Hang Seng Index rose from the base value of 100 to 10,722.

With the current state-of-the-art information technology, a real time all-stock index, which in theory is the market, is no longer out-of-reach. However, a sample-stock index is still preferred by investors for a number of practical considerations. Firstly, stock markets are still dominated by blue chips in terms of market value and turnover. Secondly, investment interest is still concentrated on the blue chips. Thirdly, the all-stock index includes inactive stocks by definition but their nominal prices are often outdated and not reflective of the prevailing market sentiments. Fourthly, for all practical purposes, investors have to use a portfolio of representative stocks to replicate the market.

The Hong Kong market typically exemplifies the merit of a sample-stock index. There were 642 listed ordinary stocks at the end of February 1998. In terms of the average market capitalization for the past 12 months, the 10 largest stocks accounted for 51% of the total; the 25 largest stocks accounted for 67% of the total; and the 148 largest stocks accounted for 90% of the total. In terms of turnover for the past 24 months, the 10 most active stocks accounted for 32% of the total; the 25 most active stocks accounted for 50%; and the 193 most active stocks accounted for 90%. Thus, the Hang Seng Index of 33 constituents, which covers 70% of the total market value, moves in tandem with the All Ordinaries Index compiled by The Stock Exchange of Hong Kong.

The selection of a representative sample of stocks to reflect the market has always been the key issue in index compilation. Unlike market research surveys, probability

sampling methods are seldom applicable in stock index construction. What really matters is not the unbiasedness and sufficiency of the sample, but the index's history and proven record in tracking the market.

The Dow Jones Industrials Average of New York is a good example. It is unweighted and comprises one share each of its 30 constituents. The Index number itself represents a simple arithmetical average of stock prices and the divisor is adjusted for capitalization changes of the constituents. This means that the Dow Jones is effectively price-weighted; the higher the unit price of a stock, the bigger its impact on the Dow Jones. Obviously, the Dow Jones is technically inferior to market capitalization indices such as the Standard & Poor's (S&P) series, but it remains the "index" of the New York market. This is largely attributable to the Dow theory of the behavior and cycles of the stock market, a proven analytical concept based on the Dow Jones, that has withstood the test of time. In fact, the movements of the Dow Jones are in tandem with the S&P 500.

The FT-30 used to be the barometer of the London market. It was started in 1935 and comprises 30 UK listed companies. Using the geometric averaging method, the index is a simple geometric mean of the price relatives of its 30 constituent stocks. Effectively, the index is price relative weighted. The index level reflects the average of the percentile changes in the closing prices of its constituents. To ordinary investors, the interpretations of the change in the index level itself and its relation with their own investment portfolios are perhaps too academic. With the launch of the market capitalization weighted FTSE-100 in 1984 to facilitate the trading of financial futures in London, the position of the FT-30 has now been replaced by the new index. Obviously, the FTSE-100 is simpler and easier to understand for investors at large.

No matter which methodology is used, a stock index effectively represents an investment portfolio. There are implicit investment assumptions associated with each method. The market capitalization method resembles a model portfolio where the interest in each constituent is always proportionate to its market values, and the daily movements of the index indicate whether investors are collectively better off or worse off given the changes in the stock prices. Moreover, cash dividends are not reinvested into the portfolio. Under the arithmetical averaging method, the investor always keeps only one share each of the component stocks in the portfolio. In case of capitalization changes, such as bonus issues, the investor will dispose of any additional holdings arising from such changes. Implicit to the geometric averaging method is a daily adjustment of

holdings in the investment portfolio by selling stocks which have risen faster in price than the market average and buying those which have risen slower than the average.

STATISTICS AS A SCIENCE AND ART

In the face of the inherent inadequacies of statistical applications in the complexity of the real world, the experience of the users helps bridge the gap between theory and practice in the use of statistics in business.

The backdating of swap deposits figures in Hong Kong for the period 1981 to 1984 is an illustration. A swap deposit is an arrangement under which a customer purchases US dollars from the bank to place a time deposit with that bank and at the same time enters into a forward contract to sell the US dollar proceeds back to the bank for Hong Kong dollars upon maturity. As the deposit is denominated in US dollars, it is not subject to Hong Kong dollar deposit rates regulations. With this arrangement, retail Hong Kong dollar time deposits would effectively enjoy market rates rather than the regulated rates.

Swap deposits were first offered by banks in 1981 when Hong Kong dollar deposits were highly regulated and subject to withholding tax. Official statistics were only available from December 1984. To backdate the series, we had to apply statistical methods. The classic statistical approach here should be time series analysis, but its application was impaired by the behavior of the series in question. The month to month fluctuations of swap deposits were rather erratic, subject to a combination of factors in addition to the gaps between the regulated deposit rates and the market rates. However, it was found that the ratio of foreign currency liabilities (excluding swap deposits) to foreign currency assets in 1985 was rather stable. It was between 96.0% to 96.6% as compared with the ratio of around 94% to 96% in the first half of 1981 when swap deposits were insignificant. Applying an estimated ratio of 96.5%, the backdated series of swap deposits was extrapolated accordingly. Cross-checking with other market information showed that the estimated figures were consistent and reliable. For instance, the extrapolated figure of HKD45 billion for June 1983 was the same as the figure then published by the Government.

In Chinese, the term “business” is literally composed of the words “life and ideas”. Incidentally, they correspond to the key words for the application of statistics in business, “adaptive and flexible”. Users should know when to apply the tool even though the underlying assumptions cannot be met in full and when to accept variation in the methodology. They should also know when to exercise judgment in interpreting the

inferences by taking into account their own experience and other qualitative factors which cannot be incorporated into the statistical model.

Statistics is applied mathematics whose proper use helps make the life of businessmen easier. However, only rarely should statistics be used as the sole basis for business decisions. Its application is both a science and an art. As a science, the statistical methods have the same fundamental theories and processes as any other natural science subject. As an art, the value of statistical methods depends very much on how they are applied and interpreted by the users.