The maths behind the results

He concludes: “We have succeeded in finding a simple formula that gives a nuanced picture and allows businesses to strike a well-informed balance between costs and the employment, we should therefore pay attention to the wage cost handicap as well as to the flexibility or inflexibility of our labour force.’

In response to the euro crisis, a number of European countries have taken steps to reform their labour markets and to make them more competitive (for example, night shifts in the automotive industry). Therefore, the situation could change.

“Where should we be manufacturing? Locally, or further afield, in low-wage countries? This is a question with which many companies struggle”, says Professor Robert Boots. The answer is dependent on a number of factors. Using a theoretical but realistic stock model, he has worked with Professor Jan Van Mieghem from the Kellogg School of Management to develop an elegant mathematical formula with which companies can calculate exactly how much they should manufacture locally, and how much they can manufacture offshore. The formula offers a clear insight into the impact of the various factors that play a role in the decision.

Robert and Jan have developed a formula for calculating the optimal – i.e. cheapest – split, taking into account the characteristics of the two available locations:

- Lead times:
  - Factor costs – variable costs such as direct material and wage costs, energy and import taxes;
  - Capacity costs – fixed costs such as investments in machines, wage costs and other overheads that cannot be directly attributed to any one product; and
  - Capacity flexibility.

This approach is new. Robert explains: “As a rule, existing models for stock optimisation questions only take into account factor costs and stock costs. However, today companies are taking into account capacity costs, and especially the flexibility of that capacity – the flexibility to produce more and to work overtime – when they make their decision. In certain parts of the world, there is quite simply more flexibility.”

In their paper, Robert and Jan describe how the formula is applied to a situation in which a company is able to use two complementary suppliers (or manufacturing locations) – one place that is more expensive, but offers shorter lead times; and a cheap location abroad whose downside is that the delivery times are longer – whilst employing various ordering rules to counterbalance any fluctuations (order smoothing policies). They explore the impact of differences in lead times, factor costs, capacity costs and capacity flexibility. The results for dual sourcing – producing in two different locations or sourcing supplies from two different suppliers – are compared to those for single sourcing.

“The rising volatility of market demand means that it is increasingly unwise to shift your manufacturing offshore to low-wage countries entirely, unless the difference in wage costs is so great that it compensates for all the other differences. I cannot pretend that our wage costs are not a problem, but it is a mistake to become fixated on wage costs alone”, Robert believes.

“The great thing about our formula is that it explicitly expresses both the various different factors that help determine overall costs, and the relationship between these factors. It also shows that inflexibility in terms of capacity – the inflexibility of staff to work overtime or of machines to produce larger volumes – has the same effect as a (wage) cost disadvantage. That sounds logical, but now we can also prove this mathematically.”

An American phenomenon?

Since wage costs in China have nearly doubled, an increasing number of American companies are relocating their production back to their own country, as The Economist reported in January 2013. However, the magazine noted that this reshoring is primarily an American – rather than a European – phenomenon. According to The Economist, the explanation lies in the rigidity of the European labour market. In response to the euro crisis, a number of European countries have taken steps to reform their labour markets and to make them more competitive (for example, night shifts in the automotive industry). Therefore, the situation could change.

Robert explains: “Our simulations confirm that measures like this can indeed encourage reshoring. To return to the wage cost issue: in the debate about economic growth and employment, we should therefore pay attention to the wage cost handicap as well as to the flexibility or inflexibility of our labour force.”

He concludes: “We have succeeded in finding a simple formula that gives a nuanced picture and allows businesses to strike a well-informed balance between costs and the ability to react quickly to demand and to changes in the market.”

New approach

Robert states: “The formula offers a clear insight into the impact of the various factors that play a role in the decision. In certain parts of the world, there is quite simply more flexibility.”
For anyone who is interested in the maths behind the results: the allocation problem dealt with in the paper is an optimisation problem. The idea is to minimise the overall cost, bearing in mind a difference in lead times, direct costs, capacity costs and flexibility with regard to capacity. This optimisation problem gives rise to a polynomial, a higher-grade comparison with a degree greater than four. For these types of polynomials, the answers can no longer be calculated exactly, only approximated. This is why Robert and Jan used Lagrange’s inversion theorem, so that things could be condensed into a simple quadratic equation that is analytically solvable. This is the first time that Lagrange’s inversion theorem has been used for stock optimisation purposes.

Source: The paper “Global Dual Sourcing and Order Smoothing: The Impact of Capacity and Lead Times” was published in Management Science, Articles in Advance, p. 1-20, 2014. You can obtain the paper from the authors, along with a 64-page Companion with deductions from and justifications for the formulas used.

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