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On 28 January 1986, 73 seconds after lift-off, the Space Shuttle Challenger disintegrated in a giant explosion, killing the whole seven-strong crew, costing NASA billions of dollars and setting back the space programme by 10 years. The cause of the disaster was later revealed to be the malfunctioning of one of the rubber O-rings supposed to seal the liquid fuel tank.

The lesson that economists took from the Challenger catastrophe was that complex products (such as a spaceship) are made up of several critical components. In fact, a leading economist (a future Nobel prize winner, no less) developed a whole new theory working out the implications of multi-component goods. These implications turned out to be far from trivial: for example, if workers vary in their skill levels (as they certainly do), then profit maximisation will ensure that high-skill workers will be coupled with high-skill workers, and low-skill workers with low-skill ones: segregation by skill.

I was puzzled by this explanation of the Challenger disaster because it ignored the real reason for the explosion and, more importantly, it contradicted the teaching of one of the greatest geniuses of the 20th century.

Googling '20th-century geniuses' does not reveal his identity, but John von Neumann is without doubt the most brilliant polymath of the last century. He made path-breaking contributions to physics, mathematics, statistics, economics and even meteorology. Being the father of the US space programme was probably one of his lesser achievements, but NASA was and still is deeply imbued with his influence.

To see the connection between von Neumann and the Challenger disaster, we need to acquaint ourselves with the von Neumann dilemma. Suppose NASA gives you a large but finite budget and one simple objective – land a

rocket on the moon – and you have enough resources to build two rockets. What is the best way to ensure that one rocket *does* land on the moon?

Notice that this is not an economics problem: economics, as commonly understood, deals with optimal *allocation* of resources, whereas here the resources (i.e. the budget) is fixed, the problem being one of optimal *organisation* of resources.

Von Neumann got to work and singlehandedly created a new branch of statistics (reliability theory) and proved an amazing theorem: if you have enough resources to build two rockets, you should *never* build two. Instead, you should always build a single rocket and use the left over components as spares, so that if one critical component (e.g. an O-ring) fails, there is another to take its place.

Now we can see the link between von Neumann and the Challenger disaster: surely NASA engineers would have fitted spare O-rings in case one malfunctioned. Of course they did! Unfortunately, the Reagan administration had compelled NASA to involve private companies in its space programme and the private company assigned to statistical analysis made an elementary but catastrophic mistake. It failed to realise that because of the very cold weather at the time of launch, every O-ring (spares included) was likely to become brittle and hence useless. Which is precisely what happened on 28 January 1986.

To see the remarkable power of the von Neumann theorem, I'll mention two relevant examples. The Manhattan project (developed to build as quickly as possible an atom bomb to be dropped on Japan) was organised along von Neumann lines: several teams of scientists worked simultaneously on different research routes, sharing information as they progressed in their findings. By the way, von Neumann himself was part of one of the teams, but his conclusion that the bomb should be exploded at an altitude of 300 metres so as to maximise the number of casualties was not implemented. Somewhat ironically, he died aged only 56 of cancer caused by radiation exposure during the Manhattan project.

The second example is more recent and happier: the incredibly fast development of a Covid-19 vaccine was the result, again, of several teams of scientists working simultaneously on different research paths and sharing information about their intermediate results.

Unfortunately, von Neumann's teaching is generally ignored and the list of examples where substantial improvements could have been achieved by following it is a long one. I was reminded of this only the other day when I was perusing the latest McKinsey Global Institute's report (*The Complication of Concentration in Global Trade*). The report shows that over 40% of world trade is 'concentrated', meaning that the importing economy relies on three or fewer nations for the supply of a given good or service.

Consider the world trade in wheat. Although there are 15 countries supplying 90% of total trade, several economies import their wheat from only a couple: for example, Turkey and the Philippines import respectively 90% and 80% of their wheat from only two countries.

The disruption in the world's supply chains brought about by the Covid-19 pandemic and Russia's invasion of Ukraine has definitely been exacerbated by this 'concentration', with Germany's suicidal reliance on Russian gas being

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a prime example.

But the loss of potential improvements due to ignoring the von Neumann legacy is even larger if we consider the case of research and development (R&D).

Billions of research funding are allocated using a sub-optimal organisation: take, for example, the EU Horizon funding (€95.5bn for 2021-27) or the UK Research and Innovation £6bn funding. Both schemes follow the long-established procedure of assessing research proposals individually, not jointly. Why is this a violation of the von Neumann theorem? Take two projects aimed at the same objective (say, the development of more efficient batteries). It is very easy to provide examples where each project assessed on its own fails the test of providing a positive expected return, whereas the two projects combined would produce a substantial expected gain.

In a similar vein, consider the case of research joint ventures. Both in the USA and in the UK, substantial advantages are given to firms that combine their research activities (in the USA, this has required a relaxation of anti-trust regulation, no less). But neither country requires research joint ventures to be organised along von Neumann lines, thereby missing out on potentially very large benefits.

I wish that John Maynard Keynes' famous pronouncement that the world is ruled by little else than the ideas of economists applied to dead genial polymaths, too.

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