LESSONS FROM THE HISTORY OF TECHNOLOGY DIFFUSION AND ADOPTION

Dr Jen Nelles, Dr Hamisu Salihu, Dr Lauren Tuckerman and Prof Tim Vorley

Oxford Brookes University, University of Warwick and University of Glasgow

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Executive Summary

The adoption and diffusion of innovations or new technologies play crucial roles in driving economic growth and societal transformation (Rodríguez-Pose, 1999; Zheng et al., 2024). However, it is important to note that both within the UK and internationally, the diffusion of technologies across industries, regions or countries has been uneven. Society is facing concurrent paradigm-shifting opportunities and challenges from rapid technological advancements in, for example, digital/AI, robotics, and bioengineering. To maximize economic, societal and environmental benefits of emerging technologies, adequately manage the risks, and do so responsibly, is likely to depend on widespread adoption and diffusion of beneficial applications of technology across businesses and society. Ideally, those technological transitions will occur within an appropriately regulated environment. The IUK's Horizon Scanning team initiated this project to understand what lessons from the past can help us to overcome adoption and diffusion challenges. This report reflects on the many barriers to adoption and diffusion of technologies, drawing lessons from the past and present to inform future innovation support.

Rather than focusing on early adopters, this research explores the factors that enable or constrain mass adoption (and hence, broad diffusion) of innovation. It is in this phase where cultural, behavioural, and social factors exert influence on adoption decisions in addition to more frequently cited constraints or enablers such as cost, regulatory environment, labour, and skills. While this report acknowledges the gamut of factors that affect technology adoption decisions, we are particularly interested in exploring issues beyond the bottom line to engage with how questions of fairness, responsibility, and risk management have shaped diffusion patterns.

This report has two main contributions:

(1) **A set of frameworks** for UKRI and government departments to sense check issues associated with the adoption and diffusion of innovations with a view to better inform and improve the design of interventions.

(2) **A series of case studies** that trace technology adoption and diffusion stories from the past and present, with reflections on how these can inform thinking about the future. We focus on three technology families: advanced materials & manufacturing, energy & environmental, and health & wellbeing. Through these examples, we want to understand what factors influenced how previous examples played out, how barriers were overcome, whether any government interventions helped improve the rate and experiences of adoption and diffusion and how we can learn from these to support adoption and diffusion of modern and emerging technologies for optimised outcomes.

The frameworks were designed to be a tool to help policy makers and programme designers develop an understanding of what kinds of barriers might exist to getting specific technologies to spread from early adopters to a wider community, and how public stakeholders might intervene to reduce constraints and multiply opportunities for adoption.

The adoption and dissemination frameworks are both designed around a series of questions that can be used either directly with target communities or to help structure programmes.

We specifically focus on how policy and interventions can support the diffusion of innovations to the critical point in technological development where they become widely adopted. There is role for policy actors in affecting both the dissemination and adoption of innovations and it is likely that targeted interventions can help individual firms or classes of firm become more receptive to innovation. However, there is no one answer that is appropriate to every firm, industry, or context. Different factors will affect businesses, and their innovation adoption decisions, differently. As the structure of the adoption framework demonstrates especially, adoption decisions are complicated and can be impacted at different stages. That is why it is crucial to understand the specific context of the target business, group of businesses, or industry and where in the decision-making process to intervene to select the appropriate factors for intervention. These frameworks are specifically designed to develop that understanding to enable more precise and effective interventions.

Exploring these case studies, which vary significantly in terms of the nature of technologies and the markets within which they have diffused, provided an opportunity to test the value of the frameworks and enabled us to revise them to fill in any gaps. This iterative process enabled us to strengthen the frameworks as well as provide a robust approach to understanding the cases themselves. The process also generated the following lessons:

- **Intermediaries can accelerate diffusion:** For many of these cases, intermediaries (most frequently governments and their stakeholders) have played an important role in shaping diffusion. This can happen on the supply side or the demand side. On the

supply side, government intervention can help technologies reach appropriate levels of development for market, provide assistance so that production can be scaled to a point to where more widespread adoption is possible, or help technologies develop features or production methods to the point where they are cost effective. On the demand side, governments can also affect costs by negotiating supply, can increase the attractiveness of certain technologies through regulatory activities (see the mRNA case for good examples of both of these), provide resources (information or material) to boost capabilities, and more.

- **Labour and workforce implications can disrupt adoption:** Degree of workforce buy in and broader impacts on labour are often considered secondary in adoption models but can be important considerations in adoption processes. Workers engaging in machine breaking slowed but did not impede the diffusion of steam powered factories. The case of industrial robotics shows that these kinds of disruptive behaviours continue to be a problem when workers have not bought into technological changes.
- **Cost/benefit analysis is shaped by a variety of factors across the willingness-capability-capacity nexus:** What the technology costs is different from what it costs business to integrate it. This is evident by how these considerations emerge at different points in the framework. For instance, the cost of a technology relative to alternatives can affect a business' willingness to consider the technology. Customer and demand patterns can also affect that willingness. Market conditions, such as demand cycles, can influence cost calculations of both capability and capacity. The capital cost of the technology influences capability whereas the costs of implementation affect both capability and capacity.
- **Technological systems matter:** Adoption of all these technologies required the development of further innovations to increase their utility, make them accessible to different industries, lower costs. Just as the boom in software was a key to the ICT revolution so too will the development of related technologies affect the perceived feasibility of the technology families studied here. Gas lighting was only possible because of developments in storage and transport infrastructure. Steam energy was only relevant to industry when a wider variety of machinery was developed to use its power. Gene editing will become more accessible when delivery methods are simplified and scalable. Solar becomes more feasible as battery storage technology improves.
- **The decision to adopt, or not adopt, a technology rarely comes down to just one consideration:** The adoption framework matrix attempts to capture the high-level considerations that influence adoption decisions – but it's still quite a lot! While case studies generalise lessons at the industry scale, they demonstrate how many factors can act on businesses and be considered simultaneously. This suggests that it may be difficult to narrow down a single barrier to adoption that is solely responsible for

adoptions decisions and rather that the *combination* of factors, both positive and negative, ultimately shape outcomes.

- **Do not overlook social and behavioural influences on adoption decisions:** Adoption frameworks often privilege tangible factors such as costs or skills while reducing fewer tangible dimensions to categories such as “culture” or “attitudes”. This research shows that considerations about values, reputation, ambition, and risk can be equally important in shaping technology adoption decisions – particularly by influencing the willingness of businesses to consider (specific types of) technological solutions. Indeed, reinforcing the previous point, these kinds of social and behavioural factors should not be considered “in addition to” the more concrete factors, but should rather be understood as important lenses that colour firm perceptions and priorities as they consider things like cost. Given that the social and behavioural factors in our framework are typically inherent to firms and their leadership, they can be more difficult to overcome than capability (e.g., resource) limitations.

Increasing technology adoption and diffusion is an important ingredient in stimulating the innovation economy and increasing prosperity. However, this research demonstrates that it is an extremely complex set of problems that defy easy or expedient solutions. This report provides some context, and a set of tools, to enable stakeholders to make sense of the technology trajectories that they want to influence. It is accompanied by a summary guidance document, which provides a quicker and more accessible introduction to the frameworks, how we used them in our case studies, and how they can be applied in other contexts. These tools will be useful in interacting with individual businesses to understand their decisions and in considering trends within whole industries. They will also be useful to understand how to effectively align public policy goals with practice to ensure that technology adoption supports sustainable, responsible, and equitable innovation.

Now you have read our report we would love to know if our research has provided you with new insights, improved your processes, or inspired innovative solutions.

Please let us know how our research is making a difference by completing our short feedback form via this QR code.

Thank you

The Innovation & Research Caucus

Authors

- Dr Jen Nelles – Oxford Brookes University
- Dr Hamisu Salihu – University of Warwick
- Dr Lauren Tuckerman – University of Glasgow
- Prof Tim Vorley – Oxford Brookes University

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Contact: info@ircaucus.ac.uk

Website: https://ircaucus.ac.uk/