INNOVATION & RESEARCH CAUCUS

Regulation and Innovation: A Review of Empirical Evidence

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Executive Summary

This State-Of-The-Art (SOTA) review explores the complex relationship between regulation and innovation. It aims to shed light on the factors and mechanisms through which regulation influences innovation across various sectors. This SOTA links with another SOTA titled "Standard and Innovation: A Review of Empirical Evidence," recognising the importance of understanding both standards and regulatory frameworks in fostering innovation ecosystems.

The relationship between regulation and innovation is multifaceted. Different types of regulation can have varying effects on innovation. Broadly, three categories of regulation are identified: economic, social, and institutional. First, economic regulation affects a company's ability and willingness to innovate by influencing competition, market structures, and utility operations. Second, social regulation addresses negative externalities and seeks to protect public interests such as health, safety, environmental sustainability, and social cohesion. Third, institutional regulation includes frameworks related to liability law, employment protection, bankruptcy procedures, and intellectual property rights (IPRs), all of which can shape the innovation landscape.

However, it is important to recognise that regulatory intervention does not affect all firms uniformly. Factors such as firm size and market structure can influence how regulation impacts innovation. Additionally, the complex relationship between regulatory compliance and incentives for R&D plays a crucial role in fostering innovation.

This review also examines evidence on the impact of regulation on innovation across various sectors, highlighting how different regulatory measures shape innovation according to sector-specific dynamics. In particular, it presents examples from sectors that are especially relevant to the UK's Priority Sectors, including ICT and digital technologies, pharmaceuticals, and manufacturing.

An examination of the evidence reveals several significant gaps in the existing research base:

- First, most current studies focus on well-established sectors and tend to examine specific types of regulation in isolation.
- Second, there is a lack of research analysing the holistic impacts of regulation on innovation across diverse contexts.
- Third, limited attention has been given to emerging sectors, particularly linked to the UK Priority Sectors, such as life sciences and clean energy.

These gaps highlight the need for further empirical research to better understand how regulation influences innovation—particularly within the UK context.

1. Background

This State-of-the-Art (SOTA) review explores the complex and evolving relationship between regulation and innovation. Regulation is commonly defined as the product of market and political processes; arising from negotiations, advocacy, and contestation among different actors of the market to advance or protect their interests through regulatory instruments (Stigler, 1971, 2021). The OECD (1997) further expands this definition, describing regulation as the implementation of formal and informal rules by public authorities to influence market activity and private actors' behaviour in the economy. This definition, focused on government-enforced rules but recognizing the role of delegated powers and informal guidance, provides the framework adopted throughout this review.

By examining the interplay between regulation and innovation, the review aims to uncover the underlying factors and mechanisms; structural, behavioural, and institutional, by which regulation can either enable or constrain innovation across diverse sectors. Importantly, the relationship between regulation and innovation is shaped by political debates and cultural perceptions. Regulation is frequently critiqued in policy and business circles as unnecessary "red tape," a barrier to entrepreneurial dynamism and economic growth. However, this simplistic view fails to account for regulation's dual function: it can impose costs and administrative burdens on firms, yet also foster competition, protect the environment, promote consumer and worker safety, and create markets for innovation. In fact, regulation is often designed precisely to correct market failures or protect societal welfare, as in the case of pollution controls, health and safety standards, and intellectual property regimes.

Through a nuanced analysis, this review moves beyond reductive narratives to uncover the dynamics by which regulatory policy can be reimagined as a tool for guiding innovation—rather than merely constraining it. Evidence is synthesised across types of regulations (economic, social, and institutional) and acknowledging sectoral differences, highlighting ways in which well-designed regulation catalyses new business models, stimulates investment in R&D, and fosters the emergence of innovative solutions to public problems. Conversely, the review also addresses instances where poorly conceived, rigid, or misaligned regulation can hinder innovative activity, stifle competition, and lock industries into obsolete technological paths.

Ultimately, this review aims to provide a holistic understanding of the regulation-innovation nexus, offering insights to policymakers, industry leaders, and researchers seeking to balance the goals of public interest, market efficiency, and sustained innovation in a rapidly changing world.

2. The Interplay between Regulation and Innovation

Summary: Regulation and innovation have a complex relationship where regulation can both hinder and stimulate innovation depending on its nature and scope. Broad regulations can encourage compliance innovation, prompting firms to develop new products or processes to meet standards, while narrowly defined regulations may lead to circumventive innovation as firms seek ways to minimise regulatory burdens. Economic regulations impact innovation variably: competition can spur innovation, but excessive competition or restrictive market rules may hinder it. Social regulations, particularly environmental ones, often positively drive green innovation by directing firms towards sustainable practices. Institutional regulations influence innovation based on their flexibility; flexible frameworks encourage risky, radical innovation, whereas rigid ones promote incremental improvements. Overall, well-designed regulation aims to balance market power, encourage entrepreneurship, and adapt to evolutionary market contexts to foster innovation

The relationship between regulation and innovation is multifaceted. One perspective focuses on the types of innovation that emerge in response to regulatory pressures. For instance, regulation can impose compliance burdens on firms, diverting time and financial resources away from other innovative activities, a commonly cited concern (Blind, 2012b, 2013). However, regulation can also drive what is known as *compliance innovation*, where firms develop new products, services, or processes specifically to meet broad regulatory requirements (Stewart, 2010). In this context, the broad scope of regulation encourages firms to innovate to achieve compliance. Conversely, when regulation is narrowly defined, it may lead to *circumventive innovation*, as firms seek creative ways to avoid or minimise regulatory burdens (Stewart, 2010).

Another perspective highlights how different types of regulations influence innovation effects. Blind (2023) categorised these regulations as *economic, social and institutional regulations*, which will be further discussed next.[1]

2.1. Economic Regulations

In comparison to non-innovative activity, innovation is shrouded in additional uncertainty due to two sources, i) the uncertainty that the product or service can actually be made or offered to market and ii) the uncertainty about the demand for a product or service that had not previously been available. Both sources of uncertainty often reduce the willingness of lenders and investors to finance innovative projects (Audretsch, 2023).

Economic regulations can affect a company's ability to innovate, as they cover aspects of competition, markets, and utilities. This includes regulations on enhancing or securing

[1] It should be noted that these are merely general classifications of regulations. In reality, especially in different country contexts, regulatory differences may exist with different phrasing or names.

competition, antitrust, mergers and acquisitions, market entry, price, and public enterprises (Blind, 2012b).

The effects of economic regulations on innovation are varied, based on the specific type of regulation and the market context. Competition regulations can spur innovation by increasing competitive pressures, but excessive competition may diminish firms' desire to innovate (Scotchmer, 2004), while antitrust measures, market entry rules and price regulation can hinder or promote innovation on a case-by-case basis (Bassanini and Ernst, 2002; Barbosa and Faria, 2011; Koch et al., 2004; Aghion et al., 2005). For example, some studies show a negative correlation between product market regulation intensity and R&D spending in OECD countries (Bassanini and Ernst, 2002; Barbosa and Faria, 2011), while others report a positive impact of antitrust regulation on R&D intensity in G7 countries (Koch et al., 2004). Ultimately, effective public policy and use of government regulation should aim at: 1) discouraging dominant firms from abusing market power to suspend innovative activities of other firms, 2) encourage entrepreneurial activity among all firms, and 3) ensure market structures are observed in their evolutionary context.

2.2. Social Regulations

Social regulations are aimed at addressing negative externalities and safeguarding public interests such as health, safety, the environment, and social cohesion (OECD, 1997). They cover areas such as environmental protection, workers' health and safety and consumer safety.

While there is a divide between the effects of economic and social regulation on innovation (Blind, 2012a), social regulations often direct innovation towards environmental protection and public welfare (Blind, 2023). Recent studies suggest that environmental regulations, a subset of social regulations, generally have positive impacts on innovation, as they encourage firms to develop new technologies and processes that comply with these regulations (Blind, 2023, Kemp, 1998). More recent literature on social regulations and its impact on innovation have focused on environmental issues, given the pressing challenge of climate change. They found that environmental regulations have a positive moderate impact on green innovation (Fan et al., 2022; Lv et al., 2021), especially when regulation related to investment is also used (Change et al., 2023). A study on corporate social responsibility supervision combined with intellectual property rights (IPR) protection have also shown a significantly positive influence on enterprise innovation motivation in Chinese SMEs (Zheng et al., 2021).

The Porter hypothesis, formulated by Michael Porter and Claas van der Linde, suggests that well-designed environmental regulations can stimulate innovation and enhance competitiveness among firms (Porter and van der Linde, 1995). However, the overall impact of social regulation on innovation can vary depending on the specific type of regulation and its implementation. For instance, regulations that impose high compliance costs may deter innovation, whereas those that offer incentives or flexible solutions can foster it (Carlin and Soskice, 2006; Crafts, 2006).

2.3. Institutional Regulations

Institutional regulations encompassing areas like liability law, employment protection, bankruptcy frameworks, and IPRs, present a complex and often ambivalent influence on innovation. Their impact is heavily contingent on the specific design of the regulation, the sector in which it is applied, and the broader economic context (Blind, 2012b).

Generally, flexible frameworks tend to encourage short-term radical innovations, encouraging greater risk-taking and experimentation by firms, the activities of which are needed for innovation. Conversely, more rigid institutional structures can foster incremental advancements and improvements within established sectors, where predictability and stability are valued (Hall and Soskice, 2001). This duality reflects the inherent trade-off between encouraging disruptive change and ensuring a stable and reliable business environment.

The specific effects of different types of institutional regulations can vary significantly. For instance, while strict liability laws may deter radical innovation due to concerns about potential legal repercussions, moderate liability standards can, in fact, spur innovation by increasing consumer confidence in new products (Viscusi and Moore, 1993, Viscusi, 2011).

Similarly, employment protection regulations can both incentivise employees to put more effort in innovative activities through increased job security and disincentivise firms from pursuing risky innovations due to higher adjustment for labour costs (Eichengreen and Iversen, 1999; Soskice, 1997). Furthermore, generous bankruptcy laws may encourage entrepreneurship by reducing the stigma of failure, though their direct impact on the *type* of innovation pursued remains less clear (Armour and Cumming, 2008). Finally, although IPRs are designed to stimulate innovation by protecting creators, empirical studies provide mixed results, with some indicating little or even a negative influence (Bessen and Meurer, 2008; Lerner, 2009).

3. Mechanisms Underlying the Effect of Regulation on Innovation

Summary: The effect of regulation on innovation varies significantly by firm size and market structure. Large firms have the resources to innovate but may face knowledge transformation challenges and could potentially stifle smaller firms through anti-competitive behavior, requiring vigilant public policy and antitrust regulation. SMEs often struggle with regulatory compliance due to resource constraints but can turn regulation into a catalyst for innovation by integrating compliance early in development and using technology to reduce burdens. National contexts also matter, in which more interventionist economies may use regulation and public support to steer innovation effects in firms, while freer market economies may use other forms of intervention such as R&D and tax credits.

3.1. The Effect of Regulation on Innovation based on Firm Size and Market Structure

Firm size and market structure can considerably change the effects of regulation on innovation (Audretsch, 2023). While large companies often enjoy a competitive advantage in amassing the financial and human resources to engage in innovative activity, they often confront an imposing knowledge filter which complicates the transformation of that new knowledge into innovative activity (Audretsch, 2023). Public policy prioritising innovation or the knowledge-based economy needs to be vigilant in ensuring that the large, dominant companies refrain from exercising that power to disadvantage the small and new companies through anti-competitive behaviours and encouraging entrepreneurial activity as a means of enhancing the innovative performance of industries (Audretsch, 2023).

This has implications on antitrust, anti-monopoly (or more importantly in the current climate, the consideration of anti-oligopoly) regulations, to enable innovation, which are contingent on the evolutionary lens of market structure and firm size. For example, the software and computer industries were characterised by a market structure that is competitive rather than monopolistic or oligopolistic in its earlier years, although this has now changed to be dominated by large firms.

In contrast, SMEs often face greater resource constraints than large firms, making regulatory compliance a significant challenge. However, regulation can also serve as a catalyst for innovation when approached strategically. For example, by understanding and integrating regulatory requirements early in product or service development, SMEs can avoid costly mistakes and build trust with stakeholders, which supports responsible innovation and growth (ACCA, 2023). Many SMEs report that regulations constrain innovation processes, especially in sectors that are highly regulated; however, regulatory guidance can actually help them innovate and expand, rather than simply holding them back (European Commission, 2021). Leveraging technology, especially compliance software and regulatory technology (RegTech) solutions, enables SMEs to streamline regulatory tasks, reduce costs, and minimise human error, freeing up resources for innovation (Teichmann et al., 2023). These tools are scalable and adapt as regulations change, allowing SMEs to focus on developing new products and services while maintaining compliance.

However, the expectation and role of regulation in shaping market dynamics and supporting innovation can vary considerably across different national contexts. In more interventionist economies, such as those found in many European countries including Germany, regulation is often viewed as an active tool for steering the market toward desired societal and economic outcomes (Chaminade & Esquist, 2010). Here, public authorities are more likely to engage in deliberate policy interventions aimed at correcting market failures, promoting strategic industries, and supporting innovation ecosystems through targeted support measures and regulatory frameworks (Aghion et al., 2023). This contrasts with more laissez-faire market economies like the United States, where regulation is generally framed as a mechanism primarily to prevent market abuses and ensure fair competition, rather than actively directing market evolution (Porter & Stern, 2001).

It should be noted however the perception of what's interventionist or not should be viewed through a much wider lens beyond regulations. A nuanced understanding of what constitutes intervention in national innovation policy must extend beyond just regulations. Regulation primarily involves setting and enforcing market rules and addressing market failures through compliance mechanisms. However, intervention encompasses a broader array of policy instruments that shape innovation ecosystems through direct and indirect support. For example, financial incentives such as matching R&D investments—common in innovation policy frameworks like the UK's—also represent forms of intervention. These instruments are designed to address market failures related to underinvestment in research and development by reducing financial risks and encouraging private sector innovation (Einhoff & Paunov, 2025; Lundvall, 2007). Matching grants, subsidies, and tax credits lower the cost barrier for firms to invest in new technologies, effectively steering market outcomes similarly to regulations that mandate compliance or protect competition.

Moreover, interventionist approaches often integrate multiple mechanisms—including public R&D programs, IP protection policies, and innovation support services—that operate in tandem to foster collective learning, capability building, and network formation within national innovation systems (Edquist, 1997; Howoldt, 2024). Such policy mixes reflect an understanding that innovation is a systemic process requiring coordinated government action beyond regulatory constraints alone (Scordato, 2022).

This broader conceptualisation highlights that the classification of a policy or country as "interventionist" cannot rely solely on the extent of formal regulation. Countries with similar regulatory regimes may differ markedly in their use of proactive financial and organisational interventions to shape innovation trajectories. Hence, comprehensive evaluation of innovation policy effectiveness and intervention intensity must consider this wider spectrum of tools designed to correct market failures and promote transformative innovation activity (Cirera & Maloney, 2017).

The higher expectation for regulatory intervention in Europe reflects broader cultural and institutional differences. European social market economies often balance free market principles with a commitment to social welfare and sustainable development, embedding innovation policy within comprehensive industrial, social, and environmental governance (Hall & Soskice, 2001). Thus, regulations may encompass industrial policies, public investments, and innovation-driven standards that offer both constraints and proactive incentives for innovation.

This divergence implies that policymakers in interventionist contexts are more inclined to use regulations not merely as shields against anti-competitive conduct but also as proactive levers of innovation policy—designing frameworks to nurture entrepreneurial ventures, stimulate cross-sector collaboration, and address grand societal challenges. Conversely, in minimal state or free-market economies, the focus tends to be on maintaining perceptions of market freedoms and reducing regulatory burdens to foster innovation, potentially resulting in less direct governmental involvement in shaping innovation pathways (Lazonick & Mazzucato, 2013).

Understanding these contextual differences is crucial when crafting innovation and competition policies designed to foster entrepreneurial activity and sustainable industrial advancement across diverse economic systems.

3.2. Regulatory Compliance and Incentives for R&D to Stimulate Innovation

Balancing the intricate relationship between regulatory compliance and incentives for R&D is crucial for stimulating innovation. The Porter hypothesis posits that the costs associated with regulatory compliance can be offset by the benefits of innovation, such as increased efficiency and competitiveness (Porter & van der Linde, 1995).

If we try to understand this in a broad setting, the costs linked to compliance can reduce the resources available for R&D, potentially dampening innovation in the short term (Crafts, 2006). Conversely, 'smart' regulation that streamlines processes can help firms reduce burdens over time, thereby freeing up resources for innovation (Stewart, 2010). When regulation is used as a tool for innovation, it can reshape R&D investment incentives, as seen in regulations surrounding patent protection. OECD (2024) outlines that tax incentives also play an important role in the policy mix to incentivise R&D for innovative outcomes, finding that 33 out of 38 OECD countries use this mechanism to stimulate positive business R&D expenditures.

However, certain types of regulation, such as price restrictions on products and services, have been found to discourage R&D investment and thus hinder innovative outcomes (Carlin and Soskice, 2006). Ultimately, to foster and stimulate innovation, it is essential to consider the net impact of regulation on innovation, balancing compliance costs with incentives for R&D effects. Porter’s hypothesis challenges the conventional view that environmental regulations are detrimental to economic growth, instead proposing a "win-win" scenario where both environmental quality and business profitability improve (Ambec et al., 2013). The hypothesis is divided into versions: the "weak" version asserts that regulations trigger innovation, the "narrow" version suggests that flexible regulations increase innovation incentives, and the "strong" version claims that the benefits of innovation exceed compliance costs (Jaffe et al., 2002). However, empirical evidence on its effectiveness is mixed, with some studies supporting its claims while others find mixed results (Ambec et al., 2013; Jaffe et al., 2002).

4. The Effect of Regulation on Innovation: Sectoral Dynamics

Summary: Regulation impacts innovation differently across sectors like ICT, pharmaceuticals, and manufacturing, reflecting each sector's unique dynamics and firm characteristics. In ICT, lighter regulation often promotes new technological services, while stringent rules can dampen innovation except in subsectors like information security. Pharmaceuticals face costly and complex regulations that may slow new drug development but also assure quality and encourage patenting, with recent regulatory improvements boosting COVID-19 vaccine innovation. Manufacturing sees environmental and safety regulations generally stimulating technological advances, such as green patents and improved workplace technologies, although market and price regulations show mixed effects. Importantly, regulatory impacts vary by firm size, market structure, and national context, highlighting the need for nuanced, sector-specific approaches to balance innovation support and compliance burdens effectively.

This section explores the evidence surrounding the impact of regulation on innovation across sectors, focusing on how different regulatory measures can shape innovation based on each sector's dynamics. We particularly focus on some sectors that are linked to the UK's eight Priority Sectors, such as ICT and digital, pharmaceutical, and manufacturing sectors.

However, it is important to note that one challenge in examining sectoral-level relationships is that regulatory interventions do not affect all players in the same way; the impact can vary widely depending on the size, resources, and market positions of individual firms. As we delve into the evidence, it will be important to consider these variations and understand how regulation can either facilitate or hinder innovation across different players within each sector.

4.1. Evidence Review from ICT and Digital Sector

Given the rapid pace of technological advancements, market dynamics, and societal changes, regulation within the ICT and digital sectors is inherently complex. These sectors are heavily reliant on competition, which makes them more dependent on asymmetrical regulation (Bauer, 2012). Bauer (2012) identifies three types of governance within ICT regulation: 1) horizontal governance, which addresses the relationships between players within a specific layer (e.g., rules on interconnection or unbundling), 2) vertical governance, which focuses on relationships across different layers, and 3) general rules that impact both horizontal and vertical dimensions, such as interoperability requirements. In addition to traditional ICT regulations, Mueller and Van Eeten (2013) and Bauer and Bohlin (2022) highlight the complementary role of internet governance in shaping the broader regulatory landscape of the sector.

Research shows that regulation in the ICT sectors has complex effects on innovation, occurring at multiple levels (e.g., Bauer, 2012; Bauer and Bohlin, 2022). For example, Bauer (2012) argues that the ICT sector holds significant innovation potential, with regulation influencing both the speed and direction of this innovation. Bauer (2012) also suggests that the ICT sector acts as a platform technology for a wide range of industries, with firms' ability

to innovate in other sectors being heavily dependent on the availability of advanced ICT infrastructure. These findings indicate that ICT regulations can lead to direct, indirect, or even systemic effects on innovation (Bauer and Bohlin, 2022).

Table 1 below summarises the evidence from the literature on the effects of various regulations in the ICT and digital sector. In general, stringent regulation is associated with negative impacts on some innovation measures (e.g., Bauer and Shim, 2012), while lighter regulation has been shown to increase the introduction of new telecommunication services (Prieger, 2002). However, regulatory compliance pressure can also drive demand for products, potentially stimulating innovation in the specific subsectors, such as security sectors (Khansa and Liginlal, 2007). Bauer and Bohlin (2022), for instance, propose that regulatory interventions may not affect all players in the same way. For instance, price regulation on resources reduces innovation incentive for the providers but reduces the costs for innovation for players and thus increases innovation incentives for players (Bauer and Bohlin, 2022). In the same paper, Bauer and Bohlin (2022) identify direct effects, indirect effects and systemic effects of various regulatory inventory in the context of the 5G market in the US. These findings suggest the challenges in examining sectoral-level relationships of regulation and innovation.

Table 1 Evidence Review of Regulation and its Effect on Innovation in ICT Sector

Types of Regulation	Effects	Data and Period	Source
Incentive Regulation	Local competition and incentive regulation complement the motivation for pursuing cost-reducing process innovation.	US. 1986-1999	Ai and Sappington (2002)
	Strict FCC regulation negatively influences service innovation.	US, 1984-1997	Prieger (2002)
	Regulation dampens firms' incentive to innovate in the telecommunication industry. Lighter regulation spurs process and product innovation.	US	Prieger and Heil (2008)
Market access regulation and price regulation	The more stringent regulation (either market access regulation or price regulation) negatively influence innovation.	32 countries, 1997-2010	Bauer et al. (2012)
	Regulation related resources reduces innovation incentives for providers, but reduces the cost for innovation for players and, thus, increases innovation incentives.	US	Bauer and Bohlin (2022)
Information security regulation	Information security regulation incentivises IT producers, stimulating technological, process, and organizational innovation.	US	Khansa and Liginlal (2007)
Intellectual Property Regulation	IP regulation provides a conducive environment for cooperation and innovation.	Global (online communities)	Bauer, Franke, and Tuertscher (2016)

4.2. Evidence Review from Pharmaceutical Sector

The pharmaceutical industry is one of the most highly regulated sectors globally, with companies required to navigate complex and costly drug approval processes. Drug candidates undergo rigorous clinical testing to assess their safety and efficacy, while identifying potential risks and side effects. These regulations influence multiple stages of drug development, including clinical trials, registration, and manufacturing (e.g., Mora et al., 2021). While intended to ensure public health and safety, such regulatory frameworks can also affect the pace and direction of innovation.

Table 2 summarizes the evidence from literature on the effect of various regulations on innovation in the pharmaceutical sectors. Drug regulation has complex effects on innovation. While drug regulation generally had an adverse impact on new drug developments due to the increased costs and risks (Grabowski and Vernon, 1997) and time delays to introduce

innovation (Mora, 2021). Stringent drug regulation provides higher quality assurance that may encourage innovation (Katz, 2007; Malmberg, 2007). Research has also shown how drug regulation may lead to short -term efficiency (e.g., Atun et al., 2007) or patenting activity (Malberg, 2007) or research productivity in larger pharmaceutical firms particularly (Thomas, 1990). In addition, improved regulatory practices by reducing administrative waiting times, can boost innovation (Jia and Ma, 2023). This was also evident in the case of COVID-19 vaccines, where the accelerated 'rolling review' process boosted research and innovation (Vagnoni and Barber, 2020).

Table 2 Evidence Review of Regulation and its Effect on Innovation in Pharmaceutical Sector

Types of Regulation	Effects	Data and Period	Source
Drug Regulation	Smaller firms experience reduction in research productivity, but larger firms benefited from regulation due to reduced competitions.	US and UK, 1960-1980	Thomas (1990)
	The 1983 Orphan Drug Act positively influences pharmaceutical innovation.	US, 1981-1998	Reaves (2003)
	Drug regulation provides certification of drug quality and encourages innovation in the pharmaceutical innovation.	US	Katz (2007)
	Stricter pharmaceutical regulation increases patenting and productivity in the short term.	Sweden	Malmberg (2007)
	Regulation has both positive and negative effects on innovation, Regulation can cause delays, increased costs, and uncertainty about return on investment.	Mexico	Mora (2021)
	Improving regulatory approval processes can promote innovation in the pharmaceutical industry.	China	Jia et al. (2023)
Price Regulation	Pricing and reimbursement regulation can adversely impact pharmaceutical innovation by reducing the value of projects and resources available for R&D.	-	Friederiszick (2009)
Market Regulation	Regulation-induced product shocks, such as product relabelling, in pharmaceutical markets significantly influence aggregate demand, firm performance, and future innovation.	US and UK, 2003-2009	Higgins et al. (2021)

4.3. Evidence Review from Manufacturing Sector

Manufacturing industry is subject to a complicated regulatory structure designed to preserve the environment, worker safety, and business competitiveness. Regulations in the industrial sector have become stricter over time, especially when it comes to occupational health and environmental effects. While the regulations in manufacturing industry often impose additional costs and operational challenges (e.g., Liu and Xie. 2020), research indicates a positive effect of innovation, particularly in the long term.

Table 3 summarises findings from the literature on the impact of various regulations on innovation in the manufacturing sector. For example, environmental regulations can stimulate technological innovation, particularly in areas related to environmental sustainability (e.g., Kneller and Manderson, 2012; Liu and Xie, 2020; Wang et al., 2022). Similar effects have been observed for safety regulations, which may also drive innovation (e.g., Shin et al., 2021). An example of safety regulations driving innovation is the impact of Occupational Safety and Health Administration (OSHA) regulations in industrial safety in the US. These regulations push companies to develop new technologies and practices that enhance worker protection and operational efficiency. For instance, OSHA standards have driven the development of advanced personal protective equipment (PPE), robotics and automation to handle hazardous environments, predictive safety analytics to prevent accidents, and virtual reality (VR) safety training programs to improve worker preparedness and safety awareness. This shows how compliance with safety standards leads to continuous improvements and technological innovations that go beyond mere regulatory adherence. Similarly, regulatory requirements in the aviation industry have forced aircraft manufacturers to improve in their sensors, navigation equipment, and air traffic control technologies (Allianz, 2015). These findings suggest that some firms perceive environmental and safety regulations as catalysts for innovation. In contrast, the effects of market and price regulations are more complex. While stringent market regulations may offer advantages to domestic firms (Lee et al., 2011), they can also hinder R&D efficiency (Franco et al., 2016), highlighting the nuanced role of regulation in shaping innovation outcomes.

Table 3 Evidence Review of Regulation and its Effect on Innovation in Manufacturing Sector

Types of Regulation	Effects	Data and Period	Source
Environmental regulation	Environmental regulation positively influences innovation.	US, 1973-1993	Pickmann, (1999)
	Increased monitoring and enforcement of environmental regulation did not provide additional incentive to innovate.	US, 1983-1992	Brunnermeier and Cohen (2003)
	Environmental regulation positively influences innovation activity, measured by patents, but does not influence productivity.	European countries, 1997-2009	Rubashkina (2014)
	Strict environmental regulation directly reduces the optimal investment in non-environmental innovation.	UK 2000-2006	Kneller and Manderson (2012)
	In the long run, environmental regulations play a key role in promoting research and development investment.	EU, 2013-2014	Yuan (2017)
	Stricter environmental regulatory framework leads to the increase of the production of green patents, i.e., pollution control technologies.	China, 2002- 2009	Kesidou and Wu (2020)
	Stringent environmental regulation hinders the independence of China's manufacturing industry, thus reducing its export competitiveness. On the other hand, environmental regulation stimulates technology introduction.	China, 2000 - 2014	Liu and Xie (2020)
	Environmental regulation stimulates firms to perform green technology innovation.	China, 2010-2019	Wang et al. (2020)
Safety regulation	Companies that view safety regulations positively are generally more innovative than those that do not.	South Korea, 2018	Shin et al. (2021)
Regulatory tax	Regulation negatively influences incremental innovation as measured by citations and text-based measures of novelty in manufacturing sectors.	France	Aghion et al. (2021)
Market regulation	Stringent performance-based technological-forcing regulation induced domestic US firms to become more innovative than foreign firms that operated in the local US market in the short term.	US	Lee et al. (2011)
	Upstream product market regulation reduces R&D efficiency, particularly in the short term.	Ten OECD countries, 1990-2002	Franco et al. (2016)

4.4. Gaps in Existing Evidence on Sectoral Dynamics

Based on the available evidence, several gaps remain in the literature:

1. **Sectoral Focus and Regulatory Coverage:**
   Most existing research concentrates on well-established sectors such as manufacturing and ICT. However, not all regulations have the same level of importance across different sectors and countries, and some regulations are studied far more extensively than others. For example, environmental regulations are predominantly examined within manufacturing, while drug regulations are heavily analysed in the pharmaceutical industry.

2. **Narrow Scope of Regulatory Impact:**
   Much of the prior research tends to investigate the effects of specific regulations within particular sectors or among specific actors. There is a noticeable lack of studies that take a more comprehensive approach, analysing the broader or holistic impacts of regulations on innovation across multiple contexts.

3. **Limited Exploration of Emerging Sectors:**
   Research on the regulatory and innovation dynamics within emerging sectors remains scarce. In relation to the UK's Priority Sectors, there is significant potential for further study on how regulations influence innovation in sectors such as clean energy and life sciences (see the UK Priority Sectors).

Despite the potential positive impacts on innovation, the literature also highlights the possible negative effects of imposing regulation, suggesting the benefits of deregulation in some sectors. For instance, deregulation has been associated with increased efficiency and competition in telecommunications and airlines industries (Brouwer, 2010). Deregulation in power sectors in India has also led to increased private participants in the electricity market (Raikar and Jajgtap, 2018).

5. The Future Direction of Regulation and its Impact on Innovation

As we move forward, there is a pressing need to address grand societal challenges and consider how regulation might influence the spaces for innovation among private actors. Traditional regulatory approaches, while effective at shaping firm behaviour and promoting incremental innovation, often focus on established technological pathways and may inadvertently reinforce existing socio-technical regimes, limiting the potential for transformative change (Porter, 1991; Pyka and Urmetzer, 2022). These formal mechanisms, whether implemented through top-down or bottom-up governance, tend to support current value creation networks rather than catalysing the systemic shifts required to address society's most urgent issues (Roberts and Geels, 2019; Geels et al., 2019)

To foster impactful innovation, it is crucial to consider informal regulation alongside formal frameworks. Informal regulation, encompassing moral norms, codes of conduct, and traditions, significantly influences individual behaviour and decision-making, particularly when formal regulations are lacking (Segura-Bonilla, 2003; Li and Ramanathan, 2018). By leveraging informal regulation through "soft" policy measures and public awareness campaigns, governments can encourage sustainable practices and drive consumer demand for sustainable innovations (Rennings, 2000; Wu, 2010). NGOs also play a vital role in shaping informal regulation by advocating for environmental issues and promoting sustainable norms (Li et al., 2021).

These could be seen, for example, in WWF's "Your Plastic Diet" campaign, which raises awareness on microplastics in the food chain, influencing consumers and eventually policy actions on plastic reduction. The campaign uses narratives and relatable visuals to call for collective action from both governments and businesses (WWF, 2024). The Chesapeake Club Campaign in the USA, running from 2004 to 2005, focused on changing lawn fertilisation in improving water quality. Measurable behavioural change has been recorded after public engagement was conducted through TV, print, and public events, contributing towards environmental improvement through water quality changes (Borawska, 2017). In the UK, the "Love Food Hate Waste" government-funded national campaign helped raise awareness on food waste which has demonstrated changes among consumers' behavioural change towards sustainable consumption practices and demands for companies to do the same (IPPR, 2025).

An integrated approach combining both formal and informal regulation, bringing different stakeholders together, can address the limitations of current regulatory frameworks and foster more sustainable economic systems (Wang and Shao, 2019). By influencing both businesses and consumers, informal regulation complements formal rules, promoting a shift towards greater sustainability and encouraging entrepreneurial activity that can constrain market power (Audretsch, 2023). Therefore, policy actors should adopt a holistic perspective that incorporates both formal and informal mechanisms to effectively drive innovation and address societal challenges.

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