Department for
Business, Energy
& Industrial Strategy

TAXONOMY OF REGULATORY TYPES AND THEIR IMPACTS ON INNOVATION

Final Report

BEIS Research Paper Series Number 2020/004

January 2020

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Acknowledgements

Ana Cordon and Rebecca Aylott contributed to the data collection for this report. The participation of interviewees to inform the case studies is gratefully acknowledged. The detailed comments received from Stephen Almond, Adam Gardiner, Shane Halai, Lindsay Taylor and Thomas Wood are gratefully acknowledged.

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Executive summary

Objectives

As set out in its White Paper on Regulation for the Fourth Industrial Revolution, the Government plans to transform the UK's regulatory system to support innovation while protecting citizens and the environment. This research has been commissioned by the Department for Business, Energy and Industrial Strategy to provide a better understanding of the ways in which different types of regulation impact on innovation.

More specifically, its main purpose was to make explicit the various theoretical mechanisms through which regulation has been understood to impact on innovation, differentiating between types of regulation, and when relevant, different types of sectors, firms, or technologies. The study also aimed to indicate to what extent those mechanisms are supported by evidence, and what, if any, gaps remain in the knowledge base on the relationship between regulation and innovation.

Method

The first phase of the study involved a review of the academic literature. This review has taken the work reviewed in Blind (2016) as its starting point. It expanded it further to include the more recent literature from innovation and regulatory economics, as well as relevant sources from organisation studies and management, political economy, and science and technology studies.

To inform the literature review and organise the presentation of mechanisms, the study team developed a conceptual framework structured into macro-, meso- and micro-level factors that are likely to contribute to shaping innovation. The framework was then applied to each regulatory area in scope of the study.

The second phase of the study involved four case studies on: Connected and Autonomous Vehicles (CAVs), automated recruitment, home heating and personalised e-health services. Case studies were based on preliminary desk research on each area and interviews with both individuals involved in the sector and relevant regulators. The case studies aimed to both identify examples of the mechanisms theorised in the literature, and to identify new mechanisms or provide qualification to mechanisms which may not have been already theorised in the literature.

Conceptual framework

Mechanisms are understood as the (generally) unobserved processes by which a factor produces an effect. Or put another way, when cause-effect relationships are

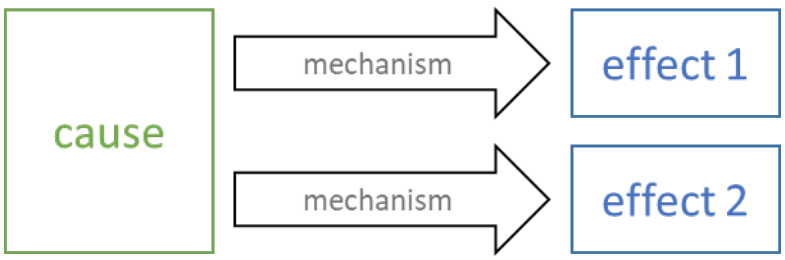
represented as an input linked by an arrow to an output, the arrow *is* the mechanism (as depicted in the figure below).

The main value of thinking in mechanisms is to "open the black box" of what is happening between causes and effects. Mechanisms are particularly helpful to distinguish between processes that might otherwise be bundled together indistinctly. By so doing, one gets a clearer and fuller picture of effects and how they come about.

There is rarely a single mechanism to link one cause to one effect. To take one example outside the scope of the present report, the current melting of ice caps in the poles has an impact on sea levels. This occurs through a *mechanical* mechanism whereby huge volumes of liquid fresh water flow into the sea thus increasing the total volume of water in the sea. But the same phenomenon has also an effect on sea currents. Sea currents are a function of a process involving both differences in temperature and salt, a *thermodynamic* mechanism.

When it comes to regulation and innovation, mechanisms are also used to distinguish between various processes and multiple effects. For example, a (fictional) new regulation requiring that all staff involved in Research & Development (R&D) activities should follow a lengthy training course will have two distinct types of effects. The first one is a direct impact on the costs businesses incur to comply with regulations, which will involve time spent actually clarifying what the new requirement is, finding a training provider (or developing that training in house), having all the staff affected by the requirement complete the training, and documenting the process in a way that would satisfy any monitoring authority. The mechanism in question here simply triggers the routine **compliance** function at targeted businesses to ensure that the business is compliant in the *present*. Yet that measure may also have an impact on the manner businesses plan *future* investments in R&D, and particularly the recruitment of new R&D staff. The mechanism at play here corresponds to interactions between the change in the environment triggered by new regulation and the manner businesses assess the costs and benefits of future projects (e.g. hiring new staff) in that environment. It is about **incentives**.

It is through the combination of different mechanisms and their different effects that one can capture the full impact of a cause. For instance, in the example above, the full impact of the regulation combines the reduction in resources the business can invest in R&D (due to higher compliance spending) and the disincentive to hire new R&D staff.



While some mechanisms can provide an explanation that links a cause (e.g. regulation) to an effect (e.g. innovation), others give meaning to only a part of the process. That is because cause-effect chains can be long. For instance, regulation does not always have a direct impact on a business. Sometimes, it has a direct impact on broader market conditions (for example, on lenders: banks, venture capital funds, etc.), which themselves have an impact on businesses. The path, therefore, is one that goes from regulation to market conditions (one mechanism), and then from market conditions to the business (another mechanism).

This framework was used to identify mechanisms in the literature.

Literature review findings

Scholars have identified a range of mechanisms to account for the relationship between regulation and innovation. The review has considered the evidence available on the following types of regulation:

- **Economic regulations**, including abuse of dominance and antitrust regulation, market entry regulation, mergers and acquisition regulation, price regulation, quantity regulation and the regulation of natural monopolies and public enterprises.
- **Social regulations**, including liability law, labour market regulation, bankruptcy law, intellectual property regulation, product quality and safety regulation, environmental regulation, worker health and safety regulation, data protection regulation and information security regulations.

While some of the mechanisms identified are specific to particular regulations, others appear to apply to all. Certain similarities were identified in the mechanisms across different types of regulations. To better assess commonalities, differences and gaps in the ways scholars think about how regulation impacts innovation, this study has identified five categories of mechanisms:

- **compliance costs:** compliance cost mechanisms are triggered by any requirement a business needs to comply with as a result of their *ongoing* activities; compliance cost mechanisms provide a channel through which regulation has a direct impact on individual businesses;
- **incentives:** incentive mechanisms refer to the ways regulatory changes affect the way businesses assess the costs and benefits of their *future* activities; incentive mechanisms provide a channel through which regulation directly impacts businesses; market conditions can also generate incentives for businesses.
- **market conditions:** market conditions mechanisms refer to the ways regulation affect the market environment in which businesses find themselves *without impacting businesses directly*; this includes any policy impact on the level of competition in the market, consumer demand, the physical, human or

financial capital available in the market, or the flow of information and knowledge across organisations and within networks;

- **capacity/capital:** capacity/capital mechanisms refer to the ways market conditions or regulation modify the financial capital (e.g. the ability to use patents as collateral for loans) or the human capital (e.g. staff expertise, motivation) that business organisations and networks have at their disposal for innovation or other endeavours; this excludes compliance costs, which by virtue of their extensive use in the literature, are considered a separate mechanism.

- **information/signalling:** information/signalling mechanisms refer to the ways regulation signals to organisations and networks what is desirable or not (Sunstein 1996); such mechanisms account for the impact that the meaning carried by regulations (distinct from any material costs and benefits) have on business behaviour. The argument here applies widely, in the sense that any legislation or standard provides information, and that information may sometimes be relevant to innovation if it gives direction towards a particular technological trajectory.

Table 1, below, provides a synthetic outline of the mechanisms and their likely impact on innovation, for all the types of regulations reviewed in the study.

Table 1. Summary of mechanisms and impacts per type of regulation

	Regulation	Impacts
Economic regulation	Competition and antitrust regulation	Most evidence suggests that competition law—where it enhances competition—increases the incentives for firms to innovate. In some instances, competition and antitrust regulations may restrict cooperation between firms, which can have a negative impact on innovation. It may also weaken incumbent firms' market power, leading to reduced profits and less investment in R&D by incumbents.
	Market entry regulation	More liberal market entry regulations can contribute to an increase in competition, which generally impacts positively on innovation. Liberal market entry regulations may also encourage more entrepreneurs (and potential innovators) to enter the market. However, allowing more new entrants is likely to reduce profits for incumbents, meaning that there is less for them to invest in R&D.

	Regulation	Impacts
	Mergers and acquisition (M&A) regulation	Where M&A regulation increases competition, this may have a positive impact on innovation (as detailed for competition and market entry regulation). M&A regulation may impact how firms choose to strategise: long-term strategies are more likely to focus on innovation, short-term strategies are less likely to fund R&D. Restrictions to M&A limit takeover pressure and may reduce incentives to innovate.
	Price regulation	Price caps can reduce the expected profitability of new products, increasing the financial risk of new product development. Innovation activities are more likely to focus on incremental innovations to existing products. Minimum pricing may reduce incentives to take risks by investing in new technologies and products. This may also lead firms to make incremental innovations to improve the quality of the product.
	Quantity regulation	Quantity regulation (such as quotas or tradeable certificates) may lead to increased compliance costs, which may in turn lead to less funding for R&D, or may lead firms to innovate to reduce those costs. Quantity regulation may also mean that existing products or processes become non-compliant. For firms that are already compliant, this may reduce incentives to innovate. For non-compliant firms, this may increase incentives to innovate. Quantity regulation may also lead to the product or process being seen as more risky. This may lead existing firms to invest more in innovation to ensure compliance, but it may also deter new firms from entering. This reduces competition, and may therefore reduce incentives to innovate.
	Regulation of natural monopolies and public entities	Regulation of natural monopolies may introduce competition by making it easier for new entrants to enter the market. Competition may incentivise innovation. However, where incumbents are already innovating in part to deter new entrants, such regulations may reduce existing incentives to innovate. Different ways of regulating natural monopolies will have different impacts: cost-based regulation appears

	Regulation	Impacts
		not to provide any incentive to innovate; price-based regulation may incentivise process-based regulations but may also increase the risk of investing in innovation for firms; output-based regulations provide direct incentives for innovation but may lead to a bias toward short-term measures rather than longer-term investment.
Social regulation	Liability law	Liability law increases the risk for litigation if products are not safe. This may encourage firms to increase innovations in process/product safety, or it may lead firms to avoid innovation and invest in "tried and tested" products and processes. Liability law may also increase consumer confidence and willingness to purchase innovative products, increasing the market certainty for such firms.
	Labour market regulation	The regulation of hiring and firing alters the flexibility and cost of human capital and this can have varying impacts on innovation. It may disincentivise employers from firing employees, which may lead to employees having greater in-house expertise and being more comfortable criticising management, which can contribute positively to innovation in the long run. Alternately, this may have a negative impact on innovation by reducing firm motivation to adopt new innovations involving automation and may have a negative impact on endeavours considered to be riskier. Where labour market regulations increase the cost of low-skilled labour, this may encourage some firms to increase spending on automation. However, this may also increase the costs of taking risks for firms, reducing the incentives for more radical innovations. Where labour market regulations allow firms to more easily hire skilled workers from abroad, this may encourage innovation by increasing firms' access to a skilled workforce.
	Bankruptcy law	More liberal personal bankruptcy laws may increase the capital available to entrepreneurs, including potentially innovative entrepreneurs.

	Regulation	Impacts
		However, this is also likely to lead to an increase in interest rates, meaning that firms with innovative projects considered to be low-risk cannot justify borrowing at higher interest rates. Stronger creditor rights may provide some firms with easier access to finance, which could contribute to greater investment in R&D. This is particularly the case for firms that hold patents, allowing them to increase collateral value. For firms without such collateral value, this may reduce access to financing thereby reducing their ability to innovate. Stronger creditor rates also mean that firms have less insurance against failure, which may lead to an avoidance of high risk endeavours such as R&D spending.
	Intellectual property regulation	Patenting increases the appropriability of knowledge and inventions and may help to reduce the risk of investing in R&D, particularly in industries where R&D requires significant and long term investments. This may also lead to some firms focusing investments on patentable innovations, at the expense of other, less patentable innovations. A large number of existing patents in an industry—particularly for complex technologies—may make it challenging to develop new innovations that do not infringe on existing patents. The use of patenting leads firms to disclose innovations rather than keep trade secrets: this can contribute to the diffusion of new ideas.
	Environmental regulation	Environmental regulation may encourage firms to innovate to meet new requirements. Depending on the type of regulation, this may be because firms have new incentives to innovate, because firms seek to mitigate compliance costs or because regulation has signalled the need for innovation to firms. Environmental regulations may also encourage innovation by creating new markets or increasing demand for existing markets.

	Regulation	Impacts
		However, in some instances, the compliance costs or requirements set by environmental regulation may be challenging for firms to meet without cutting into profits, meaning that there is a reduced ability to invest in innovation. This is more likely to be the case for smaller firms.
	Worker health and safety regulation	Worker health and safety regulations may divert resources away from R&D. However, this may also lead firms to innovate in ways that help to reduce compliance costs. Where worker health and safety regulations bring about improved labour quality, worker satisfaction and motivation, workers may be more likely to engage in innovation.
	Data protection regulation	Data protection regulations may increase firms' exposure to liability claims and the costs of doing business, and therefore reduce incentives to innovate in ways that involve personal data. Data protection regulations may also contribute to consumer confidence in new products and help create a level playing field across firms, helping to incentivise innovation.
	Information security regulation	Information security regulations can encourage responsible innovation by increasing consumer confidence and demand in new products and services, by levelling the playing field and by creating new markets for cybersecurity products. Information security regulations may cause firms to trade off investment in security for usability or interoperability, which can reduce consumer demand and disincentivise innovation in the long term. It may also increase compliance costs, reducing the available R&D funding.

Knowing whether a regulation influences innovation through compliance costs, incentives, market conditions, capacity/capital, or signalling is not enough to know whether innovation will increase or decrease. An increase in compliance costs could lead firms to innovate, or, on the contrary, could disincentivise them from investing in

R&D. The same can be said for increases in incentives or uncertainties. The literature points to a range of contextual factors that will impact the relative strength of a mechanism, such as the sector to which the regulation applies, but also the level of competition in a market, the size and nature of firms that are affected and the nature of the products and services affected. In many instances, the literature suggests that smaller firms are likely to be disproportionately impacted by increases in compliance costs and changes to market conditions, and that, while many regulations tend to negatively impact on innovation in the short term, a number of them have a beneficial impact on the long term.

The literature also highlights that characteristics of the regulation will impact the extent to which it influences innovation, namely:

- **Prescriptiveness.** The literature generally indicates that more prescriptive regulation leaves less space to innovation, or that it determines the path that innovation should take. Regulation that sets goals or outcomes, but does not prescribe means has been associated with more innovation.
- **Stringency.** More stringent, non-prescriptive regulations–especially environmental regulations–can encourage innovations that help improve commercial competitiveness.
- **Clarity.** A lack of clarity in (either prescriptive or goal-based) regulations can impact on innovation by creating uncertainty about the future (e.g. ability of firms to comply with regulation, greater exposure to liability claims). This is especially likely to reduce innovation in firms operating in sectors where innovation requires significant investment and longer timescales or where firms are operating in less financially secure markets.

Case study findings

The four case studies (Connected and Autonomous Vehicles (CAVs), automated recruitment, home heating and boilers, and personalised e-health services) confirmed many of the mechanisms identified in the literature, while also illustrating the heterogeneity of impacts both across and within sectors.

Case studies illustrated the impact compliance costs have on innovation, although the degree to which that was perceived to impact innovation differed between cases. In industries where innovation has high up-front costs and there is a relatively concentrated market, such as for boilers and CAVs, regulatory burden on SMEs is considered less crucial to innovation. In automated recruiting and personalised e-health services, by contrast, where innovation is driven by start-ups and smaller firms, regulatory burden is considered to be a more significant problem for innovation.

The case studies also illustrated that regulation poses some additional challenges to innovation not fully identified in the literature:

- In cases where innovations involve multiple sectors working together or other types of collaboration—as was the case to some extent for all cases—there is sometimes uncertainty around which actors should be liable for compliance

with various regulations. This uncertainty can sometimes lead to excessive caution and slow down the collaboration necessary to innovate.

- Many existing regulations have been developed based on an understanding of older technologies. In heavily regulated sectors in particular, this can pose barriers to bringing new products to market.
- Developing regulations that are appropriately stringent without being prescriptive can present a challenge to regulators, and in practice, some types of prescription may be required to achieve policy goals.
- The degree to which regulations are enforced or are enforceable plays a key role in determining the extent to which they impact innovation.

Introduction

This study has aimed to provide a better understanding of the ways different types of regulation impact on innovation. More specifically, its main purpose was to make explicit the various theoretical mechanisms through which regulation has been understood to impact on innovation, differentiating between different types of regulation, and when relevant, different types of sectors, firms, or technologies. The study also aims to indicate to what extent those mechanisms are supported by evidence, and what, if any, gaps remain in the knowledge base on the relationship between regulation and innovation.

Background

In June 2019, the UK Government published its White Paper on Regulation for the Fourth Industrial Revolution, setting out its plans to transform the UK's regulatory system to support innovation while protecting citizens and the environment. The White Paper builds on the UK Government's Industrial Strategy, which aims to make the UK the world's most innovative economy and sets four Grand Challenges as key areas where innovation is needed.

Developing a better understanding of the relationship between innovation and regulation matters because that relationship is not straightforward. On the contrary, it is known to be complex and difficult to encompass in one overarching theory. Improving policymakers' understanding of this complex relationship should help them to assess the impact of current UK regulatory policies on innovation. It should also help inform future reforms or new regulatory policies.

Conceptual framework

This section summarises ICF's conceptual approach to this study. In this study, a mechanism is understood as the (generally) unobserved processes by which a factor produces an effect. A mechanism tells a plausible story of how causes and effects are linked to one another (Gerring 2008, Hedström and Swedberg 1996, Astbury and Leeuw 2010). Or put another way, when cause-effect relationships are represented as an input linked by an arrow to an output, the arrow *is* the mechanism (as depicted in figure 1 below).

Figure 1. Simple outline of cause, effect and mechanism

The main value of thinking in mechanisms is to "open the black box" of what is happening between causes and effects. Mechanisms are particularly helpful to distinguish between processes that might otherwise be bundled together indistinctly.

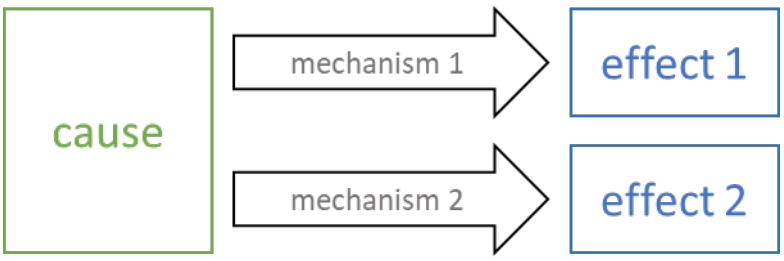
By so doing, one gets a clearer and fuller picture of effects and how they come about.

There is rarely a single mechanism to link one cause to one effect. To take one example outside the scope of the present report, the current melting of ice caps in the poles has an impact on sea levels. This occurs through a *mechanical* mechanism whereby huge volumes of liquid fresh water flow into the sea thus increasing the total volume of water in the sea. But the same phenomenon has also an effect on sea currents. Sea currents are a function of a process involving both differences in temperature and salt, a *thermodynamic* mechanism.

When it comes to regulation and innovation, mechanisms are also used to distinguish between various processes and multiple effects. For example, a (fictional) new regulation requiring that all staff involved in Research & Development (R&D) activities should follow a lengthy training course will have two distinct types of effects. The first one is a direct impact on the costs businesses incur to comply with regulations, which will involve time spent actually clarifying what the new requirement is, finding a training provider (or developing that training in house), having all the staff affected by the requirement complete the training, and documenting the process in a way that would satisfy any monitoring authority. The mechanism in question here triggers the routine **compliance** function at targeted businesses to ensure that the business is compliant at any given time. Yet that measure may also have an impact on the manner businesses plan *future* investments in R&D, and particularly the recruitment of new R&D staff. The mechanism at play here corresponds to interactions between the change in the environment triggered by new regulation and the manner businesses assess the costs and benefits of future projects (e.g. hiring new staff) in that environment. It is about **incentives**.

It is through the combination of different mechanisms and their different effects that one can capture the full impact of a cause, as schematically represented in Figure 2 below. For instance, in the example above, the full impact of the regulation combines the reduction in resources the business can invest in R&D (due to higher compliance spending) and the disincentive to hire new R&D staff.

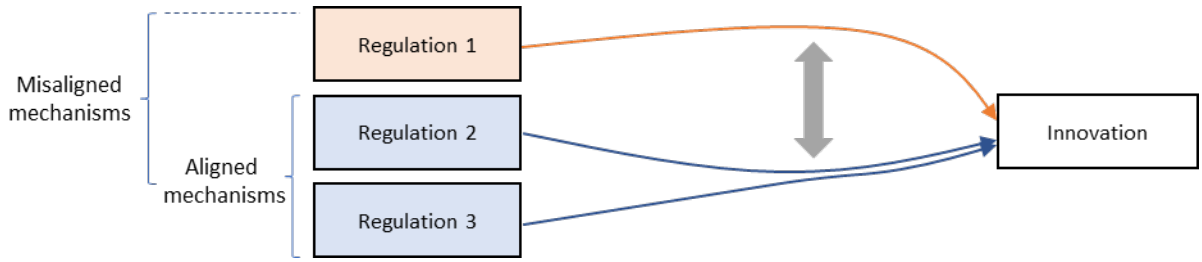
Figure 2: Representation of a single cause having two different effects through two distinct mechanisms



These combined effects may go in the same direction (e.g. discouraging innovation, as in the example provided earlier), or they may push in opposite directions. For example, on the one hand, product quality and safety regulation can create compliance costs, thereby restricting innovation. On the other hand, product quality and safety regulation can also reduce consumer fear (if any) and lead to more demand for innovative products, thereby incentivising firms to innovate.

When considering the combination of different regulations that may have an influence on innovation, an additional consideration is the level of (mis-) alignment between different elements of the 'regulatory mix' or 'regulatory regime': the combined regulatory interventions that together may have an impact on a given sector (as discussed, for example, in Ludlow et al. 2015, or Glynn 1992). Mechanisms may reinforce one another or, on the contrary, undermine each other; as represented in Figure 3, below.

Figure 3. Illustration of interactions between mechanisms across different regulations



While some mechanisms can provide an explanation that links a cause (e.g. regulation) to an effect (e.g. innovation), others give meaning to only a part of the process. That is because cause-effect chains can be long. For instance, regulation does not always have a direct impact on a business. Sometimes, it has a direct impact on broader market conditions (for example, on lenders: banks, venture capital funds, etc.), which themselves have an impact on businesses. The path, therefore, is one that goes from regulation to market conditions (one mechanism), and then from market conditions to the business (another mechanism). This is schematically represented in Figure 4, below.

Figure 4: Representation of a cause-effect relationship involving two successive steps and mechanisms

This framework was used to identify mechanisms in the literature.

In the early stages of the study, the study team observed that the literature generally does not seek to explain why regulation has an impact on innovation. There is very little information on the mechanisms through which different kinds of regulation impact on innovation. That observation is valid for all types of regulation. For example, even though environmental regulation is arguably the most researched type of regulation, and "despite the relatively large empirical evidence on the drivers of environmental innovation," there is very little literature exploring the mechanisms through which regulation impacts on innovation (Liao et al. 2018: 1568).

The lack of theorised mechanisms in the literature implies that, rather than building a conceptual framework from the bottom-up by drawing elements from the literature and then integrating them together (as was initially planned), a top-down approach was preferred, whereby the study team has developed its own conceptual framework

based on the team's understanding of key dimensions of innovation, to then refine and adjust it based on further review of the literature.

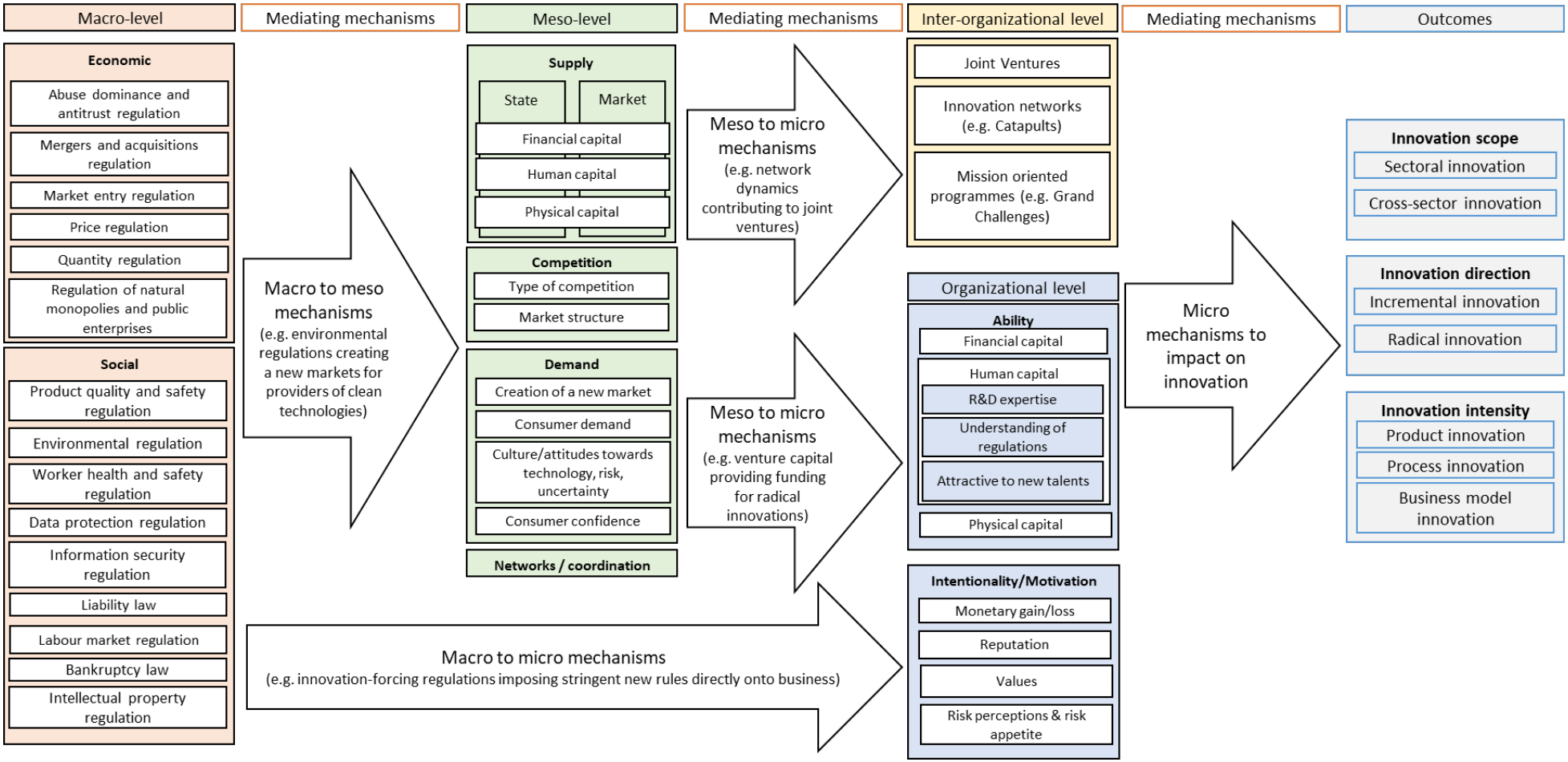
To build the structure of the conceptual framework, a classical approach would be to focus on the firm as the innovating actor and conceptualise the manner regulation at a macro-level impacts on the firm at the micro-level. This has the advantage of capturing important factors and mechanisms (including cognitive and motivational mechanisms[1]; Acar et al. 2018). Furthermore, the micro-level is impacted by factors and processes at the meso-level / market, society (such as funding, skills, competition, etc.), which are themselves influenced by regulation. However, this kind of framework is likely to be limited to capturing innovations that are specific to a particular sector in which the firm operates, which are the sorts of innovations that much of the literature tends to focus on.

It is also important to capture processes and factors that contribute to innovation within the industry or society more generally, and as such are happening at a higher level than the firm's, and particularly across sectors. Conceptualising innovation processes and outcomes at the meso-level should capture innovations that affect more than one sector or are relevant to more than one type of regulation. Indeed, some of today's most high-profile innovations are cross-sectoral and raise regulatory issues across several different regulatory domains. Thus, the development and then roll-out of driverless cars is affected in an intricate way by competition and antitrust regulation (to enable the setting up of common standards requires coordination between competitors), market entry regulation, liability law, data issues, health and safety, and consumer protection, and it involves several sectors of the economy working together (as discussed, for instance, in Brass et al. 2018).

The overarching framework that has informed the study, reflecting these considerations, is presented below, in Figure 5.

[1] The motivational route refers to mechanisms associated with the motivation to engage in creativity/innovation related activities. This route includes mechanisms such as (intrinsic) motivation to generate ideas, take risks, or experiment. The cognitive route refers to cognitive processes of creativity and innovation (e.g., cognitive fixation, opportunity identification) (Acar et al. 2018)

Figure 5. Overarching conceptual framework for the study



Note: the key factors considered are presented here at the macro-level (regulations), meso-level (markets, society), and micro-level (firm(s)). Mechanisms provide the explanation for cause-effect relationships between these different levels. The arrows are there to illustrate the principle of the mechanisms only.

Literature review

This section presents the literature review. It is structured as follows:

- The scope of the literature review is presented first, providing a very brief overview of the various strands of academic publications that have been considered, and briefly explaining the approach that was followed to extract insights from the literature.
- The findings structured per regulatory type are then summarised. Two main categories of regulation are distinguished here:
    - Economic regulation, which aims “to improve the efficiency of markets in delivering goods and services” (OECD 1997: 12); and
    - Social regulation, which aims “to protect social values and rights” (ibid.).

More detailed syntheses structured into sub-categories of regulation are provided in Annexes to the report.

Scope and method

The literature on innovation and the processes that influence innovation discusses numerous factors, one of which is regulation. The role attributed to regulation in the development of innovation varies from one literature to another. While the literature that focuses specifically on the interaction between regulation and innovation sees it as an important influence (as does the overwhelming literature cited in this report), other literatures (such as that on policy mixes[2]) tend to give it less importance (with the exception of intellectual property rules). That other literature rather emphasises the role of other policy instruments, and principally those that provide funding support. Regulation may also be a contextual factor relative to intra-organizational factors, such as a firm’s ability to use its capabilities in new and innovative ways (Kogut and Zander 1992; Acar et al. 2019).

When it comes to understanding specifically the relationship between regulation and innovation, at least four distinct literatures can be identified. They offer different, and arguably complementary, notions of what mechanisms may be at play in the relationships between regulation and innovation.

Economic literature

Economic theories on the role of regulation on innovation are principally based on the work of Carlin and Soskice (2006)[3]. They argued regulation impacts on innovation by

[2] There are various definitions of policy mixes used in the literature on policy and innovation. It designates at least the combination of policy instruments, both regulatory and non-regulatory, that together may contribute to shaping innovation. More sophisticated definitions also include policy strategies and processes into the mix (e.g. Reichardt and Rogge 2014).

[3] Carlin and Soskice (2006) determine an equilibrium rate of innovation, by using two models which work in opposite way: 1) the Solow growth model where there is a negative relationship between the

introducing: 1) compliance costs, which reduce available resources for research and investment, thereby lowering the innovation level; and 2) changes in incentives for investments in R&D, which can be both negative or positive, depending on the type of regulation. The net impact of regulation on innovation depends on the relative strength of the compliance cost effect and the incentive effect.

This literature tends to see innovation as beneficial to welfare (i.e. positive social impact, contribution to the achievement of public policy aims). It focuses on the effect of regulation on innovation, in contrast to other types of literatures that focus on how to regulate innovation (Butenko and Larouche 2015). The economic literature principally explores market mechanisms that relate to competition – which plays a key role as a driver of business decisions –, demand and availability of capital. It looks at the extent to which regulation impacts on innovation, as well as provides an assessment on the balance between the burdens of regulation and their benefits for society and the economy.

Organisation studies and management literature

When it comes to the relationship between regulation and innovation, the organisation studies and management literature has comparatively less to contribute than the economic literature and tends to be more qualitative. This literature aims to develop an understanding of how organisations might respond to changes in markets, for instance by considering the trade-offs between short-term survival and long-term development through innovation (Kogut & Zander 1992) as well as investments in capital/skills. It also examines the effect of regulatory requirements on innovation and how firms might adapt through changes in their strategic management, entrepreneurship, industrial organisation, technology and operations management, organizational behaviour, and marketing (Acar et al. 2019).

Science and technology studies (STS)

This is not as extensive on the subject of innovation as the economic or management literatures, and does not address the relationship between regulation and innovation specifically. However, this literature does provide insight into the drivers to and barriers of innovation that go beyond the traditional economic approaches to innovation.

Political economy literature

There is a lack of relevant literature here and it tends to focus on macro-level factors, such as Hall and Soskice (2001)'s cross-country comparison and examination of the varieties of capitalism and the influence of this on innovation, or Wang et al.'s (2019) study on the link between government ideology and innovation. This literature has not been relevant to identifying mechanisms, but provides some context as to why mechanisms may differ between countries based on macro-level factors.

level of capital and the rate of innovation; and 2) the Schumpeter relation where increasing capital allows more resources to be available for research and development and therefore leads to more innovation.

This literature review has taken as its starting point the work of Blind (2016), which had already identified a large portion of the economic literature. The study team sought additional sources for review through Google Scholar, ESBCO, ScienceDirect, using keywords (e.g. policy mix and regulation, labour market regulation and innovation). Relevant sources were found in journals, think tank papers and working paper series. To ensure extensive coverage of the relevant economic literature, the study team also looked for additional relevant papers in the references section of a source and among papers citing the source. Finally, the selection of sources was extended to other types of literature (i.e. organisation studies and management, political economy, and science and technology studies). This helped ICF draw complementary perspectives on the different mechanisms by which regulation can impact on innovation. Several sources for review were suggested by the two expert advisors to the study team, Prof. Knut Blind and Dr Irina Brass.

The study team designed a template setting out a common framework for extracting relevant information from the literature. This template helped record the following details:

- data sources, data quality and methodology;
- the scope of sources in terms of regulation type, sector, technology, organisations and innovation type; and
- the theoretical mechanisms that each source mentions in order to explain how regulations impact on innovation (breaking mechanisms down into their different impacts at the macro-, meso- and micro-levels).

The study team recognised that different types of regulations generate various impacts on innovation, and even a single specific regulation can influence innovation in various ways (Blind, 2016). Therefore, ICF's approach was to study the impact of regulation on innovation for each type of regulations, examining the various conditions that might influence how mechanisms operate.

- For each regulatory type, the study team used the overarching framework presented in Figure 3 and drafted a synthesis of the evidence found, clearly highlighting:
    - the different ways by which regulation can impact on innovation through its effect on several levels: macro-, meso- and micro-levels; and
    - any possible factors that might influence the impact of regulation on innovation (e.g. context, presence of other types of regulations which might have contrasting impacts on innovation etc.)

For each synthesis, the study team drew a conceptual framework chart, building on that in Figure 3.

Findings

Economic regulation

This section discusses the mechanisms by which economic regulations might have an impact on innovation. Economic regulations aim to improve the efficiency of markets in delivering goods and services.

There is a vast amount of literature looking at the impact of economic regulations on innovation. More specifically, there is a large number of sources providing insights on the mechanisms by which competition and antitrust regulation impacts on innovation.

This literature builds on two schools of thought. The first is often associated with Joseph Schumpeter, and argues that increased competition prevents innovation (Schumpeter 1942). Firms in situations of imperfect competition have an incentive and an ability to invest in long-term, large-scale R&D efforts, because they already make large profits and can appropriate all the benefits of these investments and do not have to worry about imitators. Competition and antitrust regulation erodes this incentive as it brings new entrants that can compete with incumbents on similar products/services, and it erodes incumbent firms' ability to innovate due to decreased prices and profit margins. The second is often associated with Kenneth Arrow, and argues that competition favours innovation. In situations of imperfect competition, incumbent firms are not challenged and therefore have no incentive to innovate (Arrow 1962). By increasing competition, competition and antitrust regulation causes incumbent firms to innovate if they wish to survive the new competition.

Similarly, there is a vast literature on the mechanisms by which mergers and acquisitions regulations impact on innovation. It offers two contrasting hypotheses to explain how state M&A regulation can impact on innovation through its effect on market pressures. The 'shareholder welfare hypothesis' suggests that, by protecting firms against short-term market pressures, antitakeover laws help spur innovation: they create a setting that encourages managers to act in the long-term benefit of the firm and to invest in R&D. In contrast, the 'managerial welfare hypothesis' suggests that by protecting firms against hostile takeovers, antitakeover laws reduce firms' incentives to innovate: they allow firms to forego R&D projects that might be lucrative in the long-term, in favour of ventures that offer quick payoffs.

However, the literatures focusing on the impact of market entry regulations, price regulations and quantity regulations are less developed as they tend to consider either specific highly-regulated sectors (e.g. the pharmaceutical industry for price regulation, or environmental sector for quantity regulations) or the role of competition in influencing innovation more generally.

There are several mechanisms by which economic regulations can have an impact on innovation. This section gives examples of some of the more important mechanisms in play.

The main mechanism by which economic regulations have an effect on innovation is through **their impact on competition**. There seems to be a consensus that by introducing or increasing competition in a market, economic regulations lead to a loss of market power of incumbent firms. These firms may react by investing in innovation, so as to restore market power. However, as put forward by Aghion et al. (2005) and

then tested experimentally by Aghion et al. (2014), this is mostly the case for incumbent firms that are already innovators and at similar technological levels to one another. For firms that are lagging, an increase in competition has the opposite effect and leads to a reduction in innovation investment. Competition levels may also have an impact on whether firms choose to innovate or to replicate what others have been doing. In particular, increases in competition may lead to reduced profits, in which case innovation may appear a greater risk than copying peers.

There is another example showing that the effect of economic regulations through the introduction of competition is not straightforward. Indeed by introducing or increasing competition in a market, economic regulations discourage cooperation between firms. This, in turn, leads to more secrecy and reduced communication between market actors. As a result, firms may have a more restricted access to the information they would need in order to innovate. For example, they may find it harder to cooperate in R&D. (Katz and Shelanski 2007; Spulberg 2008) to achieve follow-on innovation. Research joint ventures may still be an option in such a context, however this kind of collaboration might not be sufficient to exploit all synergies.

Economic regulations can result in an **increase in compliance costs** (e.g. time, effort and costs such as legal costs and financial penalties) for firms already in the market (Ambec et al. 2013). This will in turn have an effect on innovation as firms will move productive resource away from output and on to compliance to minimise these costs, resulting in reduced innovation activities in the areas from which the resources were relocated. However, the literature shows that such a mechanism is not always at play: increases in compliance-related expenditure can also provide an incentive for firms to innovate in order to reduce these costs.

Economic regulations also have an effect on innovation through their impact on **the ability of new firms to enter an existing market**. As such, economic regulations may increase or deplete the number of firms in a market. This in turn may have an impact on the number of potential innovators in a market. In addition, by changing market entry requirements, economic regulations can make it easier or more difficult to get quick and easy access to financial and legal security. This will have repercussions on firms' willingness to invest in innovation.

Economic regulations (takeover restrictions in particular) can also reduce **short-term market pressures**. The literature presents very different views explaining how this can have an effect on innovation. Some papers (the shareholder welfare hypothesis) argue that protecting firms against takeover can create a setting where firms and their shareholders are relieved from short-term and immediate problems and are instead able to think ahead and invest in longer-term strategies. This includes innovation. Other papers (the managerial welfare hypothesis) argue the opposite: according to their authors, reducing the risk of a hostile takeover may lead to reduced innovation, since innovation can be a way of protecting oneself from takeovers. This leads to firms foregoing innovation projects in favour of ventures that offer quicker payoffs. Finally, a third branch of the literature (Sapra et al. 2012) shows that the relationship between the degree of takeover pressure and innovation is even more complex. Aghion et al. (2005) show that there is a U-shaped relationship between the degree of innovation and takeover pressure, suggesting that innovation is fostered by either strong antitakeover laws that significantly restrict takeovers, or very strong level of takeover pressures.

Economic regulations can influence the **price and quantities of products or services.** This will have an impact on revenues and profitability, which in turn will have an impact on firms' decision to invest in innovation. For example, if firms see their profits increase, they will have more money to invest in innovation. However, setting limits to the prices firms can charge customers, and to the quantities they can produce or trade, can also reduce innovation incentives. For instance, firms which know they can secure minimum turnovers or cannot exceed a certain level of profits will not be willing to invest in innovation projects, as these would not be able to help improve their financial situation. Barbieri et al. (2016) argue that such regulations do not provide an adequate incentive for firms to innovate, as there is no 'reward' for going beyond the minimum requirement.

Economic regulations can also introduce **risk or uncertainty** in financially insecure markets, i.e. markets in which there is high price volatility. This means that firms lack market confidence to invest and their appetite to innovate is diminished. Firms that do not comply with regulations face many risks (e.g. reduced profitability, fines, reputational damage, possibility of litigation cases): potential new entrants to the affected markets might be deterred to enter them. In turn, there might be fewer potential innovators entering the market, therefore firms that are already in the market have a reduced necessity to innovate in order to stay competitive.

Finally, the literature shows that economic regulations specific to natural monopolies can have different impacts on innovation, depending on whether they are **cost-based** or **price-based**. Cost-based regulation monitors companies' costs and revises the tariffs companies can charge accordingly. In practice, this enables companies to conduct R&D: when companies invest in R&D, their overall costs increase, but this increase is offset by the fact that the cost-based regulation will increase the tariffs companies can charge. However, investments in R&D will eventually lead to cost savings, meaning that the cost-based regulation will lower the tariffs companies can charge. Therefore, Bauknecht and Koch (2011) argue that cost-based regulation does not give companies any incentive to innovate. Price-based regulation works in a different way: it has a positive effect on innovation, as companies benefit from cost reductions they can achieve, including cost reductions from process innovations, and would therefore make an effort to innovate. However, price-based regulation also increases the risk for regulated companies. Indeed, it exposes them to higher R&D costs that they cannot compensate through higher prices. This creates a disincentive for firms to innovate (Bauknecht and Koch, 2011).

Social regulation

This section discusses findings on social regulation, broadly understood as regulations that set requirements for firms to comply with, so as to safeguard values and rights, and more generally address negative market externalities.[4]

Various types of social regulation have been reviewed. They include liability law, labour market regulation, bankruptcy law, intellectual property law, product quality

[4] A negative market externality is a cost generated by the market that is incurred by a party that did not choose to incur that cost. Environmental pollution generated by industry is an example of a negative market externality, and environmental regulation as a type of social regulation aims to address that market externality.

and safety regulation, environmental regulation and worker health and safety regulation.

Many of the mechanisms identified in relation to social regulation relate to the requirements and constraints that such regulations set out for firms, and therefore the impact they have on shifting the **incentives** for innovation. Traditionally, any requirements put to firms were seen to have a negative impact on innovation and on firm performance and growth. This view was challenged in the case of environmental regulation by Porter and van der Linde (1995), who suggest that, environmental regulation can help to spur innovation. Known as the Porter hypothesis, this puts forward that well-designed environmental regulations focus firms towards innovation, encouraging creativity and investment in R&D to meet new requirements. In turn, this increase in innovation activity may help to make those firms more competitive by leading to improvements in products and processes. Similar arguments have been made within other types of social regulation, although there is very little literature available explicitly discussing the impact of product quality and safety regulation and worker health and safety regulation on innovation. By contrast, the literature on environmental regulation and its impacts on innovation is extensive.

Regardless of the area, certain compliance requirements can be said to drive firms to think in new and creative ways about their product. In other words, regulation sets certain boundaries within which firms can operate, and to some extent these limitations help set the focus and fuel creativity. However, Acar et al. (2019) find that the relationship between requirements, creativity and innovation is an inverted-U shape, where beyond a certain point, requirements will again begin to limit innovation by being too prescriptive. This implies that there is an optimal level of regulatory pressure for innovation to occur. This is echoed in the original Porter hypothesis, which recommends that to encourage innovation, regulation should be stringent but technologically neutral.

The format of the requirements, whether prescriptive or rather outcomes-based, is an important parameter. The former may mean imposing a particular technology onto businesses, which negatively impact innovation but makes compliance more straightforward than for outcomes-based regulation, in particular for smaller businesses. Tech-neutral regulation, by contrast, leaves space for innovation.

For the most part, regulatory requirements seem to lead to innovation in one of two ways, depending on the type of regulation and the firm. For regulations that specify certain design or process requirements or outcomes, firms may be driven to innovate within their existing products or processes to meet those requirements. Porter and van der Linde (1995) suggest that such innovations may in some instances generate other returns, by improving overall efficiency or leading to increased market demand. In the case of product quality and safety regulation, some literature suggests that this leads to better quality products, increased consumer confidence and has a positive impact on demand (Katz 2007, Munos 2009). In some more extreme examples, rather than simply setting design requirements, some approaches to environmental regulation may create an entirely new market or significantly increase the demand within an existing market.

Liability law can also shift requirements in a way that alters the **incentives** for innovation, in the sense that courts tend to assign liability based on ‘custom’ itself drawn from conventionally used technologies. As such liability law evaluates the new with reference to the old, which may alter incentives and deter innovation. However,

examples drawn from the regulation of the chemical industry and of medical devices suggest that strong liability law causes firms to internalise the costs of litigation, both in terms of monetary impact and reputational damage. This in turn drives efforts to develop new, safer products, and thus innovation.

For regulations that create **compliance costs**, innovations may instead focus on ways to reduce or eliminate compliance costs. This may lead to a redirection of the R&D budget, which may contribute either negatively or positively to overall innovation, depending on what changes are made.

In some instances, particularly for many types of product quality and safety and health and safety regulations, it may not be possible to reduce compliance costs and therefore there is no incentive to innovate. Instead, such costs simply reduce the overall budget that can be invested in R&D.

Although many of the mechanisms described in the literature relate to the costs of compliance, and indeed regulatory burden is often measured using compliance costs as a proxy (see, for example, Lanjouw and Mody 1996, Jaffe and Palmer 1997), there are some suggested mechanisms that do not relate directly to costs. For example, Porter and van der Linde (1995) propose that environmental regulations may trigger innovation simply by **sending a signal to firms that there is an issue or an inefficiency**. For social regulations that include reporting requirements, the process of reporting may also serve to alert firms to areas for improvement or innovation that they previously had not been aware of or monitoring.

For worker health and safety regulations, mechanisms are likely to impact innovation through impacts on the firm's **capacity**. For example, Fernández-Muñiz et al. (2009) suggest that an increase in safety management leads to a reduction in both harm to workers' health and material damage, which in turn leads to improved labour quality and worker satisfaction and motivation.

The impact of labour market regulation is ambiguous in the literature, but most mechanisms also relate to the firm's **capacity** for innovation. Wrongful dismissal laws (WDL) and employment protection legislation (EPL) make dismissal more expensive. As a result, they can discourage the hire of staff that may be needed to drive innovation at the firm. However, this may be offset if employers can reallocate employees internally within their organisation (Bassanini and Ernst 2002). Calcagnini et al. (2018) have theorised that the impact varies with time: the negative impact of high labour market regulation is a short term one, whereas the long-term impact is positive, as firms invest more in innovation to preserve rents. Wachsen and Blind (2016) have further argued that the impact varies depending on the sector, with labour market flexibility not hampering innovation in a sector or ecosystem characterised by entrepreneurial innovation (such as the Silicon Valley), but having a negative impact on sectors characterised by routinised innovation, such as the US automotive industry. Labour protection regulation can also discourage automation in the workplace. These arguments are set from the perspective of the firm.

However, from the perspective of the employee WDL or EPL can provide a sense of security, which then contributes to loyalty to the firm. In such conditions trade secrets are better kept and innovation is therefore less risky. Employees that are better protected are also more likely to contribute critical thinking and expertise, which can contribute to innovation.

From the perspective of the market, greater labour market protection can mean less circulation of ideas and knowledge from one firm to the other, and from one sector to another, impacting **market conditions**. There is some evidence that high-risk innovative sectors are smaller in countries with strict EPL. Higher turnover may also mean, however, that employees do not invest in firm-specific skills, and that is not favourable to innovation.

Wage regulation may increase labour costs, which may reduce the financial capital of firms. This has been said to negatively impact R&D. It may also delay the adoption of new technologies. However, it has also been argued that wage increases may incentivise firms to innovate so as to reduce their dependence on low skilled labour, possibly by relying more on automation. One consequence of such investments may be to lower investments in technologies that support high-skilled labour, however.

Regulations that impact the supply side of the labour force, such as visas that allow for the immigration of workers with special skills, may also encourage innovation by increasing firm's access to skilled human capital.

Labour market regulations may also shift **incentives** for innovation, by impacting the power and role of unions. The literature sets out various mechanisms illustrating the ways in which unions may impact innovation: either intentionally blocking innovation for fear of job losses or change, or through encouraging innovation as they see opportunities to appropriate the rents from such innovations. Unions may also impact innovation by increasing the cost of labour, meaning that firms are more likely to invest in automating innovations and/or reducing the capital that they have available to invest in innovation.

Bankruptcy law is a little studied area. There too, the role of context is important: scholars have found contradictory findings depending on the countries they studied. It has been generally argued that more liberal personal bankruptcy laws encourage entrepreneurs, and particularly those who are more risk averse, to invest in new endeavours, by shifting the **incentives** for innovation. That may negatively impact access to **capital**, however, with creditors tightening credit or increasing interest rates to address the risks of lending to entrepreneurs. Such a counter-effect may affect low-risk and high-risk innovators indiscriminately, and harm small businesses disproportionately. It has been argued, however, that stronger creditor rights can lead to more lending to entrepreneurs and thus more innovation, when those entrepreneurs already hold patents. In other words, they are identified as successful innovators already.

Intellectual property regulation (IPR) is extensively studied. Its role in encouraging innovation is frequently claimed, but it is not clearly supported by the evidence. As for other areas, the role of context is important in determining whether IPR has a positive or negative impact on innovation.

Patents enable firms to hold a temporary monopoly over their innovations. This enables price increases and keeps competitors out. The **incentives** for investing in innovation are therefore high, as illustrated by the pharmaceutical industry. The opposite effect has been claimed for other sectors, however, and particularly for digital products. That is because they involve copying and diffusion. The risks of litigation are therefore high and can discourage innovation. The risk of litigation is exacerbated in some industries by the proliferation of "patent thickets", where a large

number of patents in a certain complex area makes it difficult for new firms to conduct R&D within that area without risking infringement

It has been argued that the temporary monopoly enjoyed by patenting firms can lead to more strategic (in the sense of more rapidly patentable) innovation than could otherwise be achieved. IPR may also make the market less efficient, by slowing down diffusion of innovations within a sector. That may not happen when innovating firms disclose and license their innovations, however. A large number of patents within a certain sector may also constrain firms (such situations are referred to as patent thickets), significantly reducing the **incentives** for firms to innovate.

The literature also suggests that IPR may encourage innovation by leading firms to disclose innovations rather than keeping trade secrets, thus altering **market conditions**, although there is little evidence for this mechanism in practice. Very little literature is available on data protection regulation and information security regulation, as these are emergent areas and the relevant regulations are still new. However, these areas of regulation are crucial to the future of innovation. As new digital products and services are introduced on the market, and in sectors previously not associated with the digital economy, more and more data are being collected, communicated, stored, processed and acted upon. Due to the fast-changing and fluid nature of the digital sector, it is likely that the lessons learned from other types of social regulation may not all be relevant here.

Social regulations are likely to be more burdensome for certain types of firms as compared to others. For highly innovative firms, it may be hard to continuously integrate regulatory requirements into new developments. This was shown to be the case for health and safety regulation in manufacturing (Veltri et al. 1997). There may also be outsized effects on smaller firms, who lack the resources to cope with the increased regulatory burden. For example, there is evidence to suggest that quality and safety regulation in the pharmaceutical sector causes innovation to fall in smaller firms and to concentrate in larger, multinational firms (Grabowski and Vernon 1977, Thomas 1990). For environmental regulations, there is also evidence of indirect negative effects on smaller firms: where environmental regulations greatly increase demand within an existing market, smaller firms may find it difficult to increase production to the scale required, leading to larger firms dominating the market (Hoppmann et al. 2013).

Economic regulation – detailed sections

This section discusses the findings from the literature review in more detail, exploring different types of economic regulation.

Abuse of dominance and antitrust regulation

Abuse of dominance and antitrust regulation is a type of competition regulation that aims to deter agreements between independent operators which restrict competition, and prevent the abuse of a dominant position in a respective market.

The literature tends to provide good insight on the different possible mechanisms by which abuse of dominance antitrust regulation might have an impact on innovation and provides some empirical evidence on these mechanisms.

There are two opposing schools of thoughts on whether increased competition favours innovation.

- One view, often associated with Joseph Schumpeter, argues that increased competition prevents innovation (Schumpeter 1942). Firms in situation of imperfect competition have an incentive to invest in long-term, large-scale R&D efforts, because they already make large profits and can appropriate all the benefits of these investments and do not have to worry about imitators. Competition and antitrust regulation erodes this incentive.
- The opposite view, often associated with Kenneth Arrow, argues that competition favours innovation. In situations of imperfect competition, incumbent firms are not challenged and therefore have no incentive to innovate (Arrow 1962). They even have an incentive to slow the pace of technological change to increase their profits from existing products. They can also preserve or increase their market power by obstructing competitors from inventing rival products or processes. By increasing competition, competition and antitrust regulation causes incumbent firms to innovate if they wish to survive the new competition. They need to find ways to reduce costs, improve product quality, or develop new products and processes to increase their profits and get ahead of potential new entrants.

Another way to study the impact of competition on innovation was presented by Aghion et al. (2005), who found that there is an inverted U-shaped relationship between competition and innovation intensity. In general, enhancing competition increases the incentives for companies to invest in innovation activities to escape from competition. However, if competition becomes so intense that imitation activities are more attractive than innovation activities, the impact of competitive pressure on innovation may become negative. The point at which this occurs is likely to differ depending on the particular sector (e.g. varying levels of strength of patent enforcement) and jurisdiction (although why the jurisdiction should play a role

remains to be determined). The peak of the inverted U is larger, and occurs at a higher degree of competition, in more neck-and-neck industries.

An increased level of competition can reduce the market share of incumbents, leading to a reduction in rents and thereby increasing the comparative benefit provided by investments in innovation. However, as put forward by Aghion et al. (2005) and then tested experimentally by Aghion et al. (2014), this is mostly the case for incumbent firms that are already innovators and at similar technological levels to one another. For firms that are lagging, an increase in competition has the opposite effect and leads to a reduction in innovation investment.

Watzinger et al. (2017) explain how compulsory licensing of patents (e.g. where governments require patent-holding firms to license patents as opposed to holding exclusive rights) means young and small companies find it easier to strike licensing deals. However, Watzinger et al. show that compulsory licensing is only effective in driving innovation if dominant companies cannot use other exclusionary practices to keep out innovative start-ups. Similarly, Chien (2003) compared rates of patenting before and after six compulsory licenses over drugs patents in the US, and found no decline in innovation by companies affected by compulsory licenses.

Katz and Shelanski (2007) argue that antitrust regulation restricts cooperation and prevents mergers between firms. Firms are, therefore, no longer able to achieve synergies by cooperating and combining their R&D activities, which means some innovation activities cannot be initiated and possible efficiency gains cannot be exploited. Spulberg (2008) finds that abuse of dominance and antitrust regulation, such as compulsory unbundling of elements of an invention, means innovative firms have incentives for greater secrecy when competitors can request technology still under development. They pursue defensive R&D strategies to protect their IP from scrutiny. The result will be less interoperability and reduced communication of scientific and technical information within industries. Reduced communication of discoveries and R&D efforts will diminish incentives to innovate.

Abuse of dominance and antitrust regulation can result in some cases in an increase in compliance costs (e.g. time, effort and costs such as legal costs and financial penalties) for firms already in the market (Ambec et al. 2013). This suggests that firms will move productive resource away from output and on to compliance to minimise these costs, resulting in reduced innovation activities in the areas from which the resources were relocated (see Crafts 2006, Spulberg 2008, Hüschelrath 2008 and Hovenkamp 2011). However, Jaffe and Palmer (1997) argue that increases in compliance-related expenditure can also provide an incentive for firms to innovate in order to reduce these costs. No other specific sources were identified in the literature on this issue. It is therefore unclear whether the costs of complying with competition and antitrust regulation can influence the terms of entry in a market and thereby influence innovation.

The possibility of litigation cases associated with regulation enforcement has an impact on the level of risk and uncertainty perceived by firms in a market. Some of the literature suggests that the prosecution of firms alleged to have broken competition and antitrust regulations can act as a positive driver for firms' innovation. For example, Marinova et al. (2005) state that it can be seen as a mechanism that reinforces the trustworthiness and power of the legal system, including the protection of intellectual property. It therefore reassures firms on the stability of the system and encourages innovative behaviour. However, Marinova et al. argue that the possibility

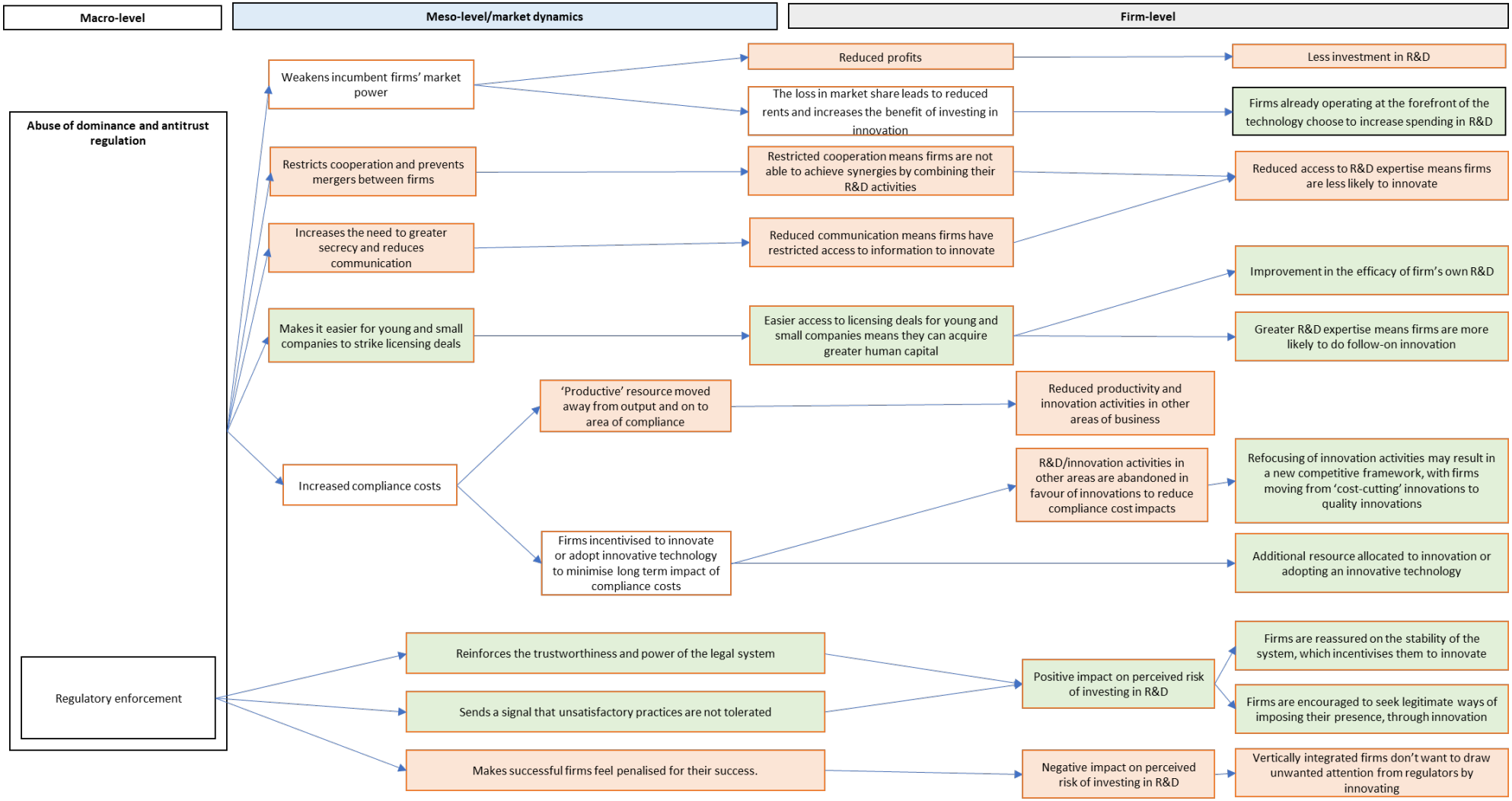
of litigation cases can also send a deterrent signal to all firms that anti-competitive practices are not tolerated. This encourages them to seek legitimate ways of imposing their presence in competitive markets.

Spulberg (2008) argues that abuse of dominance regulation, such as compulsory unbundling, means successful firms risk having their inventions disclosed to competitors: to be able to adopt or copy their invention, competitors may use the threat of an antitrust complaint. This significantly decreases or eliminates the expected financial returns of investing in costly R&D. In addition, Spulberg demonstrates that compulsory unbundling also deters innovation by competitors of leading firms. Indeed, they can now get cheaper access to R&D by simply sending a request to the leading company for the use of its innovations. They are therefore not incentivised to engage in costly R&D anymore. Borg and Sidak (2012) add that claims from Google's competitors (e.g. Microsoft, Yelp, TripAdvisor) saying that Google is making it more difficult for them to compete by including specialized search results in general search pages and limiting access to search inputs contradict real-world experiences in search. This demonstrates competitors' efforts to compete not by investing in efficiency, quality, or innovation, but by using competition and antitrust regulation to punish the successful competitor.

Some of the literature (e.g. Spulberg 2008) argues that in some cases, abuse of dominance and antitrust regulation might penalise market outcomes rather than anticompetitive behaviour, as it increases the level of risks perceived by firms. This happens when regulators view a firm's dominant position as a cause of concern itself, without considering that the dominant position might have been achieved through innovation. This can make firms feel penalised for their success and become overly cautious. These firms will seek to avoid actions (such as investing in innovation) that will improve their competitive position and draw unwanted attention from regulators. This is especially true for firms which are highly vertically integrated (i.e. firms which control more than one stage of their supply chain): these firms tend to have a dominant position in a market, and therefore tend to draw regulators' attention. However, it is their integration (and not uncompetitive behaviour) that tends to be the source of many of their innovations.

Mechanisms identified have been synthesised in Figure 6.

Figure 6. Abuse of dominance and antitrust regulation – mechanisms



Market entry regulation

A market entry regulation is a type of competition regulation that regulates market access. For simplicity, this section focuses on regulations that allow more liberal market entry (as opposed to stricter market entry). The mechanisms associated with stricter market entry are understood to be the opposite of those indicated in this section.

There is a lack of literature on market entry regulation and it tends to consider either specific highly-regulated sectors or the role of competition in influencing innovation more generally.

Transitions to more liberal market entry regulations have two potential impacts on innovation.

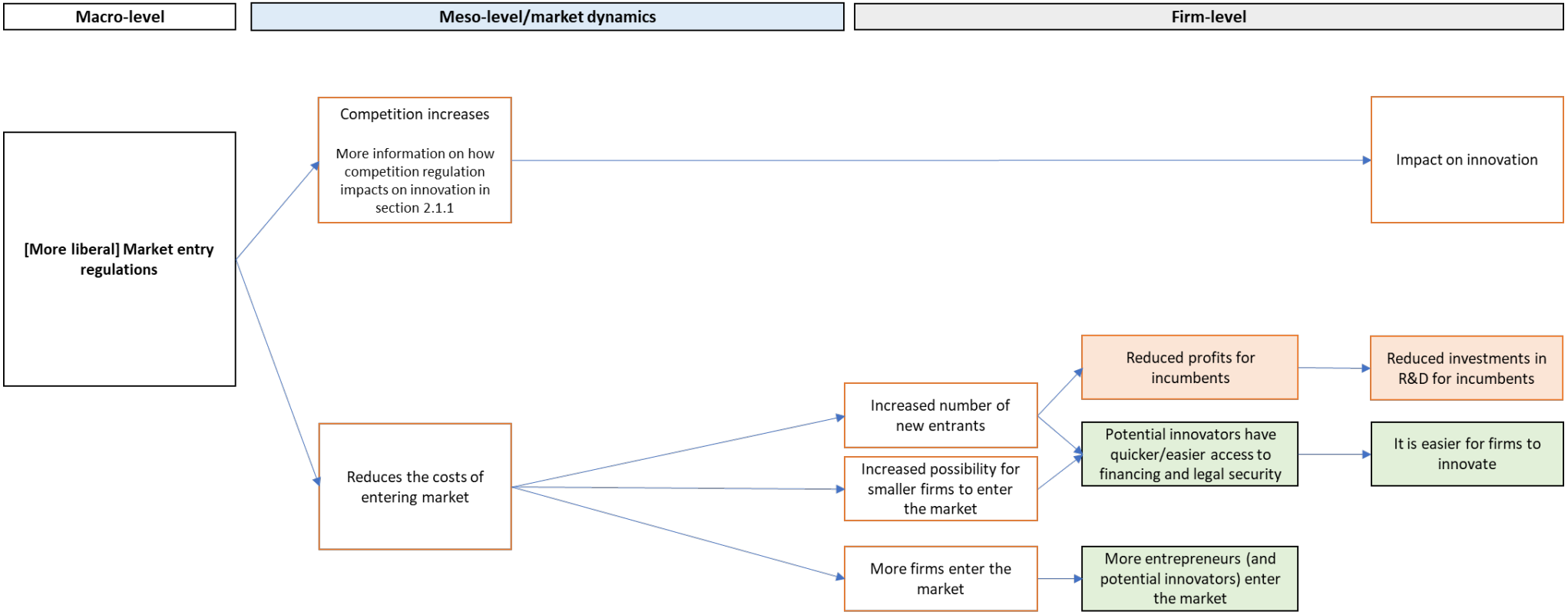
Firstly, more liberal market entry regulations may also impact innovation by more firms entering the market and thereby increasing the level of competition.

Secondly, a reduction in market entry regulations could also contribute to innovation by reducing the costs of entry and allowing more firms, particularly SMEs, to enter the market. Some literature demonstrates the relationship between market entry regulations and entrepreneurship in developing countries (see Kaplan et al. 2007 on Mexico, Mullainathan and Schnabl 2010 on Peru). Klapper et al. (2006) examine this relationship in a European context and suggest that where there are high market entry requirements, there are both fewer new entrants and companies tend to be larger at the point of incorporation; for potential new entrants, high market entry requirements may contribute to a lack of access to financing in the early phases of development.

This literature demonstrates a relationship between market entry regulation and increased entrepreneurship. However, it does not demonstrate how entrepreneurship contributes to innovation. This has been explored elsewhere (Block et al. 2017). However, that literature's findings may not apply to entrepreneurs who enter the market due to a liberalisation of market entry regulations. For instance, Branstetter et al. (2014) found that following regulatory reform in Portugal that reduced the costs of market entry, more firms entered the market. However, these additional firms tended to be smaller and in low-technology sectors. This suggests that entrants that are attracted by reduced entry requirements are unlikely to be innovators.

Mechanisms identified have been synthesised in Figure 7

Figure 7. Market entry regulation – mechanisms



Mergers and acquisition (M&A) regulation

Mergers and acquisition regulation refers to a type of competition regulation that sets the conditions under which two or more firms can consolidate into one entity.

There is an extensive literature on the impact of mergers and acquisitions (M&A) on innovation. Dezi et al. (2018) conducted a review of 55 papers on this topic, which concluded that M&As can have a negative effect on firms' innovativeness. For instance, M&As involve managerial issues, integration problems and transaction costs, which divert money away from research and development. However, M&As can have a positive impact on firms' innovativeness. For instance, M&As allow quick and effective firm growth, which is a condition for firms' innovation. In addition, M&As reduce the average cost of production and create synergies between complementary assets. This helps firms to achieve economies of scale, which encourages process innovation (Guadalupe et al. 2012) but may also reduce product innovation in sectors with high research intensity (such as the pharmaceutical industry; Haucap et al. 2019). By regulating M&As, M&A laws might have an influence on the above-mentioned mechanisms by which M&As impact on innovation. However, none of the literature identified focuses on this issue.

It is widely accepted that M&As have a negative effect on competition. For example, horizontal mergers can eliminate competition between merging firms and enable merged entities to gain substantial market power. Vertical mergers can also reduce competition, if for example the newly acquired firms decide to deal only with the acquiring firms, thereby altering competition among the acquiring firm's suppliers and competitors. Conglomerate mergers can have an anticompetitive impact as well, by converting a large firm into a dominant one with a decisive competitive advantage, for example. One of the goals of M&A regulation is to prevent such negative effect of M&As on competition, by making M&As harder to accomplish and preventing large companies from absorbing smaller competitors and establishing market dominance. However, there is a gap in the literature regarding the manner M&A regulation might impact on innovation through its effect on competition.

While mergers are mutual decisions, acquisitions (or takeovers) do not have to be and can therefore create market pressures. Because of market asymmetry, investors cannot properly evaluate a firm's investment in innovation and thus tend to undervalue firms investing in innovative projects. M&A regulation aims to address this issue by protecting target firms and establishing acceptable terms for M&As. An extensive literature offers two contrasting hypotheses to explain how state M&A regulation can impact on innovation through its effect on market pressures.

- The 'shareholder welfare hypothesis' posits that to protect themselves against hostile takeovers, firms tend to operate in the short-term interest of the firm (i.e. by putting more effort in routine tasks that offer quicker and more certain returns, rather than by investing in innovation). Therefore, the shareholder welfare hypothesis suggests that, by protecting firms against short-term market pressures, antitakeover laws help spur innovation: they create a setting that encourages managers to act in the long-term benefit of the firm and to invest in R&D. Several studies empirically demonstrate this positive impact of M&A regulation on innovation. For instance, Chemmanur and Jiao (2018) find a positive causal effect of state antitakeover provisions. They also show that

their impact is more pronounced for firms operating in markets with more severe information asymmetry and more competition. This is confirmed by Haucap et al. (2019) who show that mergers in research intensive sectors (the pharmaceutical sector in particular) have a negative impact on innovation. However, research by Phillips and Zhdanov (2013) also suggests that takeovers contribute to R&D investment in small companies, but not in large ones.

- On the other hand, the 'managerial welfare hypothesis' posits that managers of firms that are not pressured by threats of takeovers will tend to act in self-serving interests, by foregoing R&D projects in favour of ventures that offer quick payoffs. Threats of hostile takeovers help mitigate this issue by keeping firms focused on pursuing more innovative and valuable projects. Therefore, the managerial welfare hypothesis suggests that by protecting firms against hostile takeovers, antitakeover laws reduce firms' incentives to innovate. They allow firms to forego R&D projects that might be lucrative in the long-term, in favour of ventures that offer quick payoffs. Several studies empirically demonstrate this negative impact of M&A regulation on innovation. For example, Atanassov (2013) finds that US firms based in states protected by anti-takeover legislation have a smaller number of significant innovations.

The literature also includes studies offering inconclusive evidence. For instance, Sapra et al. (2012) provide empirical evidence to argue that there is a U-shaped relationship between the degree of innovation and takeover pressure. They suggest that innovation is fostered by either strong antitakeover laws that significantly restrict takeovers, or very strong level of takeover pressures (i.e. weak antitakeover laws). The theory put forward assumes that managers choose by making a trade-off between the benefits received from the innovation in case the company is not taken over and the takeover premium[5] in case the company is taken over, against the loss of control benefits (the benefits the manager loses when the company is taken over). Assuming two projects, one which is highly innovative and one that is not, the theory predicts the following outcomes:

- When takeover pressure is low, managers choose the highly innovative project because both the expected takeover premium and the expected lost control benefits are insignificant. The managers and their company enjoy the unconditional payoff from having completed the highly innovative project.

- When takeover pressure levels are moderate, the likelihood of takeover is a function of how innovative the project is. The more innovative the project, the greater the likelihood of takeover, and the higher the loss of control benefits. The theory predicts therefore that managers would choose the less innovative project in such an environment.

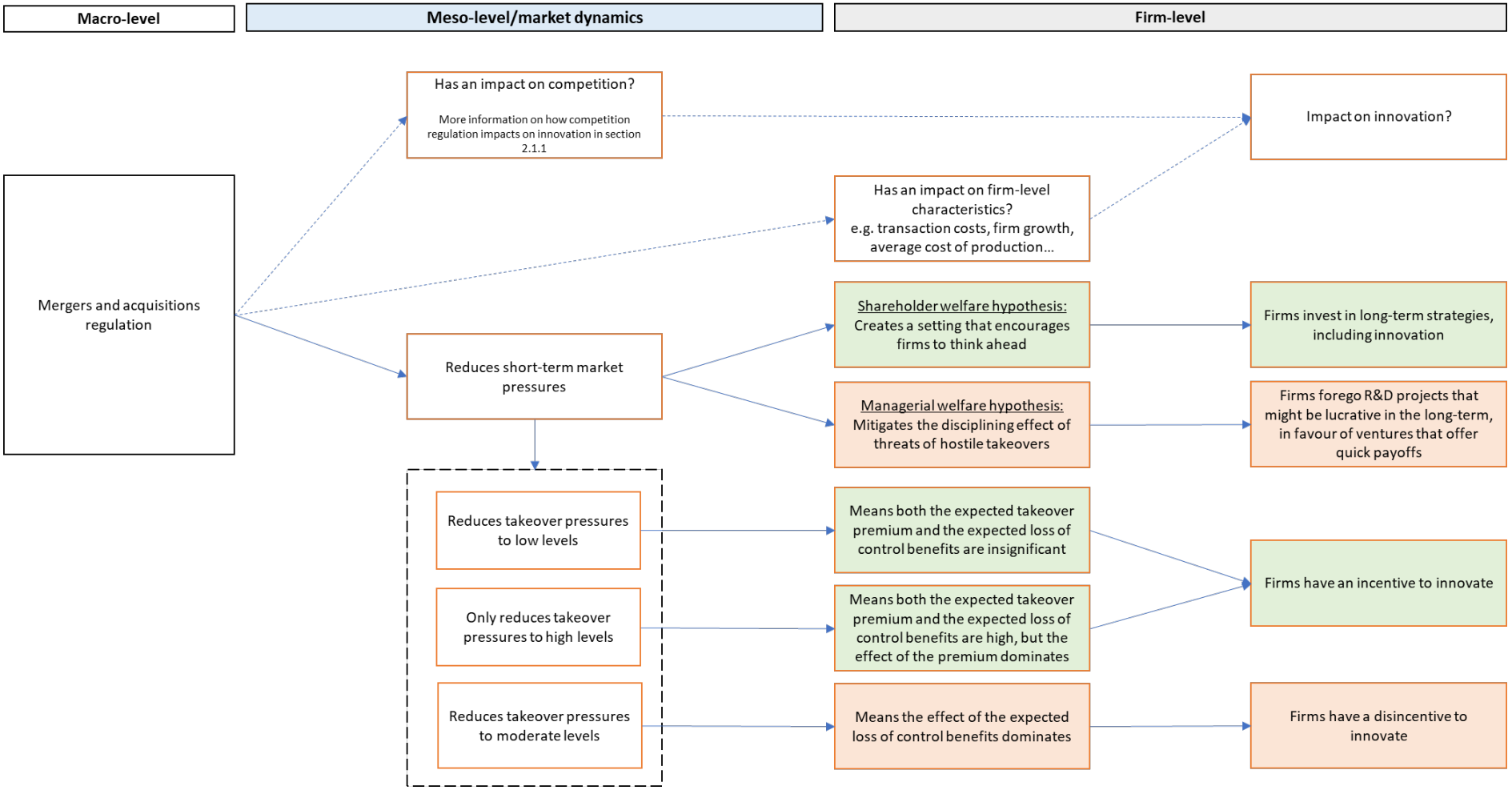
- When takeover pressure is high, it is likely that takeover will happen irrespective of how innovative the firm is. The theory assumes therefore that there is no difference to the loss of control benefits whether managers choose the highly innovative or the less innovative projects. In such a context, managers choose therefore the highly innovative project because it increases the takeover premium.

[5] Takeover premium refers to the difference between the market price (or estimated value) of a company and the actual price paid to acquire it (in %).

There is a large literature on the mechanisms by which M&A regulation impacts on innovation. However, there is a gap in the literature looking at the impact of specific types of M&A regulation (e.g. fair price laws, business combination laws and control share acquisition laws). These types of M&A regulation are quite different from one another. Therefore, they might impact on innovation through different mechanisms and might even have different effects.

Mechanisms identified have been synthesised in Figure 8.

Figure 8. M&A regulation – mechanisms



Note: As discussed in the section above, the relationship between M&As, competition and innovation is discussed in the literature, however the relationship between M&A regulation and innovation through competition is not discussed. This is indicated in the figure through question marks added to the sequence of steps linking M&A regulation and innovation through competition.

Price regulation

Price regulation refers to the setting of minimum or maximum prices for a product. It aims at protecting consumers or stabilising demand.

There is a wealth of literature on the relationship between price regulation and innovation, but this tends to focus almost exclusively on the pharmaceutical industry; though there is some discussion on the impact of feed-in tariffs for the energy industry. There is broad consensus across the literature that such regulation in the pharmaceutical industry has a detrimental impact on R&D and therefore innovation. For example, the model developed by Filson (2012) indicates that the introduction of price controls in the US could result in a substantial decline in R&D programmes ultimately reducing the number of new drugs on the market. Similarly, Grossmann's model (2011) illustrates that both price setting (e.g. minimum pricing) and price caps can result in a reduction in R&D expenditure, and Giaccotto et al.'s (2005) suggests that between 330 and 365 fewer drugs would have been introduced to the global market between 1980 and 2001 if the US had introduced price restrictions. Such findings are also reflected in Golec and Vernon (2010) and Vernon (2005). Friederiszick et al. (2009) further found that price control and reimbursement regulation options for countries can severely impact innovation in the pharmaceutical industry. To prevent this from happening, the authors stated that "in designing optimal pharmaceutical pricing and reimbursement regulation, the benefits of more affordable or cost-effective drugs must be traded against the costs of less pharmaceutical innovation".

Explanations for this effect chiefly relate to firm revenue expectations. In markets where there are fewer restrictions on pricing, such as in the US, there is increased potential for firms to profit from the introduction of innovative products and therefore more incentive to invest in R&D (Golec and Vernon, 2010). This is supported by Eger and Mahlich's study (2014) of international pharmaceutical firms, which identified a positive correlation between R&D intensity and the proportion of sales made in the US versus those in Europe. This suggests reduced profit expectations for firms operating predominantly in the more heavily regulated European market has a knock-on effect on their R&D activities. Giacotto et al. (2005) observe a positive correlation between pharmaceutical prices and industry R&D and, in a review of empirical literature on the subject, Kessler (2004) concludes that price regulation results in reduced market performance for firms, which subsequently reduces their R&D activities and ultimately the production of new products. As noted by Helms (2004), if a market is limited by price controls, firms will adjust the risk profile of their investments in the market such as reducing R&D expenditure, focusing on short-term investments, and concentrating on the areas of the market where there is highest demand.

R&D expenditure, however, does not necessarily equate to innovation, and innovations themselves can vary in quality. As recognised by Eger and Mahlich (2014), new drugs must 'meet an unmet medical need and make a significant difference to the patient' in order to outweigh the positive social attributes of price regulation, and Light and Lexchin (2012) highlight that only a small proportion of new pharmaceuticals approved by regulators can genuinely be classified as innovative, as in most cases they are only minor advancements on existing products with no clinical superiority. This is a necessary consideration given that R&D expenditure is a

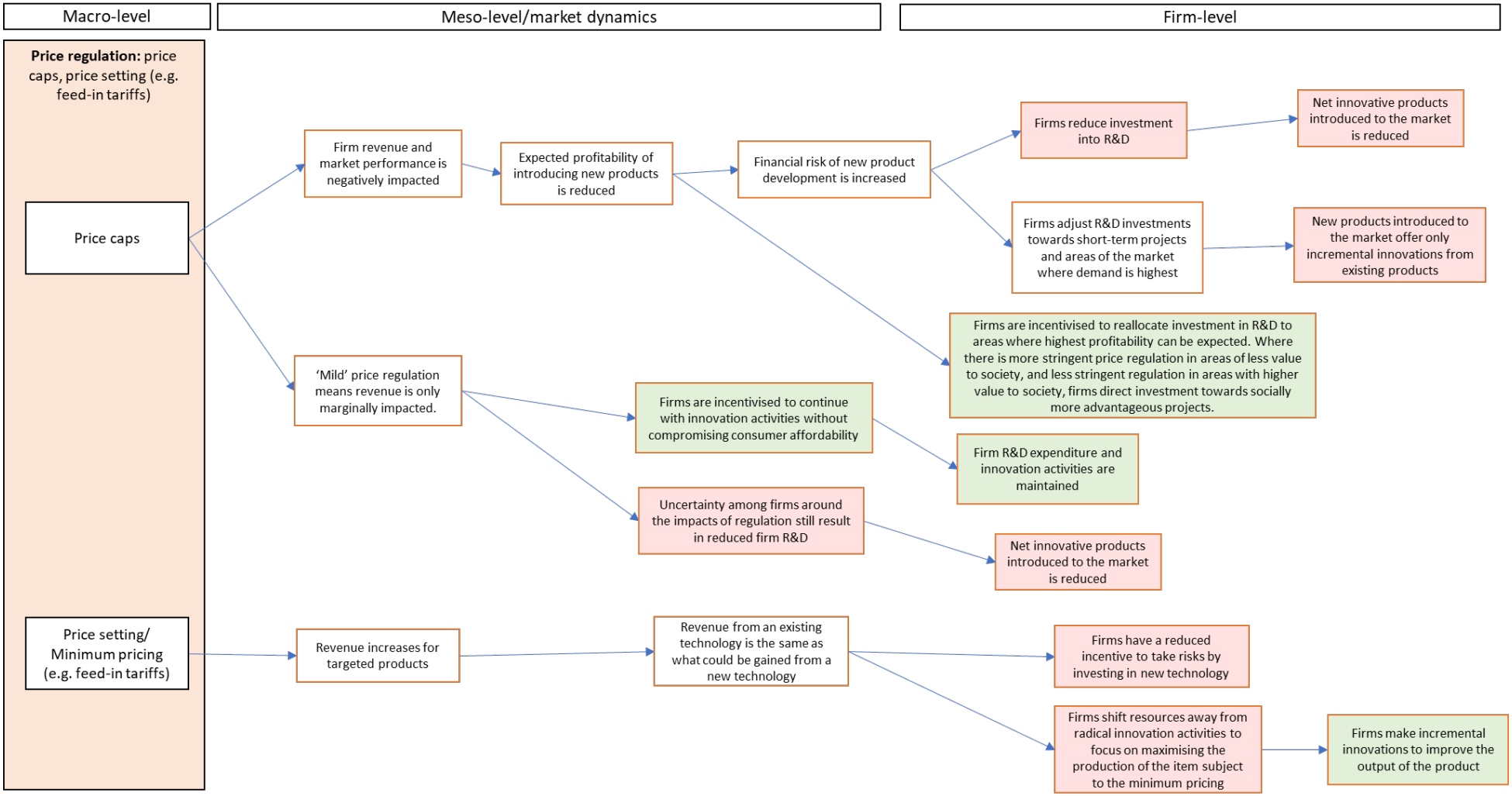
primary consideration and indicator for innovation in much of the literature on price regulation, though evidence generally points towards a positive relationship between R&D expenditure and new products on the market. For example, Jensen (1987) illustrates a correlation between R&D expenditure and new products, or New Chemical Entities (NCEs), and O'Neill and Crain (2005) find that for every 2,380 R&D employees the number of NCEs increases by one, which they consider as a positive impact.

Canoy and Tichem (2018) add another dimension to this, arguing that prices for a patented drug can be higher than the drug's societal value. Such high prices lead to excessive investment in some projects at the expense of other valuable research projects. This in turn suggests that price regulation can play a role in fostering innovative activity in the areas where it is needed. The idea that price regulation can support a healthy 'middle ground', that is able to both incentivise firms through revenue gains while maintaining affordability for consumers is also discussed by Levy and Nir (2014), who advocate for 'mild regulation' that benefits consumers without compromising pharmaceutical innovation.

There is less evidence regarding the effect of feed-in tariffs on innovation. Feed-in tariffs are specific to the energy industry. They aim to foster renewable energy generation by offering guarantees to producers (i.e. a minimum price for renewable energy that is typically higher than energy produced through fossil fuels). In Böhringer et al.'s study (2014) of feed-in tariff use in Germany, they found no impact on innovation output, even for specific technologies (e.g. photovoltaic) where prices are set very high. The proposed explanation for this is related to revenue – firms will make the same gains using an existing technology where the price is set as they will from a new technology, therefore there is little incentive to take investment risks. As seen in the literature on the pharmaceutical industry (Canoy and Tichem, 2018; Levy and Nir, 2014), increasing firm revenue potential does not necessarily equate to increased innovation activity in areas desirable for society.

Mechanisms identified have been synthesised in Figure 9.

Figure 9. Price regulation – mechanisms



Quantity regulation

Quantity regulation places restrictions on specific areas of a market, such as limiting firm outputs or the number of available permits for a specific activity.

Quantity regulation is used in a range of policy contexts, such as environmental protection through restrictions on pollution, or other sectors (e.g. fishing, financial services or hunting). However, the literature available on quantity regulation and innovation is limited and tends to be in the context of environmental economics. The main specific example of quantity regulation discussed in the literature in terms of its impact on innovation is the EU European Trading Scheme (ETS), which aims to provide incentives to develop efficient approaches to reduce emissions.

In most cases, the mechanisms by which quantity regulation impacts innovation are not explicit and hard to generalise across different markets. There is a significant gap in the literature exploring the connection between quantity regulation and innovation in other sectors where it is also used, such as the financial industry.

While literature which discusses the relationship between innovation and quantity regulation at a generic level is minimal, where mentioned, there is consensus that the financial implications for firms are significant in their decisions to innovate. For example, Johnstone et al. (2010) suggest that firms will react to quantity-based policy instruments such as tradable renewable energy certificates by innovating to the ‘cheapest alternative’ technology, and Borghesi et al. (2015) argue that firms impacted by the ETS – a quantity-based regulation – have a ‘cost saving’ motive that increases with their intensity of energy expenditure due to the cost of additional permits. However, these examples are highly contextual – Johnstone et al. acknowledge that this finding is specific to only one of the technologies investigated, and Borghesi et al.’s findings are based only on the impact of the EU ETS on Italian firms, though the regulation is EU-wide. Both studies also reflect environmentally-rooted policies.

There is recognition that quantity regulation can increase the costs of a firm’s existing practices. For example, under the EU ETS, firms may have to purchase ‘costly’ emissions permits in order to maintain the same level of output, creating a financial motive to innovate and therefore avoid the need for permits without compromising product output (Borghesi et al., 2015).

Ambec et al. (2013) similarly recognise the costs which can result from quantity regulation, when it is used as a command-and-control instrument. This type of regulation is suggested to be too prescriptive. If regulation results in increased compliance costs in a specific area, for example, funds and resource may be reallocated from innovative areas such as R&D. Similarly, other innovative activities undertaken by a firm may be constrained by the quantity regulation due to its typically restrictive nature – while Borghesi et al.’s study (2015) finds the EU ETS to be broadly conducive to innovation, it also observes that, due to the primary focus on carbon abatement technology, other innovative technology achieving energy efficiency was not recognised.

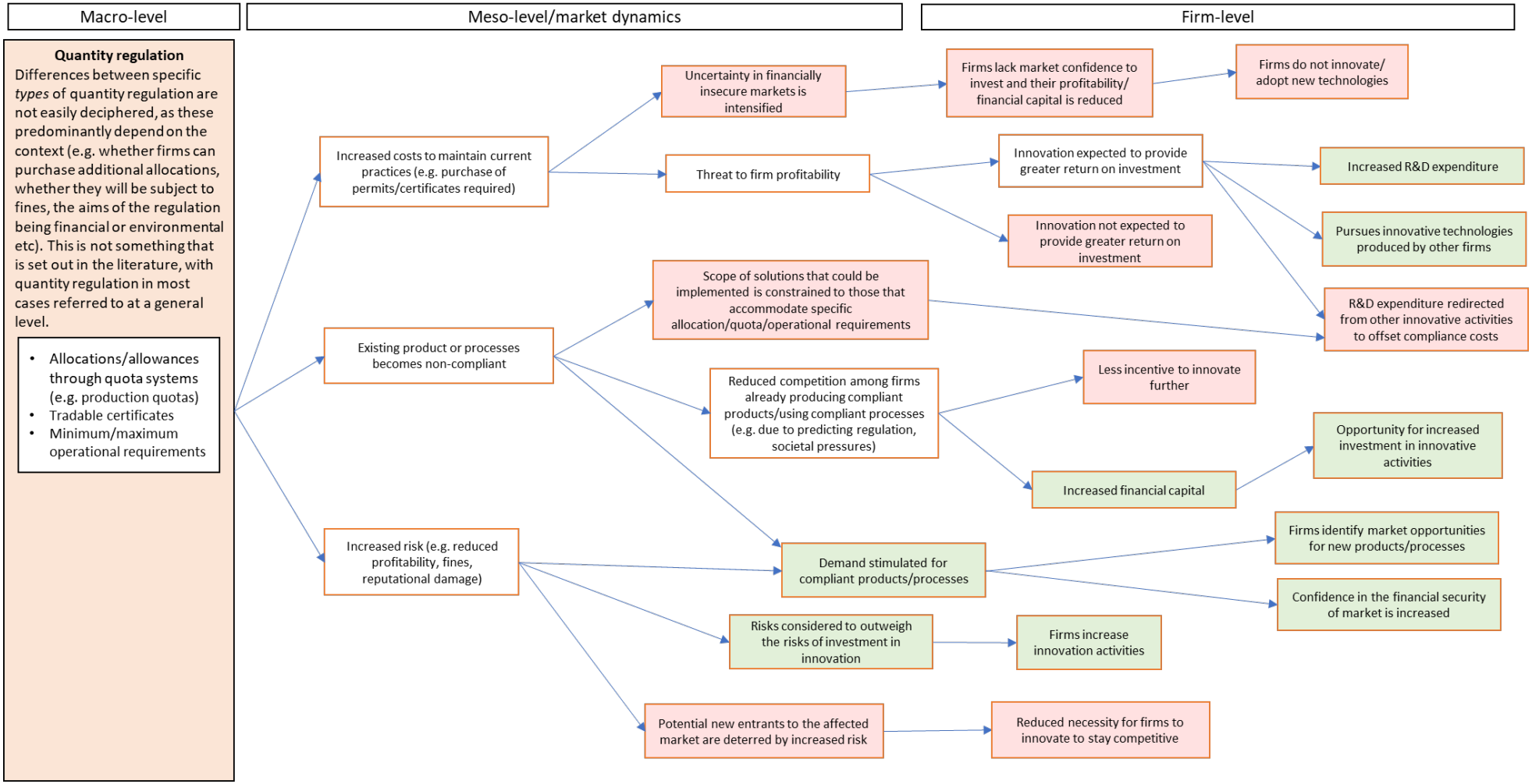
Barbieri et al. (2016) similarly argue that command-and-control regulations do not provide an adequate incentive for firms to innovate, as there is no ‘reward’ for going

beyond the minimum requirement. Arguably, however, this is achieved by such trading schemes as the EU ETS, as firms can sell their excess emission allocations.

The market context can influence the relationship between quantity regulation and innovation. For example, a quantity regulation is likely to have different impacts in markets depending on the average size of companies or the average age of companies in the markets (e.g. younger companies may be more likely to deal efficiently with regulatory burdens than older industries, such as steel manufacturers). Another example of market context which can influence the relationship between quantity regulation and innovation is a sector's financial security. This is largely conveyed through Borghesi et al.'s study (2015), where price volatility in the paper and cardboard sector appears to influence firms' willingness to innovate. Many firms in this sector chose to 'wait and see' what impact the EU ETS regulation would have on their business, rather than investing in new technologies to minimise this impact as firms in more financially secure markets would choose to do. Beyond this, the available literature on quantity regulation says very little about the mechanisms that link together its effects on innovation.

Mechanisms identified have been synthesised in Figure 10.

Figure 10. Quantity regulation – mechanisms



Regulation of natural monopolies and public enterprises

Several studies have acknowledged that the effect of regulation on innovation has not been widely discussed in the specialist literature addressing unbundled natural monopolies in network industries and the subsequently established markets. Only a few sources were identified in the economic literature, which examine the impact of regulation of natural monopolies on innovation.

One exception is Bauknecht and Koch (2011), who offer a good overview of the mechanisms by which three types of regulation (cost-based, price-based or output based) affect the innovation activities natural monopolies.

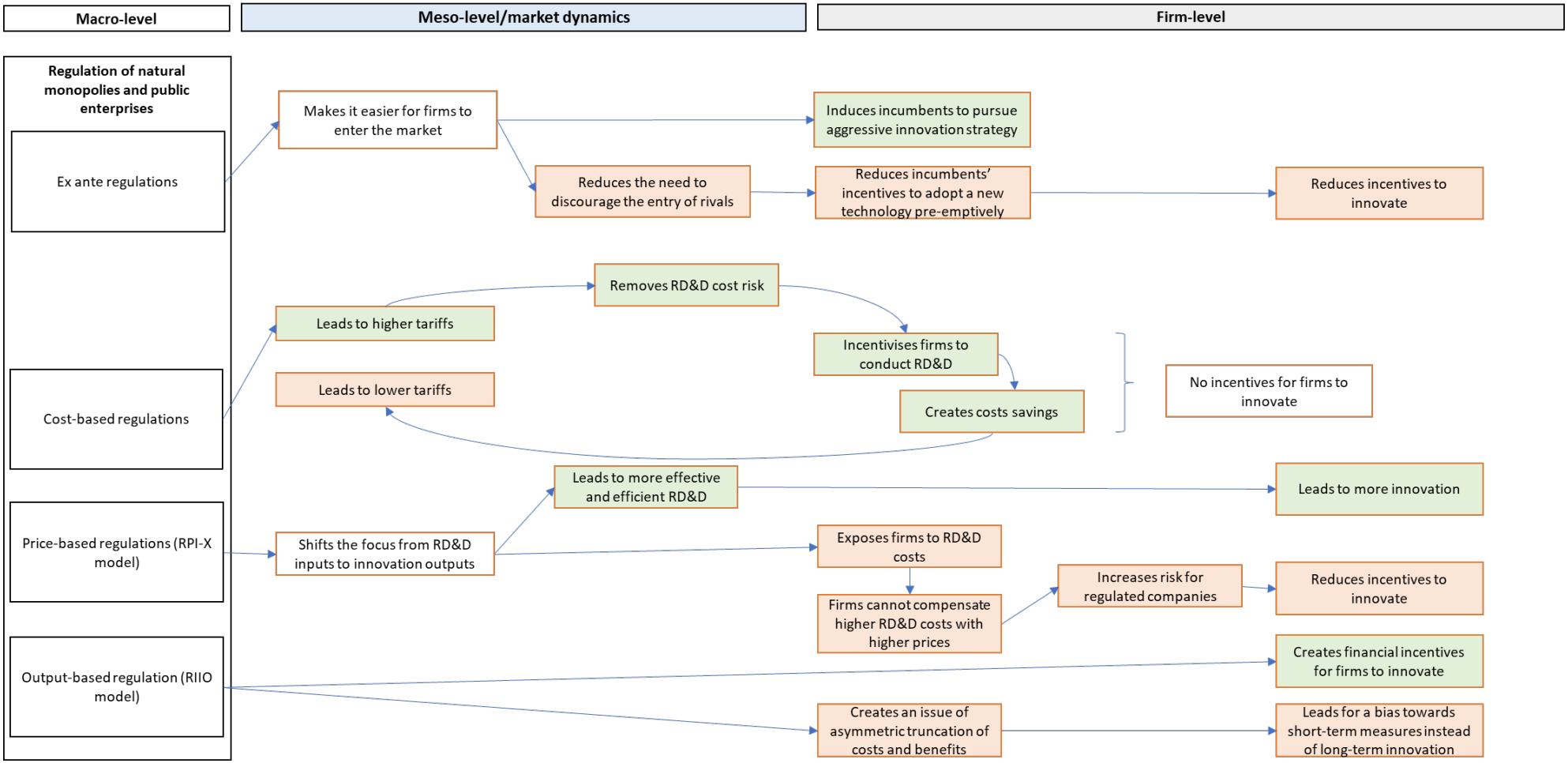
- **Cost-based regulation**: This type of regulation monitors companies' costs and revises the tariffs companies can charge accordingly. In practice, this enables companies to conduct research and development (R&D): when companies invest in R&D, their overall costs increase, but this increase is offset by the fact that the cost-based regulation will increase the tariffs companies can charge. However, investments in R&D will eventually lead to cost savings, meaning that the cost-based regulation will lower the tariffs companies can charge. Therefore, it can be argued that cost-based regulation does not give companies any incentive to innovate (Bauknecht and Koch, 2011).
- **Price-based regulation (RPI-X model):** Until recently, the most common way to regulate natural monopolies was to control price through the RPI-X framework (Retail Price Index minus X, an efficiency savings target). Price-based regulation has a positive effect on innovation, as companies benefit from cost reductions they can achieve, including cost reductions from process innovations, and would therefore make an effort to innovate. However, price-based regulation also increases the risk for regulated companies. Indeed, it exposes them to higher R&D costs that they cannot compensate through higher prices. This creates a disincentive for firms to innovate (Bauknecht and Koch, 2011).
- **Output-based regulation (RIIO model):** The RPI-X model was replaced with RIIO (Revenue = Incentives + Innovation + Outputs) which sets to encourage more innovation in energy networks to benefit consumers. The more innovative energy networks would receive more financial rewards, while those that failed to innovate sufficiently would face financial penalties and further regulatory scrutiny. This type of regulation should therefore provide an incentive to firms to innovate. However, it also creates issues: if the project fails, the company is stuck with the costs; if the project is successful, part of the benefits is passed on to consumers without taking into account the risk associated with achieving these benefits (asymmetric truncation of costs and benefits). Companies are therefore not incentivised to take risks and prefer short-term measures which lead to guaranteed benefits rather than investments in potentially risky endeavours. In other words, this can lead to a bias towards short-term measures (Bauknecht and Koch, 2011).

In a study considering the regulation of telecommunications, Bourreau (2001) looks at the role asymmetric ex ante regulations[6] play in innovation decisions as compared to ex post controls, where antitrust authorities enact competition policies. This study finds that although such regulations may help new firms enter the market and therefore encourage incumbents to innovate in the face of competition, they are more likely to make pre-emptive innovation strategies less attractive for incumbents, as incumbents are no longer able to use such tactics to discourage new entrants.

Mechanisms identified have been synthesised in Figure 11.

[6] That is, regulations that are placed on the incumbent within a natural monopoly in order to facilitate new entrants.

Figure 11. Regulation of natural monopolies – mechanisms



Social regulation – detailed sections

This Annex discusses the findings from the literature on social regulation.

Liability law

Liability law is an area of tort law that refers to the degree to which firms are held responsible for loss or harm caused by their products or practices, specifically relating to compensation or damages paid by the party or firm held legally liable when litigation action is taken against them. The literature exploring the impact of liability law on innovation is very limited. There is disagreement as to whether the impact can be classified as positive or negative, and there is evidence to suggest that this depends on contextual factors.

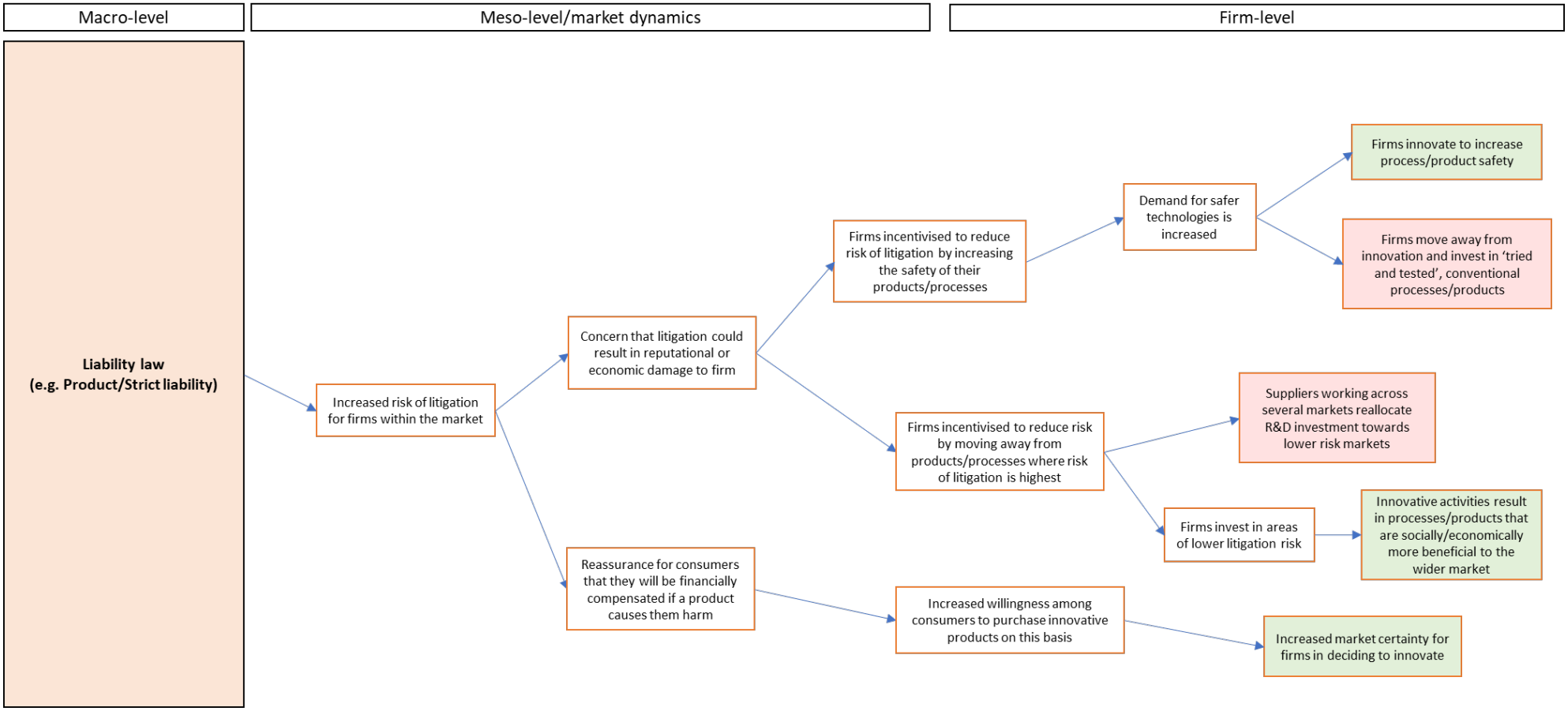
The argument put forward by Parchomovsky and Stein (2008) is that the assignment of liability by courts is based heavily upon ‘customs’, or legal precedence in an area, which is generally based on a more conventional understanding of technologies and processes. In other words, it tends to be naturally backward-looking, rather than forward-looking. Innovations represent a change in convention, and therefore an increased liability risk for innovators due to potentially being viewed by the court to be contravening standardised precautions, even in cases where the potential benefit of an innovation is greater than the convention. This is viewed as a deterrent to innovation due to the potential costs that could result from litigation action over an innovative technology. This is echoed by Priest (2011), who contends that liability law has resulted in insurance costs for firms, which itself is a ‘tax’ on innovation.

On the other hand, there are numerous studies that find a positive correlation between liability law and innovation. In their study of the chemical industry, for example, Ashford and Stone (2002) find that firms will innovate to develop safer products or processes when liability laws are introduced or expected to be introduced. This is because firms must internalise any social costs (e.g. injuries/illnesses, property damage) or economic costs (e.g. health care, lost working days lost) that result from their processes or products through the combination of litigation costs and reputational damage. The threat of litigation therefore creates a deterrent for unsafe products and processes. The greater the costs that firms must internalise are, the more incentives they have to develop or adopt innovative technology that improves safety. Similarly, Viscusi and Moore (1993) find that increased liability to costs, up to a point, result in the intensification of R&D, and Galasso and Luo’s study (2017) indicates that a cap on the compensation which can be awarded under liability law correlates with a reduction in medical instrument technologies patented. The negative effect described by Parchomovsky and Stein (2008), they argue, is outweighed by the increased demand for safer technologies that is provoked by strong liability laws.

However, Galasso and Luo’s 2018 study has very different results. In the medical device industry (implants), they found that patenting declines by just over a third with increased liability risk. Notably, they observe that liability risk targets upstream suppliers but reduces innovation activity predominantly in downstream buyers, suggesting suppliers may choose to move their focus to areas of the market with less

risk. This lack of consensus in the available evidence illustrates the highly contextual nature of the relationship between liability law and innovation, which according to Galasso and Luo are shaped by the market size, the extension of the liability risks, the spill-overs to other markets or within the value chain, any damage to the company's image, the ability to assess the risks and whether they may materialise in the short term or rather in the long term. Mechanisms identified have been synthesised in Figure 12.

Figure 12. Liability law – mechanisms



Labour market regulation

This section describes how different types of labour market regulation impact firms' decisions to innovate. It summarises the information provided in the literature on relevant mechanisms.

As described in Blind (2016), the empirical evidence on the relationship between labour market regulations and innovation is ambiguous. The impact of labour market regulations on productivity, innovation and other economic outcomes appears to be largely dependent on contextual factors: on the size of firms, the nature of innovation (radical or incremental) within a given sector, union structure, etc (e.g. Wachsen and Blind 2016).

Labour market regulation and innovation are often inextricably linked, as investments in innovation frequently depend on human resources. Labour market regulation impacts the ability of firms to gain, maintain and incentivise skilled employees to innovate and to invest in employees who will focus on R&D activities. Where innovation in a sector is driven by process innovations or risky new endeavours, innovations will frequently depend on a firm's ability to reduce or reallocate human labour, the cost and ease of which is determined by labour market regulation. The extent of the effects that stem from this linkage will likely depend on the extent to which firms are more heavily invested in capital than in labour (such as in manufacturing) or more heavily invested in labour than in capital (such as in services).

The literature does not provide empirical evidence on the specific mechanisms leading to these effects, but it puts forward several theories on what these mechanisms may be.

Much of the literature focuses on wrongful dismissal laws (WDL) and employment protection legislation (EPL). These types of regulations add costs to dismissing workers, disincentivising firms from doing so. This has several potential implications. By making it harder to fire redundant employees, firms may be reluctant to adopt or develop new automations or labour-saving innovations (Gust & Marquez 2004, Kleinknecht et al. 2014), thereby reducing investment in process innovations. The costs associated with dismissing workers also make firms more reluctant to hire in the first place, in particular for new endeavours considered to be risky (Kleinknecht et al. 2014), which suggests potential negative impacts for radical innovations. However, this impact may be offset if employers can reallocate employees internally within their organisation (Bassanini and Ernst 2002). Calcagnini et al. (2018) have theorised that the impact varies with time: the negative impact of high labour market regulation is a short term one, whereas the long-term impact is positive. Wachsen and Blind (2016) have further argued that the impact varies depending on the sector, with labour market flexibility not hampering innovation in a sector or ecosystem characterised by radical innovation (such as the Silicon Valley), but having a negative impact on sectors characterised by incremental innovation, such as the US automotive industry.

Alternatively, EPL or WDL may lead to employees feeling more secure in their positions and therefore more likely to engage in innovation activities, as both the potential failure and success of these activities are less likely to result in negative

consequences (Acharya et al. 2013). This greater sense of security, or trust between employee and employer, may also lead to employees feeling more loyalty toward firms, meaning that they are less likely to give away trade secrets and more likely to cooperate with management. This reduces the risk associated with R&D investment for management, and therefore may contribute both to increases in productivity and an increase in innovation (Kleinknecht et al. 2014). In a situation where employees feel a greater sense of loyalty to the firm, firms may also benefit from increased in-house expertise. This type of expertise is particularly important to industries that are dependent on incremental innovations (Bassanini & Ernst 2002). In addition to this, a greater sense of trust and security may favour employees providing critical feedback, questioning management and suggesting improvements, which could help lead to increased innovation activities (Kleinknecht et al. 2014).

At the market level, the incentives created at firm-level by EPL or WDL to avoid dismissal and reduce firing has been shown to reduce overall employment fluctuation in the market (Autor et al 2007).[7] This overall reduction in employment fluctuation may to some extent contribute to employees' sense of loyalty and the subsequent effects described above and at a market level, may mean that there is an overall slowdown in the reallocation of labour from old, declining sectors to new, entrepreneurial and dynamic ones, although Kleinknecht et al. (2014) also posit that this may be off-set by the fact that new and dynamic sectors are likely to offer better career opportunities and higher pay.

Employment fluctuation more generally is also potentially beneficial to the development of more 'radical' innovations, as such innovations benefit from bringing in new people, who bring along with them new and different ideas, ways of thinking and knowledge (Kleinknecht et al. 2014). This is partially supported by evidence that suggests that high-risk innovative sectors are smaller in countries with strict employment protection legislation (Bartelsman et al. 2011). Higher turnover may mean, however, that employees are reluctant to acquire firm-specific skills without a long-term commitment to the employer, and employers are less willing to invest in manpower training (Kleinknecht et al. 2014).

Menezes-Filho and Van Reenen (2003) provide an overview of many of the theoretical mechanisms presented in the literature that seek to describe how unions may influence innovation. The most direct effect is that unions may intentionally block the introduction of new technologies for fear of job losses, change or work intensification. There are examples that illustrate this, but others show that the opposite is true and that unions tend to support the introduction of new technology and assist with this introduction. This impact may differ between Coordinated Market Economies (CMEs)[8], where relationships between unions and firms tend to be more collaborative, and Liberal Market Economies (LMEs)[9], where the relationship between unions and firms tends to be more adversarial. Literature suggests that in LMEs, unions are more likely to block technologies directly. However, there is empirical evidence to suggest that in the UK, the presence of unions does not reduce R&D investment.

[7] This study, which looks at employment protection in the United States, also notes however that the impacts on employment fluctuation were greatest in the first three years following the implementation of measures. This is likely, in part, because of uncertainty immediately following implementation, as employers did not yet fully understand the consequences of the legislation.
[8] Countries such as Germany, Japan, Denmark, Sweden
[9] Countries such as the US, UK, Australia, New Zealand

Unions may also impact innovation indirectly, by creating the possibility that some of the rents gained through innovative activities will be passed along to employees rather than the firm. This has the potential to both negatively impact the firm's financial incentive to invest in innovation and to positively impact employee motivation to engage in innovative activities.

The presence of unions could also impact firms' decisions to invest in innovation by increasing the cost of labour. The regulation of wages (for example, through the establishment or increase of a minimum wage) has a similar impact. In both cases, increasing the cost of labour may influence firm decisions regarding innovation in two main ways.

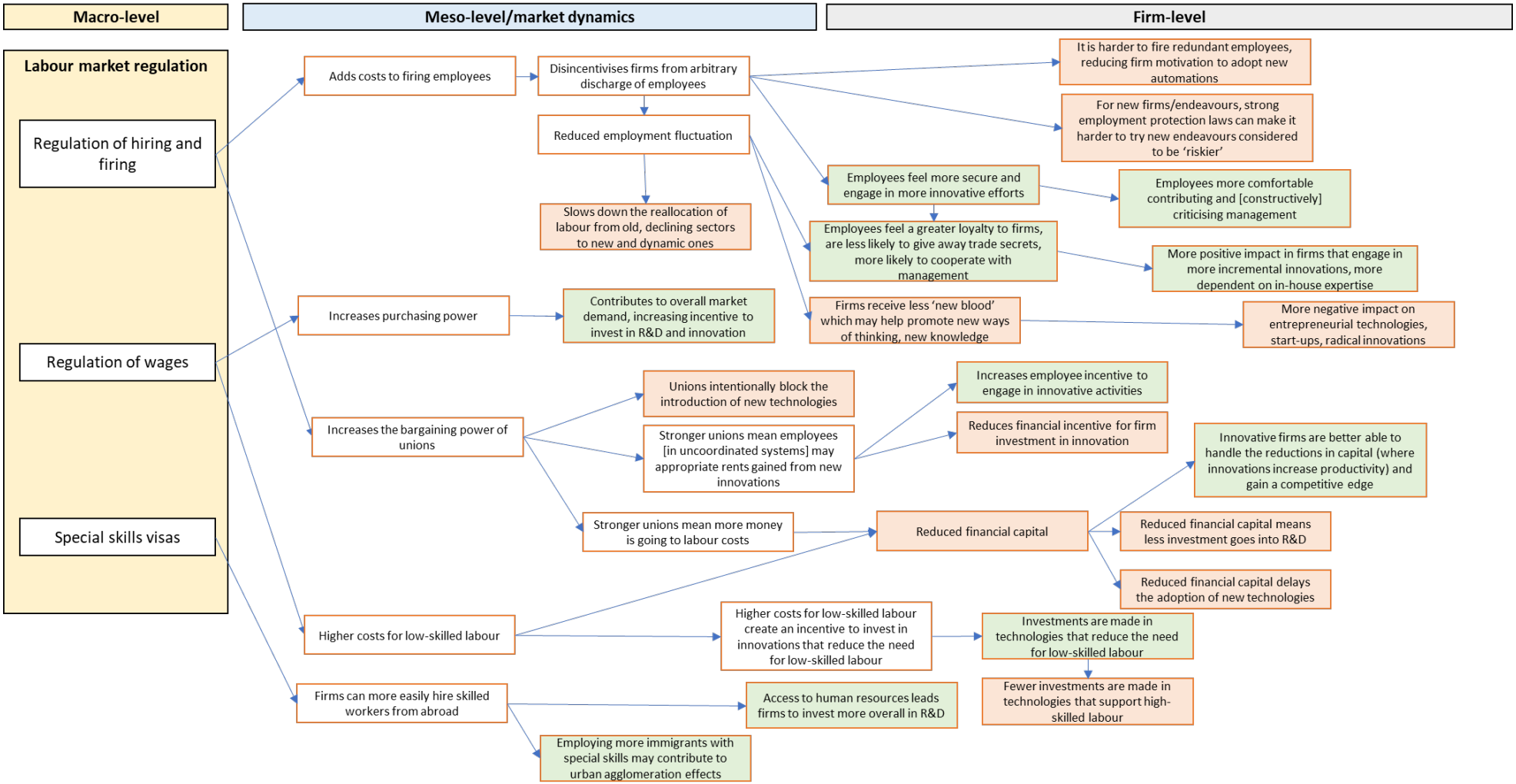
Firstly, an increase in labour costs can lead to an overall reduction in financial capital, so firms may decide to invest less overall in R&D, particularly as R&D is considered to be a high-risk investment (Menezes-Filho & Van Reenen 2003) unless perceived as an essential investment, as is the case in the pharmaceutical industry. This may also delay the adoption of new technologies where these are associated with a higher cost. In the longer term, however, these impacts may mean that firms which are already innovative and have made improvements to productivity and profitability through such changes will have a competitive edge, leading to more innovative firms dominating the market (Kleinknecht et al. 2014).

Secondly, an increase in labour costs, particularly for low-skilled labour, provides financial incentives for firms to invest in innovations that reduce the need for low-skilled labour. Where such investments are made, however, this may mean that less funding is available for investments in technologies that support high-skilled labour (Alesina et al. 2014).

In addition to the regulation of hiring and firing and the regulation of wages, regulations that impact the supply side of the labour force, such as visas that allow for the immigration of workers with special skills, may also impact innovation. Kerr and Lincoln (2008) found that the influx of immigration in the US through the H1B visa scheme led to significantly more patenting among Indian and Chinese engineering specialists in US cities. The authors also posit potential mechanisms as to how this may lead to an overall increase in innovative activities: firstly, that the access to immigrants with special skills may lead firms to devote more overall resources to R&D, and secondly that increasing the overall supply of skilled labour may contribute to urban agglomeration, or the concentration of skilled labour within a particular area, which has been shown to positively impact innovation. It is also possible that immigration regulations impact innovation by increasing diversity in the R&D workforce. This has been shown in the literature to have a mostly positive impact on innovation (Garcia Martinez et al. 2017).

Mechanisms identified have been synthesised in Figure 13.

Figure 13. Labour market regulation – mechanisms



Bankruptcy law

The small amount of literature on bankruptcy law and its influence on innovation tends to focus largely on the role of personal bankruptcy law in influencing entrepreneurship. It assumes that entrepreneurs are very often 'Schumpeterian entrepreneurs' – innovators who choose to set up on their own to pursue new ideas that could bring about breakthroughs (Armour and Cumming 2008). There is empirical evidence to support this, showing that high rates of entrepreneurship can be linked to increased innovation (Block et al. 2017 provides a review of this literature). There is a larger literature examining the relationship between personal bankruptcy law, entrepreneurship and economic outcomes more generally, but this literature does not necessarily explicitly reference the role of innovation.

Bankruptcy laws differ in how they assign rights between creditors and borrowers. More liberal bankruptcy laws provide a certain amount of insurance to borrowers in the case of failure, and stronger creditor rights provide more security to lenders that they will recover their assets. Bankruptcy law also distinguishes between personal and corporate borrowers, setting different conditions for each and the literature tends to consider these two types of bankruptcy separately.

The aforementioned literature on entrepreneurialism focuses on personal bankruptcy laws, generally pointing to the positive impact of more liberal personal bankruptcy laws on entrepreneurialism and consequently on innovation. Offering insurance against the consequences of failure means that more risk-averse entrepreneurs choose to start new endeavours (Armour and Cumming 2008) and that entrepreneurs are encouraged to pursue more explorational activities as failure and 'fresh starts' are made easier (Armour and Cumming 2006, 2008, Ederer and Manso 2011).

Providing more insurance to borrowers may, however, also have a negative impact on the availability of financing. Creditors in such situations can no longer fully discriminate between low-risk and high-risk projects and as such may increase their interest rates. This means that entrepreneurs with low-risk projects cannot justify borrowing at higher interest rates, as low-risk projects are less likely to bring returns that would justify paying such interest rates, and potentially innovative firms will have reduced access to financing (Primo and Green 2011). In addition, the lack of rights in the case of failure may simply lead to lenders tightening credit for small business, again reducing potentially innovative firms' access to financing (Armour and Cumming 2008).

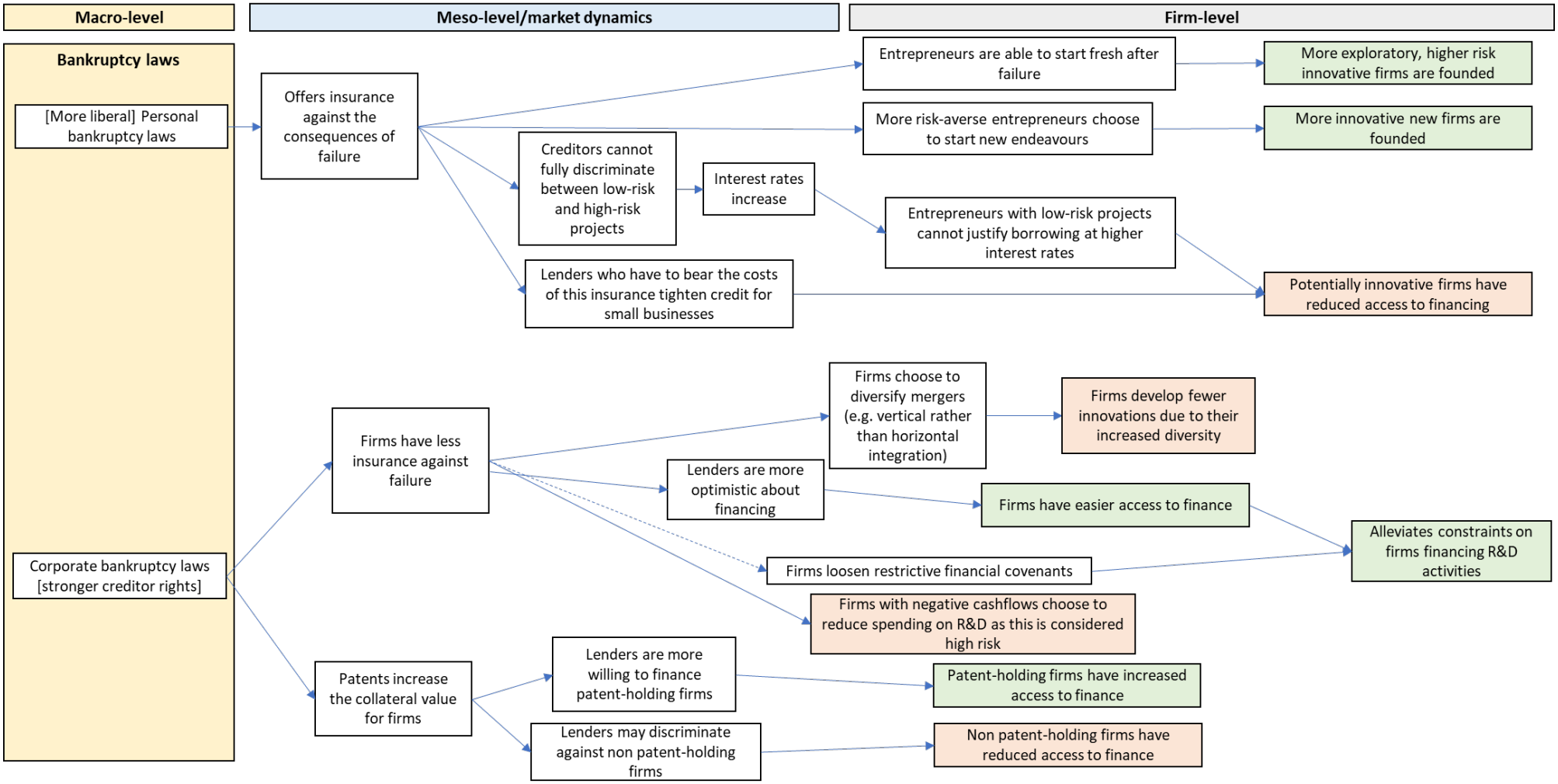
Similar mechanisms exist for corporate bankruptcy laws. Where there are stronger creditor rights, firms whose investments fail will still be liable for payment. On the one hand this can lead to firms choosing to diversify investments to reduce risk, investing R&D budgets across a broader range of projects and therefore developing fewer radical innovations (Acharya et al. 2011). This may help to explain evidence that stronger creditor rights are associated with less investment in innovation and more investment in well-established production (Acharya and Subramanian 2009). There may also be a more direct mechanism whereby firms simply choose to invest less in R&D when creditor rights are stronger (Seifert and Gonenc 2012), as R&D investment is considered a high-risk activity.

Alternately, Mann (2018) suggests that strengthening creditor rights actually increases borrowing by innovative firms and leads to a better quality and diversity of innovations. This is particularly the case for firms that hold patents, as patents can be used to increase the collateral value of firms, thereby increasing the optimism of potential lenders. Mann (2018) also found that strengthening creditor rights is associated with a loosening of restrictive financial covenants that had previously constrained firm investment policies. As such, increased access to finance combined with more liberal firm investment policies reduces overall barriers to financing R&D activities. For firms that do not hold patents, however, this may lead to a reduced access to finance.

Mann (2018) notes that these findings are counter to other contributions to the literature but seeks to reconcile this by pointing to the importance of the legal context. As this study was undertaken in a US context and the US scores low for creditor rights to begin with, strengthening creditor rights is not equivalent to the strong creditor rights seen in other jurisdictions studied, such as Europe. Therefore, it is possible that all of these proposed mechanisms are valid, but their impact may depend on the degree of strengthening or liberalisation and on the level of enforcement within a jurisdiction.

Mechanisms identified have been synthesised in Figure 14.

Figure 14. Bankruptcy law - mechanisms



Intellectual property regulation

There is an extensive literature on the influence of intellectual property rights (IPR)—notably patenting—on innovation, as the intended purpose of patenting in the first place is to encourage and support innovation. As pointed out by Blind (2016), however, there is very little empirical evidence to suggest that more IPR leads to greater investment in R&D or more innovations being developed. In fact, much of the literature questions the value of IPR to innovation, and notes that, as pointed out by Blind (2012), the impact of IPR on innovation will differ from industry to industry, in large part because innovation processes, costs and patenting rates differ between industries. As such, while some industries seem to benefit from stringent IPR (e.g. pharmaceuticals), among other industries this leads to disincentives for innovation (e.g. information and communication technology; Bessen et al. 2018)

Patenting impacts innovation by altering the incentives that lead firms to innovate. They allow firms to patent new ideas and then either obtain rents through licensing their patent or litigating against uses of their patents without a license. The threat of litigation and the ability of firms to control the use of their innovation means that firms are able to hold a temporary monopoly over their innovations. This is seen to reduce the risk of investing in innovation and therefore encourage firms to innovate. In addition to this, the ability of firms to hold a temporary monopoly over an innovation allows them to increase prices and keep free riders from driving down prices, increasing the amount they can earn from an innovation. These mechanisms have been most noticeable in the pharmaceutical industry, where patenting does appear to drive innovation (Bessen and Meurer 2008) or in other industries, such as medical devices or chemicals, where invention is highly complex and uncertain (Lemley and Feldman 2016).

For firms in other industries, however, these same mechanisms can cause disincentives to innovation. When patent-holding firms prevent other firms from using or incorporating their innovation, this negatively impacts diffusion. According to some authors, such as DeFeo et al. (2017), this poses a significant barrier to innovation in areas where copying and diffusion form the basis upon which new innovations can be developed. This is especially the case in many digital products, where technology has become increasingly complex and knowledge spillover is easily facilitated through the internet. The risk of litigation and the fear of inadvertently infringing on existing patent rights is exacerbated in some industries by the proliferation of “patent thickets”, where a large number of patents in a certain complex area makes it difficult for new firms to conduct R&D within that area without risking infringement (Baker et al. 2017, Blind 2012, von Graevenitz et al. 2011). In some instances, “patent trolls”—law firms who buy up patents specifically to look for instances of infringement and litigate—may also lead firms within an industry to avoid certain types of innovation (Baker et al. 2017).

The monopoly gained by innovative firms through patenting and the higher prices they can charge because of this can also contribute to inefficiencies in the market and slow down diffusion (Baker et al. 2017). Patents may also be used by firms as collateral to increase their access to financing (Mann 2018). The additional financial benefits gained from patenting can also lead firms to focus on quick and easily patentable projects rather than investing in longer term research less amenable to patenting (Baker et al. 2017). For example, Bessen and Hunt (2007) provide

empirical evidence for the rise of strategic patenting in the software industry at the cost of an overall reduction in R&D spending.

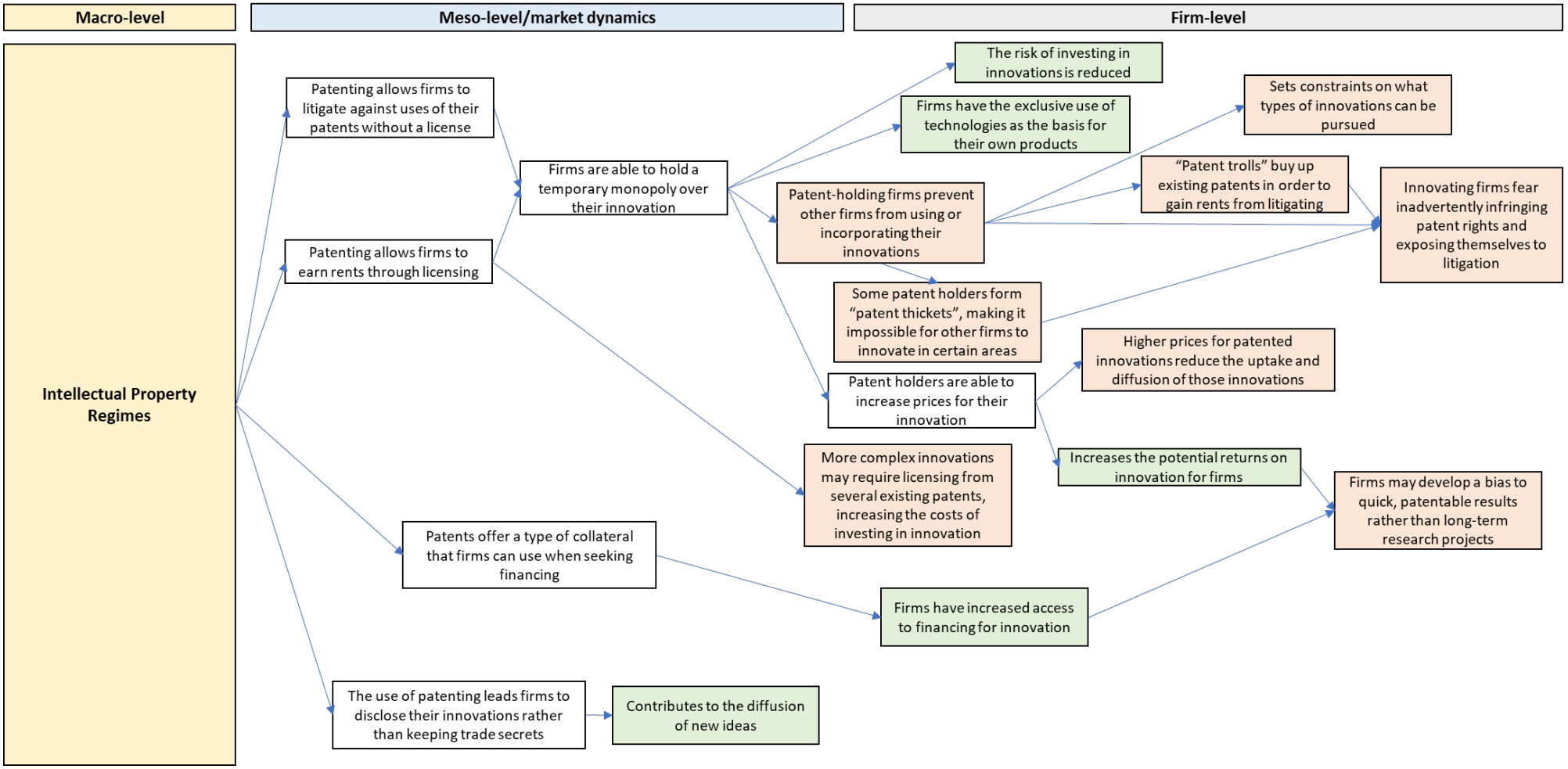
Although licensing existing patents may not prohibitively increase the costs of using individual patents, there is a risk that for more complex technologies that will rely on several existing patents, licensing costs may soon become prohibitive for potential innovators (Hall 2007).

Patenting may also contribute to innovation by leading firms to disclose their innovations rather than keeping trade secrets and therefore contributing to the diffusion of new ideas (Blind 2012). This is sometimes referred to as ‘follow-on innovation’ and there is variable evidence for its impact. Where firms not only disclose patents but also agree to license them, there is evidence that this can have a positive impact on innovation (Watzinger et al. 2017). Alternately, there is evidence that engineers in many fields do not read patents because there are too many and they cannot keep up, or in some instances they are actively discouraged from doing so to avoid legal liability. In addition to this, the quality of disclosure in many patents is poor (Lemley and Feldman 2016).

These mechanisms help to explain why in many industries, such as software development, other ways of protecting innovations (such as relying on trade secrecy, lead time advantages or seeking to earn profits from complementary products or services) are considered more effective (Bessen and Meurer 2008). Many of these mechanisms will also be influenced, however, on the details of a specific IPR regime, including how patents are granted, and how stringently patent rights are enforced (Hall 2007). This suggests there is room within existing IPR regimes to reduce the likelihood that some of the described negative mechanisms will be triggered.

Mechanisms identified have been synthesised in Figure 15.

Figure 15. Intellectual property rights regulation – mechanisms



Product quality and safety regulation

There is limited literature on quality and safety regulation and its influence on innovation, and many of the papers identified are dated. The literature tends to focus on the food or pharmaceutical sectors. There is a significant gap in the literature exploring the connection between quality and safety regulation and innovation in other sectors, such as the manufacturing industry.

Because it creates compliance requirements, quality and safety regulation causes firms to think in new and creative ways about their products, spurring either compliance innovation (i.e. occurs when the scope of the regulation is broad and the resulting innovations remain within the scope of the regulation) or circumventive innovation (i.e. occurs when the scope of the regulation is narrow and the resulting innovations allow firms to escape regulatory requirements). Where circumventive innovation is done as a way to exploit loopholes in the design, this may be a less desirable form of innovation.

One strand of the literature focuses on the impact of quality and safety regulation on compliance costs for firms. The theory is that quality and safety regulation creates compliance costs (for example, it requires testing that firms would not have undertaken in the absence of regulation), which means that either: firms spend money on compliance activities that they would otherwise have spent on R&D; or firms invest in R&D to find ways to comply with the quality and safety regulation at the expense of other, potentially more profitable R&D investments. The literature provides some empirical evidence on this: e.g. Henson and Caswell (1999) on food safety regulation, or Peltzman (1973), Grabowski et al. (1977, 1978) and Grennan and Town (2016) on drug quality and safety regulation. Studies by Grabowski and Vernon (1977) and Thomas (1990) show that quality and safety regulation in the pharmaceutical sector causes innovation to fall in smaller firms and to concentrate in larger, multinational firms (due to their better ability to deal with the compliance costs).

Some of the literature addresses the negative impact of compliance costs on innovation. For instance, Hauptman and Roberts (1987) observe that a specific quality and safety regulation in the biotechnology industry was initially followed by a reduction in innovation in the market. However, they state that after a couple of years, the trend was reversed, suggesting that firms were able to adapt their management processes to operate more effectively in the context of quality and safety regulation. In addition, Katz (2007) argues that compliance costs created by quality and safety regulation can have a positive effect on innovation. He posits that compliance costs vary depending on the quality of the products subject to regulation (e.g. it is less expensive to test and approve a product whose quality is apparent than a product which is of low-quality). Therefore, the costs of compliance associated with quality and safety regulation will primarily affect low-quality innovators, allowing high-quality innovators to prosper.

Quality and safety regulation can also impact on the level of risk and uncertainty perceived by firms (Stewart, 2010). First, firms may be uncertain as to whether their products will comply with quality and safety regulation. Second, firms may be

uncertain about the delay associated with quality and safety regulation (i.e. the time for the regulator to approve a product before it can be marketed). This, in turn, creates uncertainties about returns on investments, and creates disincentives for firms to innovate to develop new products. This is likely to be particularly the case for firms where innovation requires significant investment and longer timescales, such as pharmaceuticals, as opposed to areas such as software, where innovation is relatively cheap.

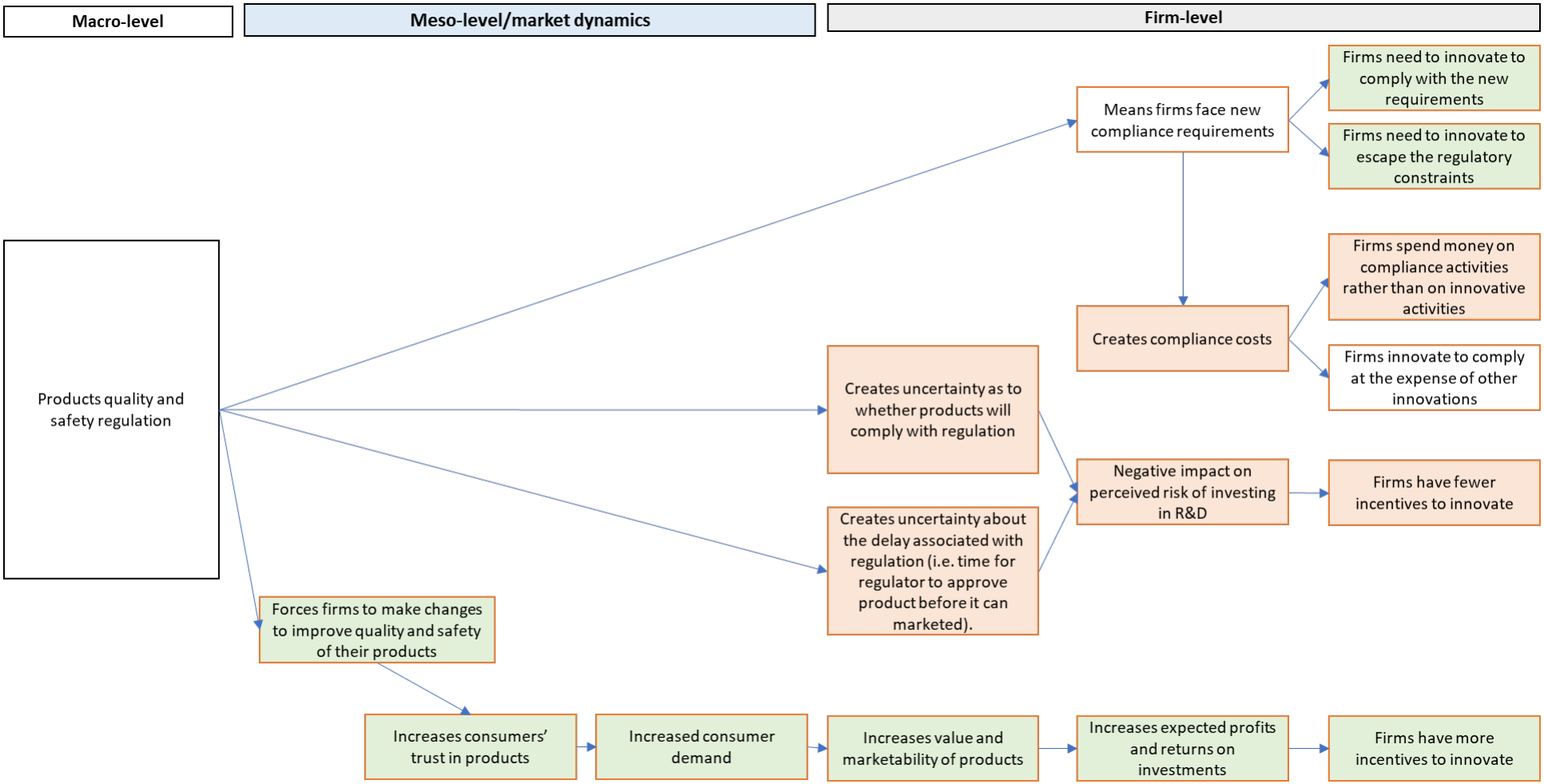
Another strand of the literature focuses on the impact of quality and safety regulation on information asymmetry within the market. There is a common concern that in unregulated markets a market failure prevails, where consumers do not have full information on the quality of the products they are buying, and firms take advantage of this by producing low-quality products (Akerlof, 1970). Quality and safety regulation sets requirement for firms to signal and commit to the quality of their products. This increases consumers' trust, and enables demand for complying products to grow, creating innovation incentives. Katz (2007) argues that in the US, forcing drug companies to conduct clinical trials and submit their results to independent expert scrutiny, the Food and Drugs Authority promotes more complete information in a market. Consumers therefore have the necessary assurance to trust the quality of drugs, and the value and marketability of drugs increase. This in turn increases firms' expected profits and returns on investment, thereby providing them more incentives to innovate. Munos (2009) adds that stringent quality and safety regulation of pharmaceuticals not only reduces the number of low-quality drugs in the domestic market, it also increases their value overseas as they gain widespread approval and market acceptance elsewhere. This further enhances market innovation within domestic pharmaceutical firms.

Katz (2007) argues that, if standards for compliance accurately reflect consumer demand, quality and safety regulation can also improve information on the producer side of the market. Higher compliance helps firms create innovative products which are of higher quality and therefore more likely to become a commercial success. This, in turn, reduces the number of low-quality inventions.

The literature also examines the impact of quality and safety regulation on information asymmetry based on whether the regulation is following a command-and-control or an incentive-based approach. For instance, Unnevehr and Jensen (1996) examine safety inspection regulation in the meat industry and conclude that, because the information asymmetry in the market makes it difficult for consumers to make an informed choice, the control-and-command regime is more efficient than the incentive-based regime.

Mechanisms identified have been synthesised in Figure 16.

Figure 16. Product quality and safety regulation – mechanisms



Environmental regulation

The literature on the impact of environmental regulation on innovation is extensive and stems largely from the field of environmental economics. A significant proportion of this literature centres on the Porter hypothesis. The Porter hypothesis, as developed by Porter and van der Linde (1995), puts forward the idea that environmental regulation leads to increased environmental innovation and this in turn leads to an increase in industry competitiveness and returns. A large body of literature has examined different aspects of this hypothesis, testing these in different sectors and scenarios. The majority of this literature does not examine the specific mechanisms through which environmental regulation influences innovation.

Literature on the impacts of environmental regulations tends to consider either command-and-control regulations or cap-and-trade approaches, which allocate emissions allowances to firms and let firms sell these allowances to one another. Some sources consider the differences between these two approaches, but a large proportion of the literature does not consider the specific type of regulation and instead considers “environmental regulation” more generally. The Porter hypothesis itself recommends regulation that is tech-neutral – or focussed on outcomes without stipulating the processes through which such outcomes should be achieved. As such, the mechanisms described in the literature are sometimes more general, and in some instances specific to a certain regulatory approach.

The general impacts of environmental regulation could take several forms. Environmental regulation may serve to signal resource inefficiencies and possible technological improvements to firms, simply by drawing their attention to poor performance in a specific area. For example, by drawing firm attention to the release of pollutants, this may highlight general inefficiencies leading to excess waste. In some instances, environmental regulation may also come with reporting or information gathering requirements (Porter and van der Linde 1995). In both instances, this signal may motivate firms to shift the focus of their innovation activities. Reporting requirements and other obligations set out by environmental regulations may also contribute to increasing the cost of compliance, which can lead firms to undertake innovation activities to reduce the costs of compliance. This general mechanism (that regulation increases the costs of compliance and innovations are undertaken to reduce these costs) is frequently tested in the literature, as regulatory burden is often measured via the proxy of compliance costs (see, for example, Lanjouw and Mody 1996, Jaffe and Palmer 1997). The Porter Hypothesis (Porter and van der Linde 1995) puts forward that the innovations undertaken to reduce compliance costs may in some instances generate other returns, by improving overall efficiency or leading to increased market demand.

A small amount of evidence, as described in Acar et al. (2019), also suggests that the output constraints created by regulation work to set design requirements which contribute to creativity by delineating search boundaries (Rosso 2014 in Acar et al. 2019), thereby defining outcomes and requiring firms to develop approaches to achieve these outcomes. In some cases, this leads individuals involved in development to go beyond the most obvious solutions (Moreau & Dahl 2005 in Acar et al. 2019). In other words, regulation sets certain boundaries within which firms can operate, and to some extent these limitations help set the focus and fuel creativity. However, Acar et al. (2019) find that the relationship between requirements, creativity

and innovation is an inverted-U shape, where beyond a certain point, requirements will again begin to limit innovation by being too prescriptive.

Environmental regulations may also have impacts beyond the direct cost of compliance, in many cases through impacts on meso-level factors. Some types of environmental regulation that penalise poor performance may lead to the costs of current products and services increasing, altering the relative costs and benefits of competing technologies (Hepburn et al. 2018). Regulations may also increase the costs of certain factors or inputs (such as energy), and this may have a similar effect, leading firms to increase exploration activities to seek alternatives (Hoppmann et al. 2013). Changes in the costs of current products and services and changes in the costs of input factors may also lead to changes in consumer demand (for example, an increase in the price of oil may lead to higher consumer demand for more fuel-efficient vehicles, see Crabb & Johnson 2010). Environmental regulations that target the users of a technology may also contribute to the creation of an entirely new market or market growth for an existing technology. For example, various deployment policies in the solar photovoltaic industry have led to a significant increase in the market for these products (Hoppmann et al. 2013). This can impact innovation in a variety of ways. It could lead firms to increase investment in lower impact or alternative technologies. For technologies that are already established, this may mean they become more profitable and rather than investing in further explorational R&D, firms will instead focus on incremental and process innovations to maximise their increased profit. For smaller firms, a sudden increase in market demand may also create challenges, as they find it difficult to increase their production in the short term to the extent required (Hoppmann et al. 2013).

For the most part, the above mechanisms rely on an assumption that firms are profit-maximising. However, as noted by Ambec et al. (2013) in a review of literature on the Porter hypothesis, the rationality of a firm is driven by managers who have their own motivations and biases. To some extent, this rationality is informed by the technological framework in question, or the basic or dominant design that becomes a reference point within the industry. In other words, most innovation is bounded by firms' and engineers' understanding of what a product should be and what the market expects. This framework leads firms to focus on certain improvements while ignoring others, frequently without specific regard for cost or demand conditions (Kemp et al. 1998; also Gunningham et al. 2003).

Regulation may also help to reduce the perceived uncertainty or risk associated with certain types of innovation, or imply that such innovation will be reputationally beneficial, rather than influencing innovation through its impact on compliance costs or markets alone. The extent to which regulation will have an impact will vary greatly between industries and types of firms. For instance, Berrone et al. (2013) found that more stringent regulation appeared to have a greater positive impact on firms that reported more environmental damage (and who presumably would be more severely impacted by the regulations) and on firms with more specific assets (such as expensive and particular machinery that would be difficult to sell off).

Some specific mechanisms have been examined for cap-and-trade approaches[10] to environmental regulation. Cap-and-trade approaches offer both financial

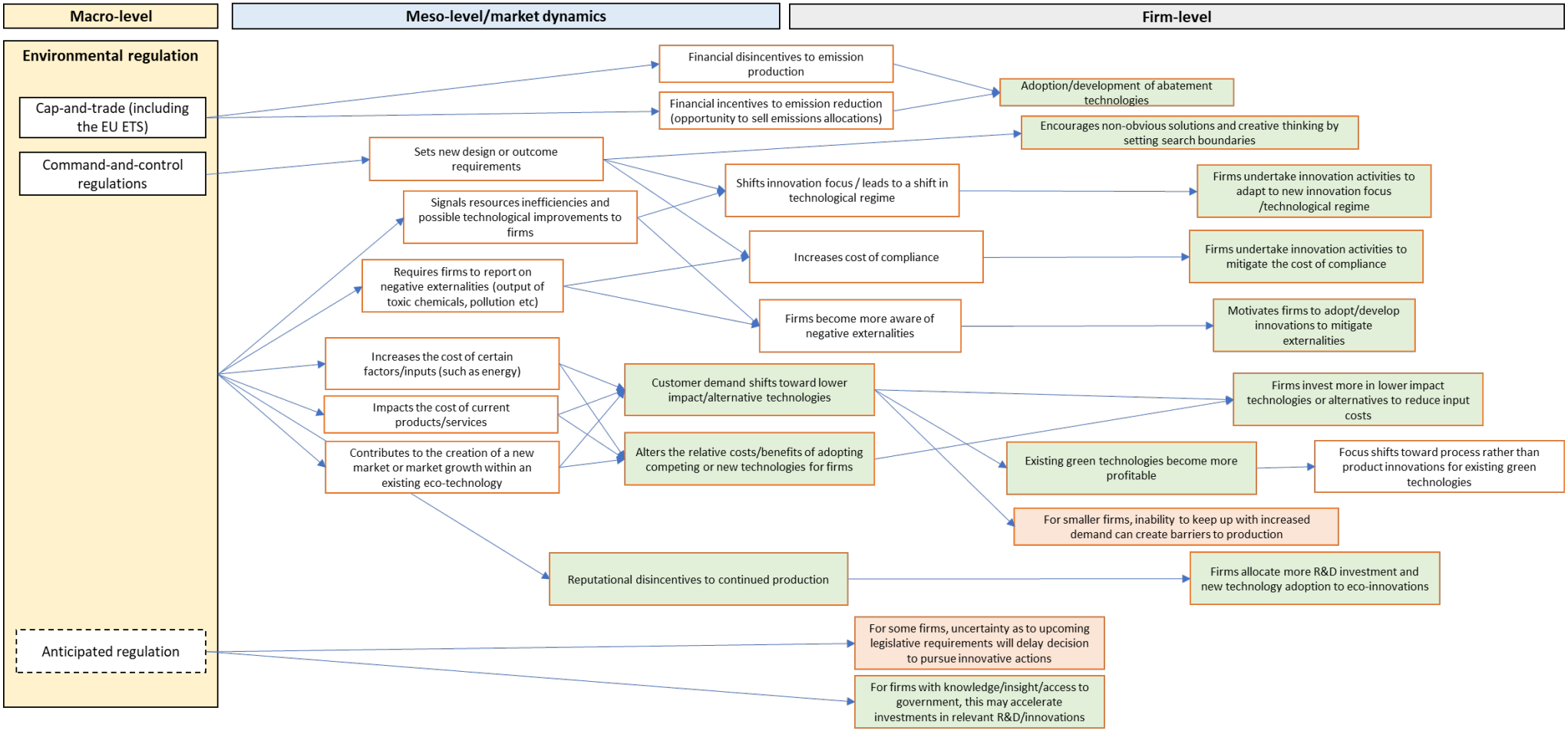
[10] Cap-and-trade approaches cap or limit the emissions a firm can produce and tax firms that exceed those limits. Firms that do not exceed their allowed limit are able to sell those allowances to other firms.

disincentives to emission production, as exceeding limits means purchasing from elsewhere or facing financial penalties, and financial incentives for emission reduction, as there is an opportunity to sell emissions allocations. This in turn leads to an increase in the adoption and development of technologies that reduce emissions, but can also risk overly favouring one type of technology (such as CO2 abatement technology) while disregarding others (such as alternative energy conserving methods like co-generation) (Borghesi et al. 2015).

Lastly, Ashford and Heaton (1983) point to the impact that the anticipation of environmental regulation could have on firms' decisions to innovate. Anticipated regulation may be subject to uncertainties, so some firms may react to uncertainty by delaying decisions to pursue innovative activities for as long as possible. Other firms, however, and especially those with greater knowledge, insight or access to decision-makers, may act to spur innovation, seeking to pre-empt regulatory requirements and capitalise on gaining a head-start to compliance. This effect has also been identified elsewhere in the literature (see, for example, Taylor et al. 2005).

Mechanisms identified have been synthesised in Figure 17.

Figure 17. Environmental regulation – mechanisms



Worker health and safety regulation

As noted by Blind (2016), the relationship between worker health and safety regulations and innovation has not been extensively reviewed in the literature. However, a small number of examples highlight specific mechanisms through which worker health and safety regulations may impact innovation.

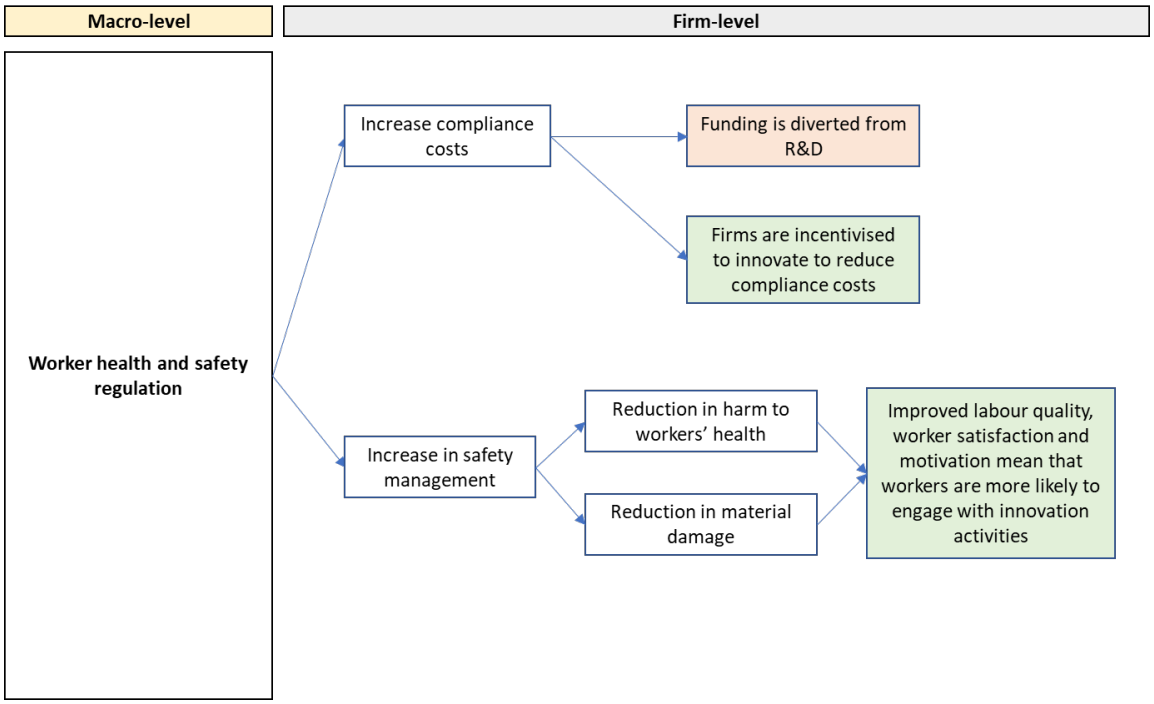
Firstly, as put forward by Blind (2016) and mentioned by Ashford (1997), traditional views of the impact of regulation on innovation would suggest that worker health and safety regulations lead to increased compliance costs, diverting funding from R&D and therefore reducing innovation. Ashford (1997), however, also theorises that the Porter hypothesis (see the previous section on environmental regulation) may equally apply to worker health and safety regulation: by placing design restrictions, such regulations contribute to innovation and lead to social benefit.

These impacts may differ between firms, however, and some evidence suggests that for highly innovative firms, complying with health and safety regulation may pose additional barriers. Veltri et al. (2007) provide evidence that highly innovative firms are likely to have a harder time integrating appropriate safety procedures within a manufacturing environment, as innovations lead to regular changes within the manufacturing environment and safety procedures may not be able to keep pace. This observation has led to the argument that liberalising product market regulation may lead to higher innovation among leading businesses, however that is not supported by evidence (Amable et al. 2016).

Secondly, worker health and safety regulations may lead to improved innovation outcomes by improving the quality of the workforce. Fernández-Muñiz et al. (2009) suggests that an increase in safety management leads to a reduction in both harm to workers' health and material damage, which in turn leads to improved labour quality and worker satisfaction and motivation. This is similar to mechanisms put forward under labour market regulation (see the section on labour market regulation), which indicate that workers that feel better protected are more likely to engage in innovative activities.

Mechanisms identified have been synthesised in Figure 18.

Figure 18. Worker health and safety regulation – mechanisms



Data protection regulation

Data protection regulation sets for businesses requirements to ensure the data they hold is sufficiently protected. Data protection laws and regulations are not new per se. But, as the collection and processing of data becomes a fundamental aspect of innovation in most sectors of the economy, the effects of data protection regulations on innovation become less straightforward. As new digital products and services are introduced on the market, and in sectors previously not associated with the digital economy, more and more data are being collected, communicated, stored, processed and acted upon.

The literature and ongoing scholarly debate about data protection and privacy regulations argues that they may be acting as a barrier to innovation.

An occurring debate is about the ability of firms – and particularly SMEs – to implement "informed consent" policies or to adhere to the principles of "data protection by design and by default" (GDPR) in their development of new products and services (Brass et al, 2019). For example, digital innovators might have greater exposure to liability claims (e.g. see the EC Liability for Emerging Digital Technologies proposal https://ec.europa.eu/digital-single-market/en/news/european-commission-staff-working-document-liability-emerging-digital-technologies). In addition, they might also find it difficult to transfer some business risk through purchasing insurance policies and adopting comprehensive risk management strategies within their organisations, resulting in a diminished incentive to innovate.

Changing regulatory frameworks to strengthen the enforcement of data protection regulation means introducing fines and requiring firms to conduct Data Protection Impact Assessments, which create high compliance costs. This might negatively impact on firms' willingness and ability to invest in innovation. In addition, there

currently are no clear guidelines on how to conduct these impact assessments, which increases uncertainty for innovators using or producing new digital technologies and services. This further reduces their incentive to innovate.

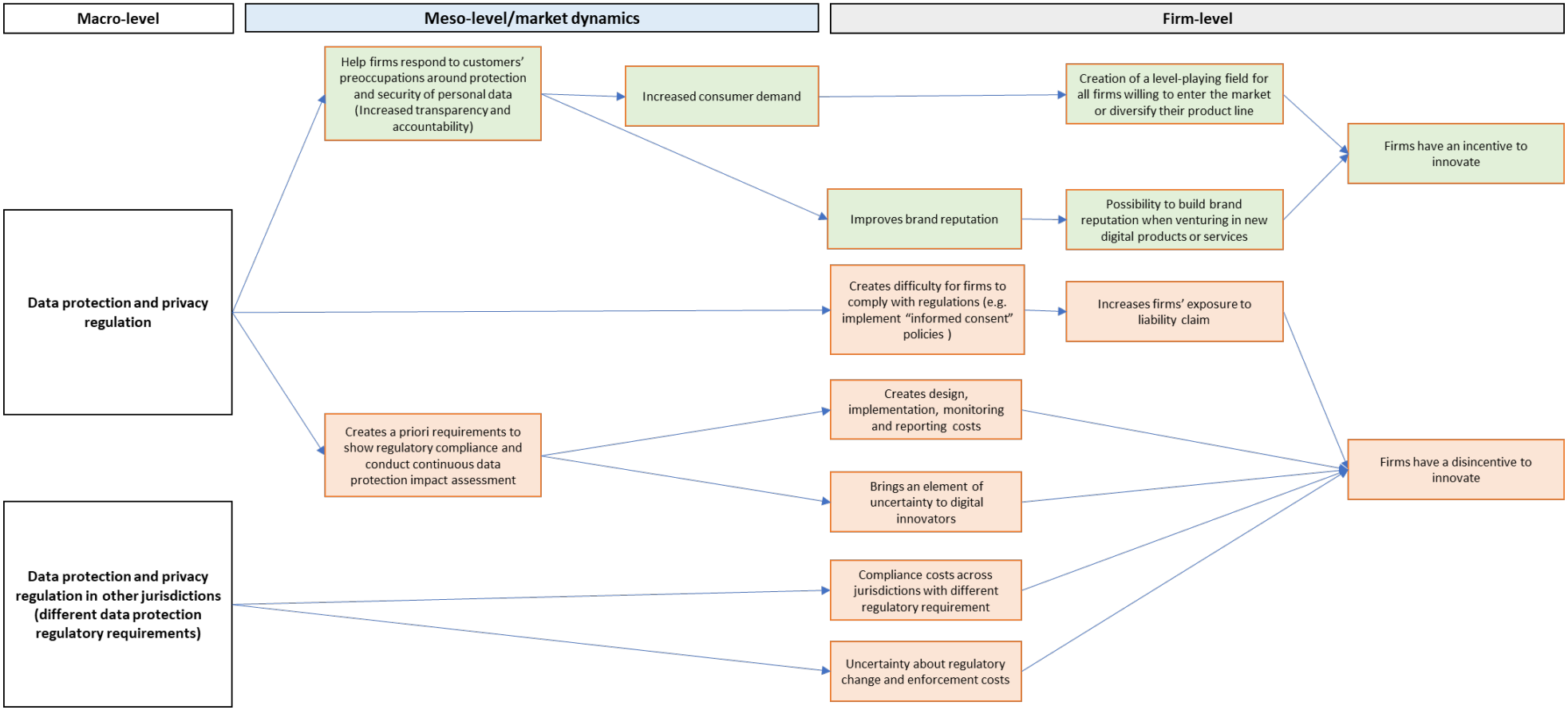
Another way through which data protection regulation can affect innovation by creating uncertainty is linked to the fact that data protection regulations are not aligned at the global level. Most data flows across several jurisdictions, each with their own data protection regulatory requirements. This adds to the uncertainty and compliance costs faced by businesses willing to innovate in or through the use of digital technologies and services.

It has also been argued that data protection and privacy regulations facilitate innovation, inasmuch as they create a level-playing field for all firms willing to enter the market or diversify their product line. In addition, clear adherence to the principles and best practices established in data protection and e-privacy laws and regulations contribute to building brand reputation, which is important to showcase if firms venture in new digital products or services. Some argue that strong privacy laws might lead to increased transparency and better communication between businesses and consumers. This in turn, could make consumers more readily willing to give up their data and trust responsibly innovative products and services.[11]

Mechanisms identified have been synthesised in Figure 19.

[11] https://www.consumersinternational.org/news-resources/news/releases/consumers-international-launches-trust-by-design-guidelines-for-consumer-iot/

Figure 19. Data protection regulation – mechanisms



Information security regulation

Information security regulations can enhance privacy as a fundamental right. In a digitised world, regulations that ensure a baseline of responsible cybersecurity/ information security are increasingly relevant and are emerging in parallel to data protection regulations. While there are some overlaps between information security and data protection laws, the two are complementary interventions seen as supplementing existing consumer protection laws that have traditionally focused on physical safety and security. Information security regulation specifically aims to encourage private and public organisations to maintain a reasonable level of security in their practices (e.g. protection of customer information, protection of manufacturing processes and digital services from cybercrime).

The regulation of security has been largely framed in terms of physical security and, subsequently, features predominantly in product safety regulations or in national security strategies and the security of critical national infrastructures facilitating the delivery of essential services. However, innovation in connected products and digital services, including the digitisation of critical infrastructures and services (e.g. transport, healthcare, financial services) has raised awareness about another dimension of security that had largely evaded the realm of mandatory regulatory frameworks – i.e. information security or cybersecurity.

The growth of e-commerce and the rapid uptake of connected devices in everyday lives rely on the secure collection, communication, storage and processing of data. Responsible information security underpins data protection and privacy (e.g. smart watches that collect health data) and also contribute to the resilience of critical cyber-physical systems and their associated services (e.g. the WannaCry ransomware attack cost the NHS £92 million).

Regulating information and network security is an emerging legislative and regulatory domain. Thus, the impact of cybersecurity / information and network security regulation on innovation has not been documented extensively (Nelson and Madnick, 2017; Thaw, 2013). Much of the research on information security has been technical, originating from computer science, safety and systems engineering. Recently, more socio-technical research is emerging on the economics of information security (Anderson and Moore, 2006), the integrated management of cybersecurity at firm level (Higgs et al., 2016), the implications of different self-regulatory mechanisms on cybersecurity (Brass et al., 2017b, 2017a; Leverett et al., n.d.) and the wider implications for the coordinated development of privacy and cybersecurity policy (Maple, 2017). This research finds that the rise of the Internet of Things, machine learning and autonomous cyber-physical systems expands the threat and vulnerability landscape for private and public entities, exposing them to new risks. It shows also that cybersecurity is becoming a crucial corporate consideration for businesses independently of their size: no longer simply an ‘IT problem’. Moreover, this research shows that cybersecurity regulations and policies are emerging within different application domains or sectors, which do not always correspond with the reality of business developments that currently develop products and services in a cross-sectoral and cross-technological manner.

As several governments start developing information security policies targeting emerging digital technologies, it is clear that a more systematic discussion about the

effects of cybersecurity regulations on innovation is needed. For instance, the UK Government has conducted a Cyber Security Regulation and Incentives Review, which informed its latest Secure by Design Code of Practice for Consumer IoT. In addition, the European Union adopted the Network and Information Security Directive (NIS), which specifies security requirements for operators of essential services. Also, the recently agreed EU Cybersecurity Act is proposing the establishment of an EU-wide cybersecurity certification scheme (currently voluntary, but possibly mandatory in the future).

Several mechanisms by which cybersecurity impacts on innovation have been identified. Potential negative effects of cybersecurity regulation on innovation include:

- Pricing cybersecurity. A recent study conducted by the BSI in collaboration with the PETRAS IoT Hub has found that several small and medium size firms interested in digital innovation find it difficult to recover the costs of integrating responsible cybersecurity in their new products and services. The report found "no clear positive externality resulting from Internet of Things businesses absorbing these costs, nor signs of consumer willingness to pay more for a secure IoT product and service" (Brass et al., 2019). These increased costs make it more difficult for firms to invest in innovation.

- Security and interoperability. Brass et al. (2019) also found that small & medium size businesses interested in digital innovation struggle to fully understand and balance the incentives associated with investment in secure products/ services versus offering interoperability with existing ecosystems (e.g. home management systems). Smart devices are not used in isolation, they are often connected to ecosystems made up of other smart devices, which provide increased functionality (e.g. smart energy management system in the home). However, a single point of vulnerability (i.e. low security) in this ecosystem can lead to compromising other devices, even if businesses try to achieve a high degree of cybersecurity for these devices at the point of purchase. This shows that cybersecurity – as opposed to safety – is a lot more difficult to ensure once a device is set up in a particular ecosystem, potentially increasing the post-marketing and cybersecurity compliance costs for SMEs.

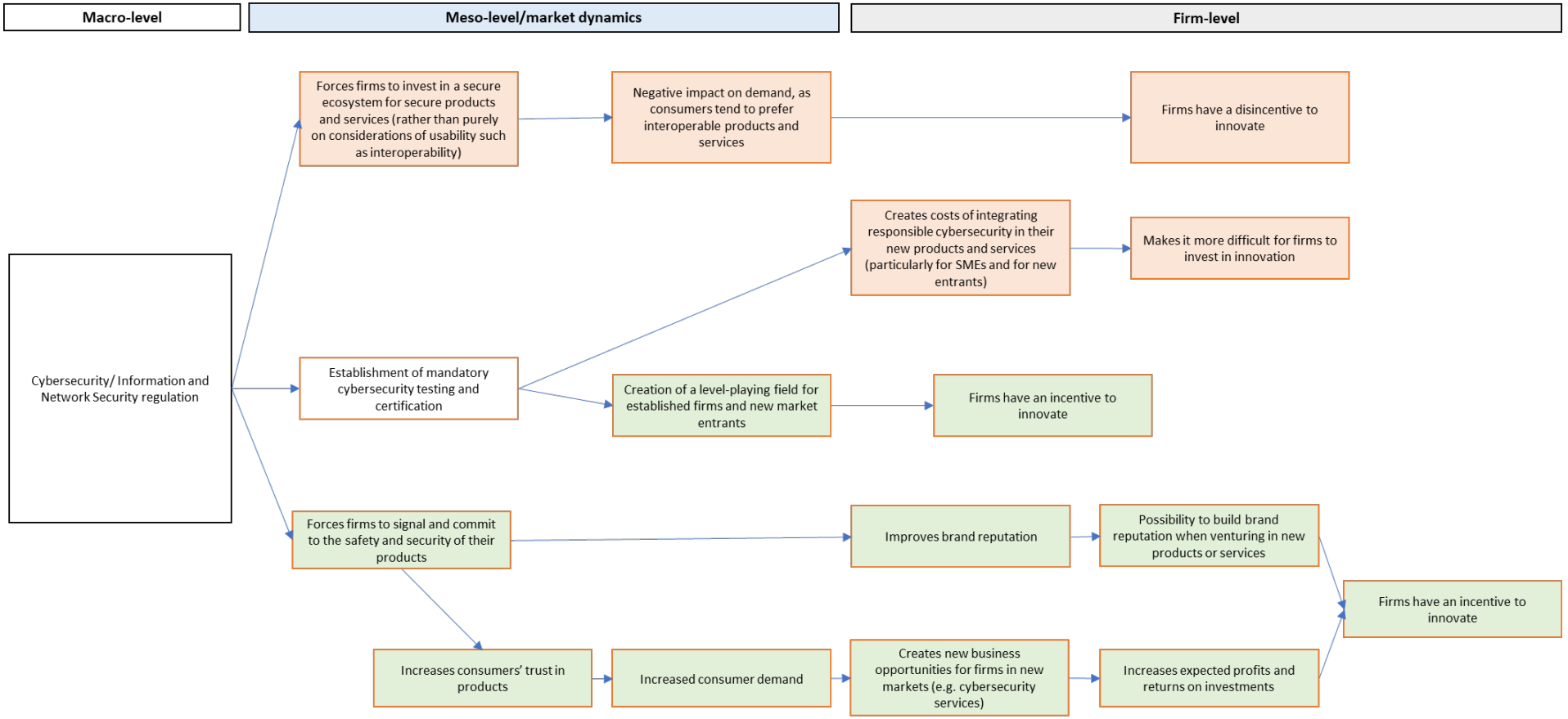
The positive effects of cybersecurity regulation on innovation are similar to those seen in the discussion about product safety and data protection regulations:

- Cybersecurity regulations and the establishment of mandatory cybersecurity certification schemes will create a level-playing field for established firms and new market entrants (although the costs of undergoing testing and certification will be felt differently by these two, which begs the question of regulatory incentives for SMEs to adopt high cybersecurity practices).

- As in the case of safety regulations, cybersecurity regulations create new markets for responsible security and safety (Giovanni and Silva, 2018; Lewis, 2009), forwarding innovation in this domain, creating business opportunities for firms in new markets (e.g. cybersecurity services) and making cybersecurity more affordable in the long term.

Mechanisms identified have been synthesised in Figure 20.

Figure 20. Information security regulation – mechanisms



Case studies

This section presents four case studies that have been completed to illustrate the mechanisms through which regulation impacts on innovation, where those mechanisms have already been theorised elsewhere. The case studies also provide the opportunity to identify that which may not have been already theorised in the literature.

Case study selection and methodology

Four case studies were chosen based on the four Grand Challenges identified in the Industrial Strategy. The cases therefore cover key areas where innovation is needed, and which should be the target of government and commercial support.

The cases were also chosen to cover differing types of innovation, both incremental and radical, and vastly different sectors, characterised by a mix of smaller and larger firms. Details of the cases chosen, including their relevance to the Grand Challenges, is shown in Table 2.

Each case study has involved desk research, used to gain an initial understanding of the sector studied, the key actors and what regulations were most important to the sector. Literature sources used ranged from academic papers, government publications and reports to legal documents. Interviews conducted for each study are detailed in Table 2.

Table 2. Summary of cases

Case study	Grand Challenge	Interviews
Connected and Autonomous Vehicles (CAVs)	Future of mobility	Four: three members of the CAVs industry (two individuals involved in manufacturing and one industry representative) and one regulator
Automated recruitment	Artificial Intelligence & Data	Three: three members of the industry: two individuals involved in developing automated recruitment technologies and one industry representative
Home heating and boilers	Clean growth	Three: two members of the industry (one individual involved in manufacturing and one industry representative) and one regulator
Personalised e-health	Ageing society	Four: four members of the personalised e-health sector

Each case study has been primarily informed by these interviews. Each interview lasted around 30-40 minutes. The final write-up synthesises and presents the findings on the research question, triangulating information from the desk research and the interviews. It should be highlighted that, because of the nature of these case studies and the scope of the data collection effort, they identify processes and impacts but do not establish the relative importance or strength of these processes and impacts. To do so would require follow up research to extend the evidence base and test the validity of the information with a larger population of stakeholders.

Case study 1 – Connected and Autonomous Vehicles (CAVs)

This section presents the case study on Connected Autonomous Vehicles (CAVs).

A brief introduction to CAVs

Connected and Autonomous Vehicles (CAVs), often referred to colloquially as “self-driving cars”, “driverless cars” or “autonomous vehicles”, are an example of a radical, disruptive innovation and of cross-sectoral innovation. Many of the component technologies involved are already in use in the automotive sector. For example, “connected vehicle” technology relates to the communications and data systems already in place in many new vehicles (Anderson et al. 2014). The degree of automation is described within the industry in terms of levels (SAE 2014). Some types of automation, such as cruise control and park assist technology (considered Level 1 automation), have already become commonplace in newer vehicles. Some examples of more complete (Level 2) automation, where system automation takes full control of the vehicle but requires the driver to remain fully alert and ready to take control, have also entered the market. However, fully connected, automated vehicles (Level 3 and above) are still being trialled on a relatively small scale and are not yet considered to be ready for deployment.

Although CAVs are expected to enhance road safety, since most crashes involve human error (OECD, 2015), highly publicised accidents and fatalities involving automated vehicles have led to public concerns around the safety of fully automated vehicles being deployed more widely (see, for example: Krishner & Lowy 2016, Pearl 2017).

The Government’s Industrial Strategy refers to CAVs as an opportunity for the UK to become a world leader in shaping the future of mobility and has set a goal of having fully self-driving cars on UK roads by 2021 (HM Government 2017).

In this framework, the UK Government has supported the trials of automated vehicles through both policy and regulation.

The impact of regulation on the development of CAVs

Interviewees (both regulators and industry) appear to view the development of the technology in terms of what has occurred during the trial phase, and what needs to occur for the deployment phase.

During the trial phase up to this point, interviewees indicated that regulation in the UK has posed few barriers to innovation, in part because the scale of regulatory issues associated with trialling is quite small, and in part because the approach to trialling taken by regulators in the UK has been accommodating, encouraging and proactive. For example, the Department for Transport (DfT) undertook its own review of the legal and regulatory framework for autonomous vehicles in the UK and found that there were no obstacles to testing AVs on public roads (DfT, 2015). In 2015, the Centre for Connected and Autonomous Vehicles was established as a joint unit between BEIS and DfT, intended to work alongside a variety of stakeholders in industry and to directly take forward regulatory reform (CCAV, 2019b). This includes the development of the Automated and Electric Vehicles Act 2018 (HM Government 2018), which ensures clarity in how liability for users and insurers should operate in the case of automation.

Commenting on the regulatory approach that had been used thus far, the regulator interviewed pointed out the importance of using alternatives to statutory regulation at this stage. There is an understanding that when deployment occurs, there will be a need to implement statutory regulations, but at the testing stage, as both industry and the regulator are learning about the technology, it is helpful to take a more flexible approach. This relates to one of the barriers noted in the framework in relation to health and safety regulation: that highly innovative firms may struggle more to comply due to the constant changes in their technology. This was also cited in interviews with the industry, and the use of a Code of Practice (DfT 2015, CCAV 2019a) rather than legislation has been seen to have contributed to a range of different types of technologies and innovations being tested.

Industry members interviewed also pointed to the importance of policy's role in supporting innovation alongside regulation.

The biggest regulatory challenge to innovation as seen by interviewees has therefore not been within the trial phase itself, but rather in understanding what the pathway from trialling the technology to deployment will entail. From a regulatory perspective, there are still several uncertainties and concerns around deployment which have contributed to shaping the direction and pace of innovation. This relates to many of the findings in the literature review across different types of regulations, which show that uncertainty caused by regulations tends to have a negative impact on the **incentives** for innovation. Resolving these regulatory and legal uncertainties may not merely be a matter for regulators, however: one manufacturer interviewed mentioned that there is a sense that many of the issues in the move from small-scale to large-scale will be decided by the courts rather than by regulation.

Impacts of uncertainties

Interviewees reported that uncertainties caused by a lack of regulatory framework have had several impacts within the sector. There was a sense among industry interviewees that no matter how good regulation is at the testing level, if regulation does not eventually let them in the market, innovation is irrelevant. The impact of uncertainty is exacerbated by the fact that investments within the industry are very expensive, and if there is not clear understanding of whether or how the market will grow, such investments are harder to justify. This alters the **incentives** for innovation.

This has also meant that, according to stakeholders interviewed, it is harder to gain financing and many of the Original Equipment Manufacturers (OEMs) are not as enthusiastic about investments in CAVs as they were initially. This reflects the mechanisms identified across regulatory types indicating how uncertainty impacts the level of investment in new technologies through **capital/capacity**.

According to one industry interviewee, the uncertainty in the sector has also had labour implications. As an emerging sector, innovation is highly dependent on individual expertise, and these experts tend to be quite expensive. Such experts are difficult to keep long-term when there is uncertainty in the market, leading to a loss of expertise and continuity.

in other words, this case study shows how regulatory uncertainty may negatively impact on innovation through mechanisms linked to **financial and human capital.**

International regulatory framework and innovation

Many of the actors involved in the development of CAVs tend to be large, multi-national firms. Because of this, their understanding of regulation and regulatory challenges is much broader than the UK context. One industry interviewee mentioned that for such firms, there is a tendency to place different research entities where they feel there is most likely to be an issue (i.e. where regulation is the most advanced and restrictive). For example, one manufacturer has put its cybersecurity research team in the United States and has placed researchers looking at how to deal with personally identifiable information in Germany.

In terms of safety regulation, this also means that many manufacturers will rely on international standards (such as ISO 26262) rather than specific national regulations. These international standards are generally designed as a superset of national regulations, bringing together existing standards in different national markets. This is also seen as more desirable for the industry, as car manufacturers tend to be international and sell their products in many different markets, and a harmonised standard facilitates this. In this sense, one industry stakeholder noted that the lack of additional UK requirements in terms of safety regulations has facilitated innovation. The harmonisation and standardisation of regulations seems key to encouraging innovation in industries that rely on international trade. The role of trade in relation to regulation was not, however, identified in any of the mechanisms in the literature review.

Although working to such international standards was considered to be important for marketability, one industry interviewee did suggest that safety standards have caused the industry to overengineer their safety concepts. If such standards were not required, there would be opportunities to simplify the products and thereby to also significantly reduce costs. This relates to mechanisms around **compliance costs** and the hypothesis that liberalising safety regulation would foster innovation and growth. However, testing of this hypothesis in the literature (see Amable et al. 2016) has not led to any supporting evidence.

Smaller players, cross-sectoral innovation and contradictions

According to one industry interviewee, although there are some small and niche players who provide key products, such firms generally struggle to keep up with regulatory requirements. Otherwise, there was not a sense among interviewees that regulations have posed particular barriers to smaller firms up to this point.

Some industry interviewees did indicate that cross-sectoral innovation has been hampered by aspects of regulation. One issue relates to liability, and concerns among the sector around where responsibility lies: who is liable and to what extent in the case of failure. A lack of clarity on this and on liability in general has been an issue for some firms, and they have responded by investing significantly in legal teams, as well as consulting with insurance companies and academics to determine how these issues might impact development. In other words, uncertainty here has meant an increase in **compliance costs**. However, these issues have been largely addressed by fit-for-purpose liability regulations brought out in 2018 through the Automated and Electric Vehicles Act 2018 (HM Government 2018).

Data protection regulation was also cited as a potential barrier to cross-sector innovation. One industry interviewee explained that in many instances, useful data to drive innovation has been kept in silos by certain companies or within certain sectors. This has been caused in part by a belief that holding onto the data gives firms a competitive edge and can create value, but also because concerns around sharing data and data protection regulation have made legal teams overly cautious about agreeing to any type of data sharing. In other words, this suggests that data protection regulation might have impacted negatively on innovation by altering **market conditions** on the level of knowledge available to operators and their ability to exchange and thus innovate.

Cross-sectoral innovation may also be impacted by competition law and the approach taken by competition authorities. One industry interviewee cited past experience of the Competition Markets Authority (CMA) interpreting collaboration between manufacturers in the sector as collusion, and this leading manufacturers to approach collaborative work more cautiously. This suggests that competition law and the manner it has been implemented/enforced may therefore also contribute to altering **market conditions** negatively and thus discourage innovation.

The regulator interviewed indicated that there may be some cross-sectoral challenges caused by regulations stemming from the fact that different sectors know their own regulatory framework very well and may find it difficult to think outside of that. For example, safety regulations within the automotive industry generally require extensive testing before a product is put to market, while in digital sectors regulation plays a very different role.

This may help to explain the divergent responses received from interviewees on the issue of data protection regulation. Two industry interviewees indicated that there was a potential contradiction between data protection regulation and safety regulations, in that the provision of certain safety features relies on the availability of what could be considered personal data. An example of this might be that to avoid an object around the corner, you need to know where a person is and how that vehicle interacts with the driver. In the trial phase, this has not been a significant concern, as the limited scope meant that it was easy to justify why data protection regulations did not apply, but this will have an impact in the longer term. The other industry interviewee did not consider this to be a conflict, but did suggest that there was a chance future conflicts might arise. One interviewee was aware of work being done to develop an end-user privacy model that would essentially solve data protection and management concerns for connected services. This suggests that to some extent this apparent conflict, or the fear of a future conflict, is leading to the development of specific new innovations.

The IP regime

CAVs provide an interesting case study for the IP regime as the cross-sectoral nature of the innovation means that both traditional manufacturing and digital sectors are involved. Industry interviewees expressed a range of views on the IP regime. For one, the overall impact of the IP regime on innovation was seen to be neutral: sometimes the IP regime helps and sometimes it hinders innovation. For another, patenting was rarely used at this phase and there was a much greater reliance on trade secrets. Looking into the future, however, this interviewee also noted that patenting could become a problem, as too many patents within the industry might lead to what is referred to in the industry as patent thickets, where the sheer volume of patents makes it difficult for innovators to develop new products that do not infringe on at least one pre-existing patent. This was also explored within the mechanisms identified in the literature review and is an example of how **market conditions** can impact innovation.

Another industry interviewee stated that the IP regime in the UK was largely positive for innovation, and that most innovators within the automotive sector make use of patents. There were, however, challenges to patenting outside the UK. While the UK was felt to have strong institutions for holding up IP law, the multinational nature of the automotive business means that the comparatively weak institutions in other countries can lead to problems. The same interviewee also noted that as automation progresses and the sector becomes increasingly digital, the approach to intellectual property will likely become less focused on patents and copyrights and more collaborative, as it has in other digital industries.

Summary & conclusions

As an emerging technology, CAVs face a great deal of regulatory uncertainty, which appears to have some negative impacts on innovation. This reflects many of the mechanisms identified in the literature, including mechanisms related to incentives, capital and capacity, compliance costs and market conditions. For example, Stewart (2010) finds that the uncertainty around whether products will comply with quality and safety regulation and the uncertainty around any potential delays this may cause in turn creates uncertainties about the return on investments, and therefore creates disincentives for firms to innovate. The literature also notes that this impact is particularly important within sectors that require significant upfront financial investments. This mechanism was described in some form by all industry interviewees, although the uncertainty in this case seems to extend beyond quality and safety regulation, and also includes questions around liability and insurance, data protection, road traffic regulations and many others.

Mechanisms identified around the IP regime were largely in line with what was identified within the literature, showing that a range of both positive and negative mechanisms exist, and that the use of IP appears to depend largely on the sector.

New mechanisms were identified relating to the cross-sectoral nature of the industry, whereby fear or misunderstandings of certain types of regulations, including competition law and data protection regulation, reduced the sector's appetite for sharing and collaborating with other firms and across sectors. Such mechanisms relate to the **market conditions** that support innovation.

Overall, interviewees seemed to consider the future of regulation extremely important to the sector, but did not seem to feel that regulation had overly directed innovation in one way or another. One industry interviewee went so far as to refer to the impact of regulation as “neutral”, although this seemed to contradict many of the apparent impacts discussed above. From the perspective of stakeholders, policy more generally and the availability of funding in the sector seemed to play a greater role. Although the availability of funding may be related to regulation, as evidenced by many of the findings in the literature on economic regulation, these effects tend to be more indirect and as such were not cited by interviewees.

Case study 2 – Automated recruitment

This case study focuses on the development of automated recruitment technologies in the UK.

A brief introduction to automated recruitment

Automated recruitment refers to a diverse range of technologies, where AI and machine learning have been used to improve the speed, accuracy and quality of hiring decisions at different points in the process. Because different industries have different hiring needs and look for different qualities in recruitment, machine learning technologies designed to assist recruitment differ in their scope and purpose.

According to the Recruitment & Employment Confederation (REC), the majority of recruiters within the UK (70%) are in favour of embracing AI and other technological developments in the industry (REC, 2018). In practice, this means that many larger, established firms are automating parts of their processes and investing in machine learning technologies, but recruitment is also a space where there have been a recent proliferation of mobile apps and start-up technologies led by small businesses.

In the UK, innovation in recruitment has been driven in part by lower unemployment rates and increased competition among businesses for staff (KPMG & REC, 2019), as well as an understanding that the recruitment sector needs to stay relevant in a rapidly evolving labour market. The use of AI and machine learning is seen as a way to reduce time and cost to hire, improve the quality of hire and contribute positively to reducing hiring bias and improving workplace diversity (Bogen & Rieke, 2018).

Despite the hope that automated recruiting technologies could help to reduce bias, there are also fears that machine learning technologies may learn systematic bias and that there is a lack of transparency around many of the algorithms in practice. This was highlighted by the highly-publicised experience Amazon had with their trial of automated recruiting technology, which developed a systematic bias against female candidates based on the profiles of previous hires. This programme was ultimately scrapped by Amazon, but it raised serious questions about the extent to which machine learning may exacerbate human biases and whether algorithms can be made transparent and held liable (Dastin, 2018).

This case study provides examples of how **data protection** and **labour protection regulations** may impact on innovation.

The impact of regulation on the development of automated recruitment

Data protection regulation

The EU's General Data Protection Regulation (GDPR) was mentioned by all interviewees as key to development in the automated recruitment sector, although in different capacities. All interviewees agreed that the intention behind GDPR was necessary to prevent bad actors from misusing personal data and create an environment of trust, and that this would encourage innovation in the long term. However, in the short term, there was a sense that the implementation of the regulations has hampered innovation by contributing excessively to **compliance costs**. The role that regulation could play in encouraging innovation by helping to establish public trust is similar to the mechanism discussed in the literature in relation to liability law: that liability law may increase consumer confidence and willingness to purchase innovative products, therefore leading to a more certain market for innovators. In that regard, it could contribute to **market conditions** favourable to innovation.

For approaches to automated recruitment that rely on personal data, keeping this data over a longer period of time contributes to developing better, more accurate models. One interviewee noted that GDPR's implications for data retention make this difficult, and that their evidence base had become less robust since becoming GDPR compliant. This interpretation of GDPR's impact suggests that it has created **disincentives** for innovation while also affecting **capacity** at those businesses. This interviewee also noted, however, that larger competitors faced these same challenges with data retention, and that although it had hampered innovation, GDPR had also helped to level the playing field, thus affecting **market conditions** in a manner that could positively contribute to innovation. Another interviewee also noted the difficulties in complying with GDPR, but found that clients faced these same difficulties, and were more willing than before to leave recruiting firms in control of the data as a way to reduce their own **compliance costs**. In this way, GDPR may have contributed to altering **market conditions**.

Interviewees also reported how automated recruitment firms incurred significant compliance costs (time, legal advisor fees) with GDPR, particularly because of the lack of clarity in the regulations. For larger organisations, obtaining legal advice poses less of a challenge, but for many of the smaller or start-up businesses involved in developing automated recruitment technologies, becoming compliant with GDPR consumed a significant portion of their resources. In turn, this took funding and resources away from research and development. This reflects many of the mechanisms related to **compliance costs** identified in the literature.

Labour market regulations

The development of automated recruitment technologies has also been influenced by labour market regulations, and the requirements these set for the hiring process. This reflects some of the mechanisms identified in the literature in relation to environmental regulations and the role regulation can play in defining and establishing a market. In this way, regulations create **incentives** for innovation.

In some respects, some interviewees felt that these requirements have not kept pace with technology. For example, requirements that right-to-work documents need to be presented in person make remote recruitment challenging, and there is a sense

among established recruitment agencies that many new start-ups in the field are not fully compliant with regulations. However, one interviewee noted that the paperwork and due diligence required for hiring new employees has also created a market for automated technologies that speed this process up, another example of how regulation may impact innovation by altering **market conditions**.

Labour market regulations on hiring discrimination have also helped to create a market for automated recruitment technologies that reduce bias and therefore discrimination in hiring. In this case, regulation on discrimination has by no means driven the development of such technologies, but some interviewees involved in bias-reducing technologies felt it had helped to send a **signal** to firms to better address discrimination in the hiring process, which has in turn contributed to heightened interest for automated recruitment technology.

Although such regulations have helped to create the market for automated recruitment technologies, they have also led to firms being cautious around accidentally developing models that mirror and perpetuate human biases. Much of this caution is due to uncertainty, as current discrimination regulations do not appropriately address the issue of liability when it comes to machine learning. Concerns have also been heightened by media reporting on the problems with Amazon's recruiting technology, which has created a **disincentive** for innovation.

The role of entrepreneurship

Many of the firms developing new technologies in the automated recruitment space are start-ups, and as such are also reliant on regulations that impact the ease of doing business. From the perspective of interviewees, the business regulatory environment in the UK encourages start-ups, and has helped innovation in this sector to flourish, by keeping **compliance costs** low and facilitating access to **capital** This reflects some of the mechanisms identified in the literature in relation to economic regulations. However, the approach to other types of regulation, such as the GDPR, may have put a disproportionate burden on smaller businesses.

Summary & conclusions

The development of automated recruitment, like many new digital technologies, has been impacted by GDPR and data protection regulations, but interviews suggest that these impacts have been ambivalent: causing challenges to some and conveying benefits to others. This emphasises the fact that the way a firm will react to regulation and therefore what mechanisms are triggered will often depend on context and factors specific to an individual firm and its products.

Mechanisms identified in this case study relate to all five of the channels identified in the literature review: incentives, market conditions, compliance costs, capacity/capital and signalling.

Automated recruitment also provides an example of how regulations can help to shape the market for an innovation. In this case, labour market regulations have helped to define the expectations for automated recruitment technologies. This mirrors many of the mechanisms discussed in the literature for social regulation and illustrates how various types of regulations can contribute to establishing and encouraging new markets.

Lastly, automated recruitment is a sector where start-ups are particularly active and drive much of the innovation. The experiences discussed by interviewees with GDPR illustrate the disproportionately negative impacts the introduction of new and complex regulations can have on younger and smaller businesses.

Case study 3 – Home heating and boilers

This case study focuses on the development of home heating technologies—namely boilers—in the UK.

A brief introduction to home heating and boilers

Heating accounts for over a third of the UK's greenhouse gas emissions, and as such, the home heating industry is crucial to the Government's strategy for decarbonisation.

Home heating in the majority (85%) of homes in the UK is currently provided by boilers powered by natural gas. The UK's reliance on natural gas stems from the discovery of natural gas reserves in the North Sea in the 1960s—this reliance is not necessarily the case in other countries, meaning that the UK is one of the most important markets for gas boilers. There is also a small market for oil-fired boilers and home heating systems powered by electricity. Although there is a noted need to transition away from natural gas to meet climate goals, significant progress has been made in improving the efficiency of existing technologies through regulation (BEIS, 2018). This case study therefore focuses on the boiler industry and the regulations that have targeted this industry.

The boiler industry in the UK is made up largely of manufacturers and installers. The manufacturing sector is highly concentrated, with four manufacturers accounting for over 80% of the market (AMA Research, 2018). The installer market, by contrast, is dominated in part by British Gas, but otherwise serviced by a large number of small and microbusinesses. As many of the regulatory obligations fall on installers, and installers are key to directing homeowner decisions on which boiler to purchase, installers are important for determining which innovations are picked up by the market.

This case study provides an example of environmental regulation having an impact on innovation, and illustrates some of the mechanisms described by the Porter Hypothesis.

The impact of regulation on the development of boilers

Environmental regulations are highly important to development and design in the home heating industry. As such, this was the focus of the interviews. Industry interviewees also discussed the role of building regulations and how these might impact innovation.

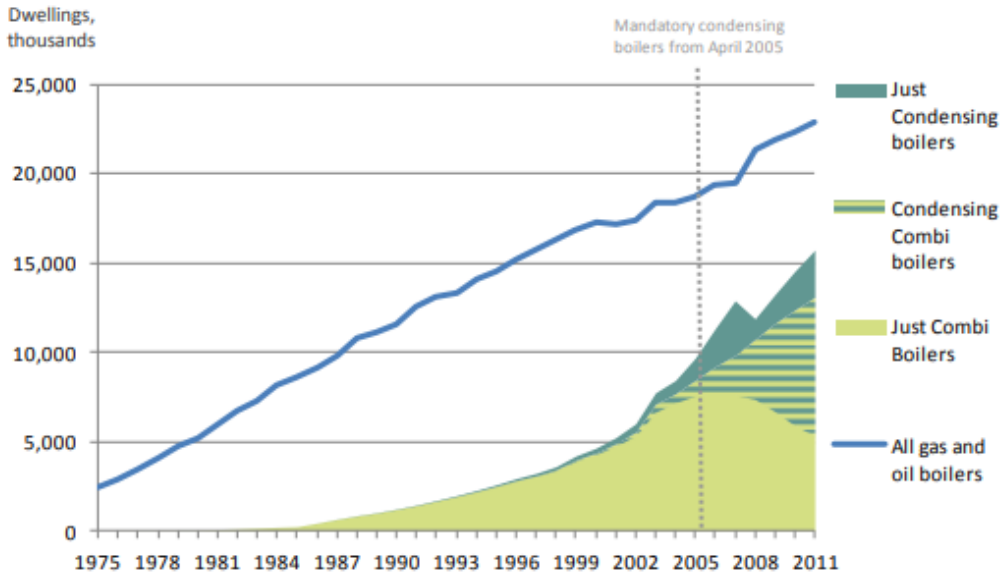
Interviewees seemed largely in agreement that regulation was needed to improve the efficiency of boilers and home heating. As one industry member pointed out, boilers are not an aspirational good, and home owners and installers will almost always choose the cheapest model available. For this reason, the industry members

interviewed were supportive of such regulations, seeing them as essential to their business. In this way, these regulations have created **incentives** for innovation, by helping to establish the market for improved technologies.

Two main sets of regulations were discussed: the Condensing Boiler Regulations, introduced in 2005, and the Boiler Plus Regulations, introduced in 2017. These regulations have gone beyond the standards set in other EU countries.

The *Condensing Boiler Regulations* stipulated that all gas-fired boilers fitted would need to be condensing boilers beginning in 2005, and that the same would need to be true for oil-fired boilers from 2007. Condensing boilers were between 15-30% more efficient than the older models that preceded them, significantly improving energy efficiency. These regulations led to a significant increase in the ownership of condensing boilers in the UK, as indicated in Figure 19.

Figure 19. Ownership of Condensing and Combi Boilers (Source: Palmer & Cooper, 2013)



According to the two industry interviewees, the Condensing Boiler Regulations had a significant impact on innovation in the industry. One interviewee stated that up to 2-3 years before the regulations, they were not selling any condensing boilers in the UK. Following the regulations, they invested tens of millions of pounds into development, leading to a whole suite of condensing boilers for the UK market.

The *Boiler Plus Regulations* were developed in close consultation with industry and stipulated that all new boilers installed would need to meet certain conditions and at least 92% efficiency. According to industry interviewees, these requirements have led to increased investment and innovation in certain technologies, although they have not had as significant of an impact as the Condensing Boiler Regulations. Both of these examples clearly reflect many of the mechanisms identified in relation to environmental regulation and the Porter Hypothesis.

Technology neutral regulations

The goal of regulations on boilers has been to support innovations that encourage increased energy efficiency and decarbonisation. According to the regulator

interviewed, this meant that the most recent set of regulations—Boiler Plus—were designed to be as technology neutral as possible without undermining the intended policy. This was challenging, as outcome measurements were not sophisticated enough to allow policies to be fully outcome-based. In practice, this means that the regulations are not fully technology neutral, but instead try to avoid being prescriptive in a way that would stifle innovation. When developing Boiler Plus, significant research was undertaken to ensure that the technologies included were appropriate and there was evidence for their benefits.

The attempt to balance technological neutrality with policy goals has proved challenging. According to the regulator interviewed, early on in the policy development phase for Boiler Plus, a more goals-based approach was considered. This would have been based on the EU Energy-related Products (ErP) labelling Directive and would have been largely technology neutral. This approach would have set a system limit for energy efficiency, allowing consumers and installers to decide between them what options would suit best to remain within that limit. However, there were several issues with this potential approach. For example, although there is a clear and robust methodology for assigning the efficiency of boilers, there is no such equivalent methodology for thermostats, and there were concerns that a system approach could be too easily manipulated. There were also concerns that the design of the ErP and the calculation of system limits would not recognise certain technologies that would also yield efficiency benefits, undermining the supposed neutrality of the approach.

Instead, Boiler Plus seeks to include a range of technology options and avoid prescription as much as possible. Implementation of these regulations have indicated, however, that this approach is also not without challenges. One example provided was the case of smart controls. Within the Boiler Plus Regulations, the term “smart” is intentionally not fully defined as there was an understanding that “smart” technologies might develop in different ways. However, because it is also not a technical term, this has led to some examples being put on the market which claim to be “smart” but clearly do not fit the intended meaning. The regulator interviewed felt that this was something already being dealt with to some extent by the market, but that it would be one aspect that would need to be considered in the upcoming evaluation of the regulations.

This suggests that remaining technology neutral and avoiding prescriptive regulations, which is considered within the literature—and the Porter Hypothesis in particular—to be necessary to encourage innovation, can lead to challenges for regulators who seek to balance this with policy goals.

Impacting innovation through market creation

For both the Condensing Boiler Regulations and the Boiler Plus Regulations, regulations have largely functioned to increase the market for an existing technology. This means that where they have encouraged innovation, it has largely been incremental innovations to pre-existing niche technologies which have not yet achieved a significant market share. This aligns with mechanisms identified in the literature that suggest that environmental regulations help to encourage the dissemination of best available technologies.

For example, in the case of condensing boilers, regulations led to significant investment by industry to bring the product into the mainstream and increase its

affordability. Regulation created a new market and the industry invested in R&D to respond, thus altering the **market conditions** for innovation.

For the Boiler Plus regulations, the regulations have established specific outcomes and different technologies through which these can be fulfilled, meaning that the impact on industry has been more diverse and gradual than what occurred under the Condensing Boiler Regulations. The regulations appear to have particularly influenced the development of certain technologies. For example, following Boiler Plus there has been an increase in investment and development of new types of smart controls. This suggests that in addition to creating **incentives** for innovation, these regulations have also acted as **signals** to indicate where innovation should be headed.

This suggests that environmental regulations are encouraging innovation in the industry both by setting specifications and by reducing the risk of R&D investment in certain technologies by standardising them and ensuring a market.

Although the majority of regulation's impact in this area appears to be on incremental innovations, the regulator interviewed provided one example of a technology—a type of weather compensation—that did not exist prior to the regulations, but which was developed in response to some of the criteria set. This suggests that to some extent, regulation in this area has played a small role in anticipating and encouraging more radical innovations.

The anticipation of regulation—and the market regulation can create—has also potentially impacted innovation in the sector. One industry interviewee noted that they were able to capitalise on increasing regulations by beginning their work to comply as soon as possible. This extended to actively collaborating with the regulator during the prototype phase for radical innovations, to be ahead of the curve on future regulations.

While sentiment on boiler-specific environmental regulations and their contribution to innovation were largely positive, industry interviewees mentioned some challenges associated with building regulations. One interviewee mentioned, for example, that the difficulty involved in getting a new product onto the Standard Assessment Procedure (SAP) list made it challenging to bring radical innovations to market and may contribute to reducing manufacturers' willingness to develop such products. This is an example where **compliance costs** are considered too high for firms considering innovation. Another interviewee mentioned that SAP gives preferential treatment to combi boilers with a high hot water efficiency rating. This led to installers choosing lower quality boilers that were designed to show high hot water efficiency at testing, reducing money spent on insulation, resulting in homes that were overall less efficient. Although these are anecdotal examples, it gives an example of how even where purpose-designed regulation may be **incentivising** innovation, regulation in other areas may contribute to **disincentivising** those same innovations.

Timing

All interviewees mentioned the challenge of timing when introducing environmental regulations, and the adverse effects that a shorter warning period can have on smaller firms. Larger manufacturers have the capacity to develop new technologies to comply with regulations, or may have already developed such technologies, while smaller manufacturers will find it much harder to comply and capitalise on upcoming

regulations. The regulator interviewed highlighted the extensive efforts BEIS made prior to Boiler Plus to alert and engage the industry before introduction and felt that this was for the most part successful. One industry interviewee suggested that a better roadmap on emissions would be helpful to provide clarity for businesses. However, as most manufacturing and innovation in this sector is undertaken by larger firms, adverse impacts on some smaller players are unlikely to significantly impact innovation in the sector overall. The role of timing was not addressed in any of the mechanisms identified within the literature review.

Summary & conclusions

This case study provides a clear illustration of many of the mechanisms identified in the literature related to environmental regulation and has highlighted mechanisms related to several of the channels identified through the literature review: compliance costs, incentives, market conditions and signalling. In accordance with the Porter hypothesis, regulation has altered the **incentives** for innovation and led to investment in innovation by firms and improvements to energy efficiency. According to interviewees, this has also contributed to competitiveness.

Regulations on boilers have stimulated innovation largely by forcing firms to innovate within existing products or processes to meet new requirements. Regulators in this area appear to have kept the conditions set by the Porter hypothesis in mind during design, developing regulations that were both stringent but as technology neutral as possible. The experience of regulators and the industry in developing and implementing regulations that meet these criteria suggests that in practice, well-designed environmental regulation requires compromise, extensive consultation and trial and error.

This case study also confirmed that the mechanisms related to environmental regulation are likely to have more adverse effects on smaller businesses. Larger manufacturers will have the capacity to invest in innovation and also appear to be collaborating directly with regulators in order to stay ahead of the curve and capitalise on future regulations. Smaller businesses are less likely to have the foreknowledge and resources to adjust within the timescale set, which may contribute to a further concentration of the market.

Case study 4 – Personalised e-health services

This section presents the case study on personalised e-health services.

Introduction to personalised e-health services

Personalised e-health services encompass a range of technologies that promote the digitisation of care pathways and models of care through electronic processes and technology. These have been identified by the NHS as a key priority for future work. Developing e-health services is linked to several intended benefits:

- improving the quality of healthcare for people and empowering them to have more control over their health;

- reducing the costs of healthcare services in terms of the administrative resource required by healthcare professionals; and
- supporting innovation in terms of developing new treatments and medicine (NHS England, 2014).

The government's ambition for the development of digital healthcare is set out in their 'Personalised health and care 2020' framework for action (NHS England, 2014). The framework calls for the transformation of personalised healthcare and digital technology in the health space. It sets out key proposals for action to be achieved by 2020. This policy support means that the potential UK market for digital healthcare is very large (Joshi, 2018). This includes services such as tele-monitoring, telecare, e-medicine and mobile health to bring accessible and affordable health services to everyone. This is achieved through combining clinical expertise and the healthcare workforce with remote devices such as smartphones and artificial intelligence.

To ensure patient and clinical safety, digital healthcare is a heavily regulated sector. Regulators include: the Care Quality Commission (CQC), NHS Improvement and the Medicines & Healthcare products Regulatory Agency (MHRA).

When it comes to innovation in e-health services the following regulations have been identified as potentially relevant:

- personal data regulation;
- product quality and safety regulation;
- market entry regulation; and
- labour regulation.

Impact of regulation on the development of personalised e-health services

Interviewees identified several barriers to innovation that they indicated were generated by regulations.

Procurement rules

An interviewee from a large business described that regulation itself and its structure do not pose barriers to innovation but rather that the problem lies in the way services are procured. The interpretation of procurement rules impacts on market entry and therefore **market conditions**; for example, the primary care sector governed by local contracts was described as a very circumscribed arena where the General Medical Services (GMS) contract for delivering primary care services means that they can only be held by a very small number of organisations (e.g. not by a corporate organisation). This favours the dominant model of delivering primary care which is usually by GPs: "*the contractual [procurement] structures are very deliberately designed to prevent new entrants in primary care … it's taken us a lot of work, energy and legal advice to find appropriate and compliant routes to operate*". Many innovative firms may therefore find it difficult to navigate a very complicated landscape that favours the dominant model.

CQC / MHRA inspections

Industry members interviewed suggested that rules were implemented differently for different actors. New entrants are subjected to more stringent enforcement of regulations (through CQC / MHRA inspection) as compared to traditional organisations. In the case of primary care, this is reflected in the significant differences in the level of scrutiny between GP practices and newer digital health services. For example, digital primary care services have more data through video appointments than traditional GP practices where consultations cannot be observed. This facilitates scrutiny by the regulator and means that digital services are subjected to greater levels of regulatory oversight, and therefore greater **compliance costs** as compared to more traditional providers.

Regulatory requirements as barriers

Depending on the type of technology under development, different regulatory requirements may pose a challenge to innovation. Many technologies in the e-health space rely on the collection and transfer of personal data. One industry member suggested that data sharing and regulations on data protection in the UK are making it difficult to innovate by creating **compliance costs** and **disincentives** to pursue certain approaches.

Industry members were in consensus that medical device regulation was also impacting on innovation, as medical devices are required to fulfil additional requirements and are subjected to an increased level of clinical governance. One industry interviewee stated that they advised customers to avoid developing functions that could lead to their technology being classified as a medical device as a way to minimise **compliance costs**.

This reflects many of the mechanisms identified in the literature which suggest that regulatory burden—which is likely to be higher when regulations are complex—can have a negative impact on innovation.

Impacts on small and big players

Industry members interviewed were in consensus that regulation impacted small organisations more so than larger ones. Small players were regarded by one interviewee as "*not having the courage to push their own services*" because of the resource investment required to do so. This is problematic because newer and smaller entrants are seen to drive more innovation in the sector. The barriers to newer and smaller entrants were mentioned particularly in relation to **compliance costs**:

- The costs associated with regulation are more likely to significantly impact on the resources available to invest in R&D for smaller firms. This gives preference to the bigger global tech companies such as IBM.
- Industry interviewees felt that navigating the multitude of regulations is confusing and can deter organisations from developing new ideas because of the intense resource required in understanding them. Such costs associated with familiarisation are another type of **compliance cost.** As noted by one interviewee:

"In the health space generally, there's a lot of overarching government bodies and it's not entirely clear which one you're supposed to be conforming against. Which one has the overarching rule. E.g. there's guidelines from NHS Digital, NHSE, MHRA, NICE and it's sometimes very confusing from a small business perspective to understand which guidelines are actually applicable to your organisation so this causes confusion in the market place."

Misalignment and tensions between regulations

Some interviewees noted that existing regulations were not future-looking enough, and that this contributed to uncertainty in the market and presented a barrier to innovation. This is similar to some of the mechanisms identified in the literature that suggest that uncertainty can **disincentivise** innovation.

Summary and conclusion

Personalised e-health services illustrate a case where there is a demonstrated public need for further innovation, where innovation is moving very quickly and where many small businesses are involved in the development of innovative products and services. Mechanisms identified in this case study relate largely to compliance costs, market conditions and incentives.

According to interviewees, regulations appear to be disproportionately burdening these organisations. This confirms findings in the literature, and illustrates how this effect might be exacerbated in an environment where regulations are more complex and where technology is evolving rapidly.

Discussion

This review has explored how regulation may impact on innovation. Scholars have identified a range of mechanisms to account for this relationship. The literature – both theories and empirical studies – is often looking at specific areas (e.g. antitrust, intellectual property, etc.) At present there is no comprehensive framework that brings these insights together, and this study has been a small step towards the development of such a framework.

Alongside the academic literature, this study has also drawn on four case studies (Connected and Automated Vehicles, automated recruitment, home heating and boilers and personalised e-health services) to understand how the mechanisms identified in the literature play out in different industries. The case studies confirmed many of the mechanisms identified in the literature, while also illustrating the heterogeneity of impacts both across and within sectors. Case studies were based largely on interviews with industry and regulators.

To better assess commonalities, differences and gaps in the ways scholars think about how regulation impacts innovation, the mechanisms this study has identified can be sorted into five categories:

- **compliance costs:** compliance cost mechanisms are triggered by any requirement a business needs to comply with as a result of their *ongoing*

activities; compliance cost mechanisms provide a channel through which regulation has a direct impact on individual businesses;

- **incentives:** incentive mechanisms refer to the ways regulatory changes affect the way businesses assess the costs and benefits of their *future* activities; incentive mechanisms provide a channel through which regulation directly impacts businesses; market conditions can also generate incentives for businesses.

- **market conditions:** market conditions mechanisms refer to the ways regulation affect the market environment in which businesses find themselves *without impacting businesses directly*; this includes any policy impact on the level of competition in the market, consumer demand, the physical, human or financial capital available in the market, or the flow of information and knowledge across organisations and within networks;

- **capacity/capital:** capacity/capital mechanisms refer to the ways market conditions or regulation modify the financial capital (e.g. the ability to use patents as collateral for loans) or the human capital (e.g. staff expertise, motivation) that business organisations and networks have at their disposal for innovation or other endeavours; this excludes compliance costs, which by virtue of their extensive use in the literature, are considered a separate mechanism.

- **information/signalling:** information/signalling mechanisms refer to the ways regulation signals to organisations and networks what is desirable or not (Sunstein 1996); such mechanisms account for the impact that the meaning carried by regulations (distinct from any material costs and benefits) have on business behaviour. The argument here applies widely, in the sense that any legislation or standard provides information, and that information may sometimes be relevant to innovation if it gives direction towards a particular technological trajectory.

The literature and case studies provide numerous examples of incentives and compliance costs mechanisms. In several instances, the process leading from regulation to innovation involves a combination of mechanisms, such as compliance costs mechanisms, incentives mechanisms, and market conditions mechanisms . For example, innovations undertaken to reduce compliance costs ('compliance costs' mechanism) may in some instances generate other returns, by improving overall efficiency or leading to increased market demand ('incentives' mechanism). Another example would be an environmental regulation that leads firms to experience an increase of the costs of their energy inputs. There is a first 'compliance costs' mechanism at play here. There is then an ‘incentives’ mechanism, as firms would anticipate those costs and try to seek alternatives and increase their exploration activities to find innovative, more environment-friendly products. However, there is also a ‘market conditions’ mechanism at play, as the increase in the costs of inputs would increase the costs consumers experience, and thus lead to consumer demand shifting to more environment-friendly products and services, a change in market conditions. Businesses may then anticipate new revenues by responding to this new market demand, an incentive mechanism leading firms to innovate further.

There are instances in which regulation is theorised to shape innovation through its impact on capacity or capital. For example, intellectual property rights regulation (and

notably patenting) supports firms in a market by offering them a type of collateral that they can use when they seek financing. In turn, this means that firms have increased access to financing and are therefore more able to invest in innovation. Another example is the manner labour market regulations can influence innovation by influencing workers' behaviours (e.g. by contributing to a sense of security and loyalty to the firm, which then is conducive to innovation).

The literature has otherwise little to say on other processes through which regulation might impact innovation. For instance, the literature does not provide much insight on how regulation impacts innovation through meso-level factors (e.g. state and market supply of capital), or inter-organisational factors (e.g. joint ventures, innovation network etc.). There are elements in the literature to suggest that meso-level factors in particular are shaped by non-regulatory policies (such as R&D funding support, or policies aimed at the development of skills and expertise through universities and research centres), which are outside the scope of this study. Likewise, processes leading to innovation within firms or across members of a network have been studied within the organization studies literature. However, the link between those processes and regulation in that literature is tenuous (see Acar et al. 2019). It may also be worth noting that other literatures have conceptualised the influence of regulation on business in other ways than those identified in this study (for instance, the regulation studies literature entertains complex models of business motivations that go beyond material interest, and thus consider other mechanisms than compliance costs or incentives to account for the way regulation influences businesses). However, those concepts and mechanisms have generally not been applied to the topic of innovation.

Knowing whether a regulation influences innovation through compliance costs, incentives, market conditions, capacity/capital, or signalling is not enough to know whether innovation will increase or decrease. An increase in compliance costs could lead firms to innovate, or, on the contrary, could disincentivise them from investing in R&D (and the same can be said for increases in incentives or uncertainties). For instance, if a regulation creates compliance costs, it can either make firms think in new and creative ways about their products to escape regulatory requirements, or it can make them spend money on compliance activities that they would otherwise have spent on R&D.

The relative strength of a mechanism depends on many different factors, such as the sector to which the regulation applies, but also the level of competition in a market, the size and nature of firms that are affected, the nature of the products and services affected to name only a few. This study showed that only a closer look and a detailed study can say what mechanisms are at play and whether a specific regulation will positively or negatively impact on innovation.

Some of the mechanisms identified are specific to particular regulations. For example, the mechanism by which a regulation increases the cost of labour, and thereby incentivise firms to invest in innovations that reduce the need to labour is specific to social regulations (and in particular, to workers' health and safety and labour market regulations).

However, there are also some mechanisms that appear to apply to both types of regulation (i.e. economic, social). For instance, the mechanism by which a regulation increases compliance costs, and thereby drives firms to spend money on compliance activities that they would otherwise have spent on R&D is not specific to one type of

regulation, but instead applies to all types of regulations. The impact of compliance costs was highlighted by interviewees in all four case studies.

Table A1. lists and categorises the mechanisms at play.

As mentioned above, these mechanisms are complex. The analysis below summarises the nuances and subtleties of how they work.

The literature shows the importance of a **regulation's characteristics** for its impact on innovation.

Whether a regulation provides incentive for firms to innovate depends on the extent to which it is prescriptive. The literature in that regard generally indicates that more prescriptive regulation leaves less space to innovation, or that it determines the path that innovation should take. The Porter hypothesis posits that the level of stringency of non-prescriptive regulations – with reference to environmental regulations in particular – can encourage innovations that help improve commercial competitiveness, notably because it sets firms' focus and fuels their creativity to innovate. However, the case study on boilers points to the challenges facing regulators who seek to develop regulations that are appropriately stringent without being prescriptive and suggests that in practice, some types of prescription may be required to achieve policy goals.

This hypothesis has been said to apply to a range of social regulations. However, the case study on automated recruitment suggests that for some niche sectors, other types of regulation may contribute to innovation in a similar way (such as the impact of labour market regulations on automated recruitment).

Mechanisms by which regulations can impact on innovation are influenced by the specificities of each regulation. For instance, the extent to which an intellectual property rights regulation affects innovation depends on the details of the intellectual property rights regime it is establishing (e.g. how patents are granted, how stringently patent rights are enforced etc.). Case studies also suggested that the degree to which regulations are enforced or are enforceable plays a key role in determining the extent to which they impact innovation.

In addition, the level of takeover pressures allowed by competition regulation can affect how much innovation firms will undertake. Indeed, there is a U-shaped relationship between the level of takeover pressure in a market and the degree of innovation, suggesting that innovation is fostered by either strong antitakeover laws that significantly restrict takeovers, or very strong levels of takeover pressures.

The literature shows that the **characteristics of the sectors** to which regulations apply are also important to determine their impact on innovation.

The mechanisms by which regulations impact on innovation by creating uncertainty about the future (e.g. ability of firms to comply with regulation, greater exposure to liability claims) depend on the sectors in which regulated firms operate. By introducing compliance uncertainty, a regulation is more likely to reduce innovation in firms operating in sectors where innovation requires significant investment and longer timescales (e.g. pharmaceutical) rather than firms operating in sectors where innovation is relatively cheap (e.g. software, IT).

Similarly, how firms choose to react to uncertainties created by anticipated regulations depends on their areas of activity: firms operating in more financially secure markets, i.e. markets with low levels of price volatility, are likely to act to spur innovation, while firms operating in less financially secure markets tend to prefer to 'wait and see' what impact the regulation might have on their business. The case studies also indicated that within a more concentrated sector dominated by high upfront costs, such as the boiler industry, some firms may seek to reduce uncertainty by interacting and cooperating with regulators in advance of new regulations.

There are also examples specific to certain regulations.

- M&A regulations - by protecting firms against short-term market pressures, antitakeover laws help spur innovation: they create a setting that encourages managers to act in the long-term benefit of the firm and to invest in R&D. However, the literature also shows that this impact is more pronounced for firms operating in markets with more severe information asymmetry and more competition.

- Labour market regulations - an increase in labour costs can provide financial incentives for firms to invest in innovations that reduce the need for labour. However, this is particularly true for sectors relying mainly on low-skilled labour.

The literature also shows the importance of regulated **firms' characteristics** when determining the impact of a regulation on innovation.

Compliance costs are not likely to have the same impact on innovation depending on whether regulated firms are large or small. Innovation tends to fall in smaller firms and concentrate in larger, multinational firms (due to their greater ability to deal with the compliance costs). This was confirmed by all four case studies, although the degree to which that was perceived to impact innovation differed between cases. In industries where innovation has high up-front costs and there is a relatively concentrated market, such as for boilers and CAVs, barriers to SMEs are considered less crucial to innovation. In automated recruiting and personalised e-health services, by contrast, where innovation is driven by start-ups and smaller firms, regulatory burden is considered to be a more significant problem for innovation.

The role of regulated firms' characteristics in shaping a regulation's impact on innovation is also demonstrated by examples specific to certain regulations.

- Abuse of dominance and antitrust regulations - increased competition can reduce the market share of firms. This leads to a reduction in their rents and encourages them to innovate. However, this mechanism depends on firms' characteristics: it is mostly at play for incumbent firms that are already innovators and at similar technological levels to one another. For firms that are lagging, an increase in competition has the opposite effect and leads to a reduction in innovation investment.

- Liability regulations - liability risk targets upstream suppliers but reduces innovation activity predominantly in downstream buyers, suggesting suppliers may choose to move their focus to areas of the market with less risk.

- Workers' health and safety regulations - complying with regulations may be more difficult for highly innovative firms. Indeed, they are likely to have a

harder time integrating appropriate safety procedures within a manufacturing environment, as innovations lead to regular changes within the manufacturing environment and safety procedures may not be able to keep pace. In some specific industries, health and safety regulations could restrict highly innovative firms.

- Environmental regulations - how mechanisms work depends on the type of the firms affected. For instance, stringent regulations appear to have a greater positive impact on firms that report more environmental damage (and who presumably are more severely impacted by the regulations) and on firms with more specific assets (such as expensive and particular machinery that are difficult to sell off).

The literature also suggests that the impact of a regulation could depend on the **characteristics of the regulated products and services**. For example, the literature on quality and safety regulation highlights that compliance costs vary depending on the quality of the products subject to regulation (e.g. it is less expensive to test and approve a product whose quality is apparent than a product which is of low-quality). Therefore, costs of compliance will primarily affect low-quality innovators, allowing high-quality innovators to prosper.

The literature provides some examples of times where the impact of regulations depends on **external factors**. For example, the literature on intellectual property rights regulation argues that in theory, patenting may contribute to innovation, by leading firms to disclose their innovations and share new ideas rather than keeping trade secrets. However, the literature shows that in practice, this mechanism might not be at play, considering that the quality of disclosure in many patents is poor and that engineers in many fields do not actually read patents (either because there are too many and they cannot keep up, or because they are actively discouraged from doing so to avoid legal liability).

The literature discusses how impacts of regulations could be differentiated into the **long and short term**. Blind (2012) finds that the short term impacts of regulation are often negative for innovation, while long term impacts vary depending on the regulation. Specifically, there is more evidence in the literature on environmental regulations that negative impacts dominate in the short term, and positive impacts dominate in the long term. Similarly, one of the sources reviewed within the literature on quality and safety regulation hints that regulation in the biotechnology industry can initially lead to a reduction in innovation but eventually be followed by a trend reversion after a couple of years. This suggests that firms are able to adapt their management processes, and, while regulation might initially impact negatively on innovation, this impact is only temporary.

Annex 1 - Synthesis – all mechanisms

Table A1. Categorisation of all mechanisms identified in the literature review

Economic	Social	Mechanisms	Incentive	Compliance costs	Market conditions	Capacity / capital	Information signalling
	X	Anticipated regulation creates uncertainties => firms delay decisions to pursue innovative activities for as long as possible	X				
	X	Anticipated regulation creates uncertainties => firms may act to spur innovation	X				
	X	Greater exposure to liability claims) => firms are uncertain about their future returns on investments => firms become hesitant to invest in innovation	X				
	X	New compliance requirements => sets boundaries within which firms can operate => these limitations help set the focus and fuel the creativity of firms => this helps firms innovate	X				
	X	New compliance requirements => sets boundaries within which firms should operate => these limitations become too prescriptive and	X				

		prevent firms from being creative => firms are disincentivised to innovate					
	X	New compliance costs => firms divert money from investing on activities to increase customers' satisfaction towards investing on compliance activities => consumers' satisfaction decreases => demand for products/services decreases => firms are disincentivised to innovate	X	X			
X	X	New compliance costs => firms need to think in new and creative ways about their products => circumventive innovation (i.e. occurs when the scope of the regulation is narrow, and the resulting innovations allow firms to escape the regulatory requirements)	X	X			
X	X	New compliance costs => firms need to think in new and creative ways about their products => compliance innovation (i.e. occurs when the scope of the regulation is broad, and the resulting innovations remain within the scope of the regulation)	X	X			
	X	New compliance costs => firms invest in R&D to find ways to comply with regulations at the expense of other, potentially more profitable R&D investments.		X			
X	X	New compliance costs => firms spend money on compliance activities that they would otherwise have spent on R&D		X			
	X	New compliance costs => firms struggle to recover these costs (no clear positive externality resulting from these costs, nor signs of consumer willingness to pay more) => firms are not incentivised to innovate		X			
X		Increase in competition => firms that previously were in a situation of imperfect competition are now challenged => these firms need to survive the new competition => these firms are incentivised to innovate	X				

X		Increase in competition => firms that previously were in a situation of imperfect competition now have competitors, have smaller profits and do not anymore benefit from all the benefits of investing in innovation => firms are disincentivised to innovate.	X				
X		Increase in competition => reduces market share of incumbent firms and reduces their rents => the comparative benefit provided by investments in innovation increases	X				
X		Output-based regulation => in case of project failure, the company is stuck with the costs => firms are disincentivised to innovate.	X				
X		Output-based regulation => in case of project success, part of the benefits is passed on to consumers without taking into account the risk associated with achieving these benefits => firms are disincentivised to innovate	X				
X		Output-based regulation => the most innovative firms receive financial rewards while the least innovative firms face financial penalties and further regulatory scrutiny => firms are incentivised to innovate.	X				
X		Price caps => firms' revenue and market performance are negatively impacted => expected profitability of introducing new products is reduced => firms are disincentivised to innovate	X				
X		Price caps => firms' revenue and market performance are negatively impacted => firms are incentivised to reallocate investment in R&D to areas where highest profitability can be expected	X				
X		Price setting / minimum prices => revenue increases for targeted products => revenue from an existing technology is the same as what could be gained from a new technology => firms are disincentivised to take risk in innovating	X				

X		Price-based regulation => exposes firms to higher RD&D costs that they cannot compensate through higher prices => firms are disincentivised to innovate.	X				
X		Price-based regulation => firms benefit from cost reductions they can achieve, including cost reductions from process innovations => firms are incentivised to innovate.	X				
X		Protection against short-term pressures => create a setting that encourages managers to act in the long-term benefit of the firm and to invest in R&D => firms are incentivised to innovate	X				
X		Protection against short-term pressures => creates a setting that allow firms to forego R&D projects that might be lucrative in the long-term, in favour of ventures that offer quick payoffs => firms are disincentivised to innovate	X				
X		Reduction in costs of entering a market => firms find it easier and quicker to have access to financing and legal security => firms are incentivised to innovate	X				
X		Increase in competition => competitors can request technology still under development => decreases or eliminates the expected financial returns of investing in costly R&D (for both innovative firms and for their competitors)	X		X		
X		Increase in competition => competitors can request technology still under development => firms have a greater need for secrecy => firms pursue defensive R&D strategies to protect their IP from scrutiny of their competitors => reduced communication of scientific and technical information within industries => fewer opportunities to innovate	X		X		
X		Reduction in costs of entering a market => increases the possibility for smaller, innovative firms to enter the market		X			

X		Increase in competition => restricted cooperation between firms => firms are no longer able to achieve synergies by combining their R&D activities => some innovation activities cannot be initiated anymore			X		
	X	Bankruptcy law => insurance against the consequences of failure => firms are more willing to take risks => firms are incentivised to innovate	X				
	X	Existence of liability regulation => increases consumers' reassurance that they will be financially compensated if needed => demand for products and services increases => firms' expected profits and returns on investment grow => firms are incentivised to innovate	X				
	X	Increased risk of litigation => firms are incentivised to reduce this risk by increasing the safety of their products/services => firms are incentivised to innovate	X				
	X	Increased risk of litigation => firms are incentivised to reduce this risk by increasing the safety of their products/services => firms prefer to invest in 'tried and tested', conventional products/services => firms are disincentivised to innovate	X				
	X	Patenting => firms are able to hold a temporary monopoly on their innovation => firms can increase prices => profits increase => reduces the risk of investing in innovation => firms are incentivised to innovate	X				
	X	Patents offer a type of collateral that firms can use when seeking financing => firms have increased access to financing for innovation => firms may develop a bias to quick, patentable results rather than long-term research projects	X				
	X	Greater costs of labour => firms are incentivised to invest in innovations that reduce the need to labour	X	X			
	X	New costs to dismissing workers => firms are disincentivised from firing workers => firms may be reluctant to adopt or develop new	X	X			

		automations or labour-saving innovations => firms are disincentivised to innovate					
	X	Patenting => firms are incentivised to disclose their innovation rather than keeping trade secrets => this contributes to the diffusion of new ideas	X		X		
	X	Improvement in labour quality and worker satisfaction and motivation => workers feel more loyalty toward firms => workers are less likely to give away trade secrets => this reduces the risk associated with R&D investment for management => firms are incentivised to innovate	X			X	
	X	New licensing costs => potential innovators might find these prohibitive		X			
	X	Higher costs to dismiss workers => firms are disincentivised from firing workers => firms are more reluctant to hire in the first place, especially for new endeavours considered to be risky=> firms are less likely to do radical innovation		X		X	
	X	Increase in the cost of labour => reduces the overall financial capital => firms decide to invest less overall in R&D compliance costs + capital/capacity		X		X	
	X	Insurance against the consequences of failure => creditors cannot discriminate between low-and high-risk projects => interest rates increase => lenders tighten credit for small businesses => potentially innovate firms have reduced access to financing for innovation			X		
	X	Patents offer a type of collateral that firms can use when seeking financing => firms have increased access to financing for innovation			X		
	X	Improvement in labour quality and worker satisfaction and motivation => potential failure and success of these activities are less likely to result in negative consequences => workers feel more secure in their positions => workers are more likely to engage in innovative activities.				X	

	X	Improvement in labour quality and worker satisfaction and motivation => potential failure and success of these activities are less likely to result in negative consequences => workers feel more secure in their positions => workers provide more critical feedback, question management and suggest improvement => this helps firms innovate				X	
	X	Creation of new markets => creates business opportunities for firms in new markets => encourages potential innovators to invest in long-term	X				
	X	Increase in the costs of certain factors or inputs (e.g. energy) that firms use in their production process => demand shifts to more environment-friendly products/services => firms are incentivised to innovate	X				
	X	Uncertainty about the delay associated with regulation (i.e. the time for the regulator to approve a product before it can be marketed) => firms are uncertain about their future returns on investments => firms are disincentivised from innovating	X				
	X	Requirement for firms to signal and commit to the quality of their products => increases consumers' trust => value and marketability of products increase => demand for products increases => firms' expected profits and returns on investment => firms are incentivised to innovate	X	X			
	X	Increase in the costs of certain factors or inputs (e.g. energy) that firms use in their production process => firms need to seek alternatives => firms increase their exploration/innovation activities		X			
	X	Creation of a level-playing field for all firms willing to enter the market or diversify their product line => facilitates innovation			X		
	X	Improvement in labour quality and worker satisfaction and motivation => workers feel better protected => workers are more likely to engage in innovative activities				X	

	X	New signal to businesses on resource inefficiencies and possible technological improvements => motivates firms to shift their approach to innovation					X

NB: An 'X' in the first three columns indicates the specific literature in which the mechanism was identified. A shaded green cell in the first three columns indicates that the mechanism can be generalised to both types of regulation.

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