ESSAYS IN COMPETITION POLICY, INNOVATION AND BANKING REGULATION

Jacob Seifert

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Essays in Competition Policy, Innovation and Banking Regulation

Jacob Seifert

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Abstract

This thesis investigates the optimal enforcement of competition policy in innovative industries and in the banking sector. Chapter 2 analyses the welfare impact of compulsory licensing in the context of unilateral refusals to license intellectual property. When the risk-free rate is low, compulsory licensing is shown unambiguously to increase consumer surplus. Compulsory licensing has an ambiguous effect on total welfare, but is more likely to increase total welfare in industries that are naturally less competitive. Compulsory licensing is also shown to be an effective policy to protect competition *per se*. The chapter also demonstrates the robustness of these results to alternative settings of R&D competition.

Chapter 3 develops a much more general framework for the study of optimal competition policy enforcement in innovative industries. A major contribution of this chapter is to separate carefully a firm's decision to innovate from its decision to take some generic anti-competitive action. This allows us to differentiate between firms' counterfactual behaviour, according to whether or not they would have innovated in the absence of any potentially anti-competitive conduct. In contrast to the existing literature, it is shown that the stringency of optimal policy will be harsher towards firms that have innovated in addition to taking a given anti-competitive action.

Chapter 4 develops a framework for competition policy in the banking sector, which takes explicit account of capital regulation. In particular, conditions are derived under which increases in the capital requirement increase the incentives of banks to engage in a generic abuse of dominance in the loan market, and to exploit depositors through the sale of ancillary financial products. Thus the central contribution of this chapter is to clarify the conditions under which stability-focused capital regulation conflicts with competition and consumer protection policy in the banking sector.

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Contents

Chapter 1

Introduction & Preliminaries

The term "competition policy" describes the set of measures that are implemented in order to ensure that competition works effectively for consumers, by preventing three classes of anti-competitive actions: collusion or price fixing, anti-competitive mergers, and abuses of a dominant position.[1] The economic literature in the field of competition policy may be broadly split into two phases: while early work focused quite narrowly on establishing conditions under which various business practices might exhibit pro- or anti-competitive effects, economists have much more recently begun to consider questions relating to the optimal design of competition authority decisional and enforcement procedures (concerning, for example, optimal fine levels, the role of courts, etc.).[2] The aim of this thesis is to extend the academic literature on optimal competition policy enforcement in abuse of dominance cases.[3] In particular, we investigate the welfare impact of compulsory licensing in the context of unilateral refusals to license intellectual property in Chapter 2, before considering competition policy enforcement in innovative industries more generally in Chapter 3. Chapter 4 considers the implications of prudential regulation for abuse of dominance cases in the banking sector.

The debate around optimal competition policy enforcement is not limited to academic circles. In the policy-making arena, competition enforcement bodies at both the national and cross-national (i.e. EU) level have, in recent years, been subject to numerous reforms, notable among which has been a move towards a more economics- or effects-based approach to competition policy, rather than one based on *per se* decision rules. While *per se* rules ban or permit an entire class of actions, without regard to sub-classes of actions that may merit exception from the standard, under an effects-based approach, the competition authority is required to conduct an investigation and arrive at a conclusion based on explicit

[1]Etro (2007)

[2]The notion of 'optimality' that applies in these discussions is discussed in Section 1.1.

[3]There is a separate, growing literature that investigates optimal competition policy enforcement for mergers (see, e.g., Nocke (2013, 2010)) and cartels (see, e.g., Harrington (2013, 2011, 2010) and related literature).

criteria for deeming actions to be pro- or anti-competitive.[4]

Other recent reforms of EU competition policy procedures include the Commission's Regulation 1/2003 and the 139/2004 Regulation on the Control of Concentrations. Moreover, the Commission and many national competition authorities have, since 2004, undertaken a series of further important changes to their enforcement structures.[5] In the context of these ongoing reforms, an important secondary objective of this thesis is to inform, at a policy level, the optimal enforcement of competition policy in abuse of dominance cases that occur in innovative industries and in the banking sector.

Before setting out our precise research questions in Section 1.4, we begin by describing a very general framework for competition policy enforcement, which draws on existing work. This general framework covers three broad themes that have a bearing on our research at a fundamental level, and that will help to place our work in the context of the literature. These are:

1. the characterisation of "optimal" competition policy,
2. the appropriate choice of welfare standard, and
3. the implications of legal uncertainty.

Detailed reviews of the literature relevant to each research question are provided in the appropriate chapters.

1.1 Characterising "Optimal" Competition Policy

A first issue that arises in the analysis of optimal competition policy is the very characterisation of "optimality". Key to this question is a recognition that the decision-making environment faced by a competition authority is invariably one of imperfect information concerning the true nature of an action, be it harmful or benign. It follows that the decisions made by a competition authority will be subject to errors of type I (false convictions) and type II (false acquittals). It is in terms of these decision errors that early contributions characterised the "optimal" policy. Intuitively, under this *decision-theoretic* approach, the optimal policy minimises the cost of decision errors of both type I and II.[6]

Importantly, however, this approach only considers the decision-making ability of the authority in those cases that actually come to its attention. It does not take account of the fact that the stringency of competition policy may influence

[4] See, e.g., EAGCP Report (2005), Vickers (2005, 2007).

[5] Concerning, for example, the introduction of system review panels, chief economists departments. See Lianos and Kokkoris (2010) for further discussion of these reforms.

[6] See, in particular, Easterbrook (1984), and also Ahlborn *et al.* (2005), Beckner and Salop (1999), Christiansen and Kerber (2006), Evans and Padilla (2005a, 2005b), Hylton and Salinger (2001), Joskow (2002), Salinger (2006) and Tom and Pak (2000). In relation to the debate on effects-based vs. *per se* decision rules, it is worth noting that a *per se* rule will only ever be associated with errors of one type (type I errors in the case of *per se* illegality, and type II errors for *per se* legality), while effects-based rules will typically generate errors of both types.

the decisions of firms to engage in anti-competitive conduct in the first place. In other words, it ignores deterrence effects. Under a welfare approach to "optimal" competition policy, the deterrence and procedural aspects of competition policy must be added to decision-theoretic concerns. Thus Will and Schmidtchen (2008), for example, examine the impact of Council Regulation (EC) 1/2003 from a welfare perspective.[7] This piece of legislation replaced the mandatory notification and authorisation for cartels with a legal exception system: rather than all agreements having to be notified, they can be conducted without notification but are subject to penalties if investigated and found to be anti-competitive by the competition authority. The authors find that such a relaxation in the notification requirements need not necessarily produce adverse deterrence effects in the form of increased cartel formation.[8]

Sorgard (2009) also bridges the gap between the decision-theoretic approach and a full welfare analysis by including deterrence effects. This is done in the context of coverage rates[9] for merger investigations. Increasing the coverage rate brings about two effects: less mergers are proposed (deterrent effect) and the welfare effect of possible prohibitions following an investigation changes (enforcement effect). Since the mergers that are deterred are assumed to be the most harmful ones, the authority's investigation itself is shown to have a potentially negative impact on welfare, due to a large probability of type I errors. Moreover, if the authority cannot commit to a coverage rate *ex ante*, but rather decides the coverage rate once the number of proposed mergers is observed, welfare may be lower than with commitment.

Similarly to Sorgard (2009), Schinkel and Tuinstra (2006) examine the optimal coverage rate, this time in a model of collusion. Both types of decision-making errors are shown to lead to an increased incidence of anti-competitive behaviour. Type II errors decrease the expected fine, while increased probability of type I errors leads firms to collude as a precautionary measure. Hence there is a link between decision errors and deterrence: imperfect competition law enforcement can bring about an increase in anti-competitive behaviour.

While these papers are set in the context of specific anti-competitive practices (mergers and cartels), Katsoulacos and Ulph (2009) develop a welfare-based model for a very general action (which may also capture an abuse of dominance type action), and use this to compare the desirability of *per se* and effects-based decision rules. This action is assumed to entail both a private benefit for firms taking the action, but, depending on the circumstances under which the action is taken, it may be socially harmful. More precisely, firms taking the action may come from

[7]In fact, they use a measure of "effectiveness" – comprising a no cartel formation (i.e. deterrence) component and the probability of type I and II errors — as a proxy for welfare.

[8]Intuitively, to ensure cartel formation does not increase, the fine must be sufficiently high.

[9]Generally, resource constraints mean that a competition authority cannot investigate every incidence of a given competition offence. In many models of competition policy, the 'coverage rate' therefore defines that fraction of all actions of a given type that, if undertaken, will be investigated by the competition authority under an effects-based approach.

either a harmful or benign environment, with associated harm from taking the action given by $h_H > 0$ and $h_B < 0$, respectively. The model assumes that a fraction γ, $0 < \gamma < 1$, of firms come from the harmful environment, which implies that the average harm, denoted by $\overline{h}$, is equal to

$$\overline{h} = \gamma h_H + (1 - \gamma) h_B.$$

Actions are then characterised according to whether they are presumptively legal (if $\overline{h} < 0$) or presumptively illegal (if $\overline{h} > 0$). Furthermore, the *strength of presumption of legality* (denoted s_L) or *illegality* (denoted s_I), which indicates how far a particular action is from being borderline presumptively legal or illegal, is defined as

$$s_L = \frac{(1 - \gamma)(-h_B)}{\gamma h_H}$$

and

$$s_I = \frac{\gamma h_H}{(1 - \gamma)(-h_B)},$$

respectively.

Under an effects-based regime, the competition authority is assumed to make, with exogenous probability, errors in determining the true harm associated with a given action. Specifically, the parameters (p_H, p_B) define the probability that an action taken by a firm from the harmful or benign environment, respectively, will be correctly identified as such.

A necessary and sufficient condition for an effects-based rule to have lower cost of decision errors than the appropriate *per se* rule is then shown to be that the quality of the authority's decision-making rule, denoted by q_e, $e = H, B$ and itself a function of (p_H, p_B), is greater than the strength of presumption of legality or illegality. That is, for a presumptively legal action, we require that

$$q_H \equiv \frac{p_H}{(1 - p_B)} > s_L, \tag{1.1}$$

while, for a presumptively illegal action, we require that

$$q_B \equiv \frac{p_B}{(1 - p_H)} > s_I. \tag{1.2}$$

When considering a full welfare comparison of effects-based vs. *per se*, there are two distinct impacts to consider. Besides the (absolute) deterrent effect, whereby firms (from either environment) are deterred from taking a given action, an effects-based rule is shown to generate *differential* deterrence effects, whereby firms from the harmful environment are deterred more strongly than firms from the benign environment, which are absent under a *per se* rule. On the other hand, *per se* rules will outperform effects-based rules in absolute deterrence terms, since an effects-based rule will have too strong a deterrent effect when the action is presumptively legal, and so on balance benign, while it will have too weak a deterrent effect when the action is presumptively illegal, and so on balance harmful.

However, it is shown that, if the strength of presumption of legality or illegality is weak, then an effects-based rule will be welfare superior to *per se*. This follows because, with a weak presumption of (il)legality, the conditions for effects-based rules to be superior in decision-error terms will be met (see (1.1) and (1.2)). Furthermore, the average harm $\overline{h}$ will, in such cases, not be significantly different from zero, implying that absolute deterrence will be low. Finally, since the differential deterrence effect always works in favour of an effects-based rule, it will welfare dominate *per se*.

In Katsoulacos and Ulph (2011a), this framework is extended to analyse the impact of judicial reviews and internal error correction mechanisms. Since these will tend to reduce the costs of false convictions (type I errors) and increase the cost of false acquittals (type II errors), they will increase the attractiveness (in decision error terms) of effects-based rules when the former effect outweighs the latter. Furthermore, mechanisms operating under the principle of unanimity will tend to reduce deterrence, and therefore tend to improve overall *welfare* for presumptively legal actions, and worsen overall welfare for presumptively illegal actions.

In this thesis, we will make use of both notions of optimality, depending on the specific modelling context. We describe our research aims and modelling approach more carefully in Section 1.4.

1.2 Welfare Standards

Another issue, which is closely related to the definition of optimal policy, concerns the choice of welfare standard for competition policy. The welfare standard specifies the terms in which the harm from a given competition offence is measured, be it consumer surplus, or the sum of producer and consumer surplus (that is, total welfare).[10] Against the background of conventional welfare economics, which has tended to rely heavily on total welfare as the underlying social objective,[11] it is notable that competition authorities in practice (including in the US and EU) tend to use a consumer surplus standard.[12] This has also led the majority of the academic work in the competition policy field to assume, albeit at times implicitly, a consumer surplus standard.[13]

[10] A hybrid standard, attaching different weights to the consumer and producer surplus elements of total welfare, is also possible.

[11] As, for example, in the textbook treatment of deadweight loss from monopoly.

[12] Canada and New Zealand are rare examples of countries that employ a total welfare standard to judge competition issues, see, e.g., Heyer (2006).

[13] As, for example, in Katsoulacos and Ulph (2009), where firm profits are not aggregated with the standalone 'harm' of the action. Some authors have, however, relied on a total welfare standard in their analysis of competition policy enforcement. See, e.g., Connor and Lande (2005, 2006) in the context of optimal cartel penalties.

This divergence between the conventional welfare economics approach on the one hand, and the practice of competition authorities on the other, raises a number of interesting questions. Firstly, are there factors specific to the competition policy context, which make a consumer surplus standard optimal? Secondly, even if total welfare were the relevant standard for competition policy, are there operational factors which might make the delegation of a consumer surplus standard to the authority optimal?

With regard to the first question, there are a number of factors that may be suggested. Firstly, there may be a distributional issue, in the sense that the gains and losses of competition law infringements may accrue to different income groups.[14] To the extent that losses are suffered primarily by lower-income consumers, while gains accrue to shareholders of firms that, on average, enjoy higher income, the competition authority should indeed (assuming decreasing marginal utility of income) attach greater significance to the losses suffered by consumers than to the gains enjoyed by firms. In other words, it should move from a total welfare standard towards a consumer surplus standard.[15]

This line of argument also relates to the case for a total welfare standard made by Carlton (2007). Since, he argues, firms' profits ultimately accrue to consumers in their shareholding capacity, consumer and producer groups are not clearly delineated. Therefore, a consumer surplus standard is ultimately equivalent to one based on total welfare. This does not hold if we take account of distributional issues: if shareholders are, on average, a higher income group than non-shareholders, producer and consumer groups can be meaningfully separated, and the distributional issue would imply that a stronger emphasis on consumer surplus is justified.[16]

A second factor concerns the ability of affected parties to seek private redress or, more broadly, represent their interests to the competition authorities. Since firms represent a unified organisation, it is typically supposed that they face fewer challenges in representing their views to the competition authority than do the (very disparate) consumers associated with any given product.[17] Neven and Röller (2005) have shown that, if firms (but not consumers) can lobby the competition authority, and the authority is imperfectly monitored in how it applies its delegated welfare standard, adopting a standard that favours consumers can compensate for their lack of lobbying capacity. Essentially, the argument for a consumer surplus standard that emerges here is that, since firms typically have the

[14]Such distributional issues are typically ignored in the conventional welfare economics approach, implying that gains and losses can simply be netted off against each other.

[15]See, e.g., Cseres (2007).

[16]Carlton (2007) further argues against the use of a consumer surplus standard on the basis that it favours short run price reductions over long run efficiency gains, and that fixed cost savings are ignored. Moreover, disregarding producers would also ignore issues of monopsony power, making buying cartels perfectly legal. See also Farrell and Katz (2006) for arguments in favour of a total welfare standard.

[17]See, e.g., Neven and Röller (2005).

ability to lobby and seek redress for themselves, it is the uncorrected externality suffered by consumers that should be the focus of competition policy.

These are two factors that suggest consumer surplus may indeed be the appropriate welfare standard for competition policy. We now turn to the second question, namely, what operational factors may make the implementation of a consumer surplus standard optimal, even if total welfare were the ultimate objective? A first factor to consider here is the feasibility of measuring the total welfare effects of competition infringements. In particular, problems arise when it comes to measuring 'harm' suffered by competitor firms. There are many examples of firms taking actions (such as innovating) that can harm competitors, but that are not anti-competitive in and of themselves.[18] Salop (2010) has made a separate feasibility argument in favour of a consumer surplus standard, claiming that it would be difficult for consumers to be compensated by a tax authority for welfare losses due to specific mergers, if total welfare remained the objective and income redistribution were attempted via this channel.

In addition to these feasibility issues, another reason why it may be optimal to delegate a consumer surplus standard to a competition authority, even if total welfare were deemed to be the appropriate welfare measure, relates to the strategic choices by firms over anti-competitive actions. It has been shown that there are situations in which delegating a consumer surplus standard to the competition authority can bring about higher total welfare than would have arisen, had the authority implemented a total welfare standard directly. The intuition is that, while the authority can approve or disallow an action based on its likely impact on the chosen welfare measure, it cannot directly influence firms to take another action which might have brought about *even higher* welfare. However, when firms choose actions strategically, implementing a consumer surplus standard can influence firms' decisions as to which action to choose, potentially (though not always) resulting in higher total welfare.

This insight is originally due to Lyons (2002). In his model of merger choice, firms propose the most profitable merger to the competition authority. Adopting a (more stringent) consumer surplus-based rule can result in higher welfare when it directs firms towards a less profitable, but socially preferable merger – a phenomenon now commonly referred to as the "Lyons Effect". Other authors have demonstrated similar results. Besanko and Spulber (1993), for example, develop a model of asymmetric information, in which firms have better information about the marginal cost savings arising from a merger. It is shown that total welfare is maximised when the authority implements a welfare standard that gives greater weight to consumers than to producers. Finally, Fridolfsson (2007) develops a two-firm model, in which the firms may either merge or bring about an alterna-

[18]This issue also comes out in the ongoing disputes between *Microsoft* and *Google*, for example, concerning dominance in the search engine market. The arguments are typically not made in terms of harm suffered by consumers as a result of *Google's* dominance, but rather in terms of the harm suffered by competitor firms.

tive change in the market structure (for example via a partial merger). Although there is no endogenous merger formation game as in Lyons (2002), it is shown that, in order to maximise total welfare, the competition authority should follow a standard that is biased in favour of consumers.

While all of the above analysis is carried out in the context of mergers, Katsoulacos and Ulph (2011b) develop a model which demonstrates the potential for a Lyons effect in a more general setting. The general action that is modelled in this paper includes a price-cost margin raising component and a marginal cost reducing component. These action parameters interact with the "competitive environment" from which the firm comes (as captured in the inverse price elasticity of demand) to generate a given consumer surplus and total welfare effect. The model shows that, for actions that are equivalent in their cost-reducing potential, total welfare for any given environment is lower when higher-profit actions are chosen. Moreover, higher profit actions may pass a total welfare standard, but not a consumer surplus standard. As such, there will exist environments for which a consumer surplus standard pushes firms to adopt lower-profit actions that result in higher total welfare – giving rise to a Lyons Effect.[19]

Throughout this thesis, we will typically follow the practice of the majority of competition authorities around the globe, by relying on a consumer surplus standard. In cases where it is interesting to investigate the implications of different welfare standards (as we do in Chapter 2), total welfare will also be considered. See Section 1.4 for further details.

1.3 Legal Uncertainty

A final important and overarching issue relating to the optimal enforcement of competition policy, and in particular to the choice between effects-based and *per se* decision rules, is that of legal uncertainty. This term may be defined loosely as the inability to predict the outcome of a legal process.[20] Until recently, it was argued that, because effects-based rules generate greater legal uncertainty than do *per se* rules, *per se* should be used.[21] Moreover, if effects-based rules are used, penalties should be lower.[22]

In Katsoulacos and Ulph (2014a), the question of legal uncertainty is subjected to a first systematic analysis from an economic perspective, yielding quite different results. The paper firstly clarifies the dimensions in which legal uncertainty can arise. These are twofold: firstly, firms may not know the true nature of their action (whether it is harmful or benign); secondly, firms may not know with certainty

[19] An important limitation of this model is that it does not incorporate profit effects running via rival firms in the market. This is an important question for future research that will not be addressed in this thesis.

[20] See D'Amato (1983) and Davis (2011).

[21] Easterbrook (1992)

[22] Dethmers and Engelen (2011)

whether their action will be deemed to be harmful by the competition authority, if investigated.

With reference to these two dimensions of potential legal uncertainty, Katsoulacos and Ulph (2014a) identify three scenarios that are of particular relevance in the competition policy context. Firstly, in a setting of *no legal uncertainty*, firms know what the outcome of the competition authority's investigation would be, should its action come under scrutiny. Secondly, under *partial legal uncertainty*, firms know the true harm that is implied by their action if they take it. However, they do not know with certainty how their action would be judged by the competition authority, if investigated. Rather, they only know the average conviction rate that applies to actions of their type (harmful or benign). Finally, under *complete legal uncertainty*, firms do not know even the nature of their own action, and therefore base their inferences on an average conviction probability, where the average is taken across the conviction probabilities for both harmful and benign actions.

A first implication of this approach is that an effects-based rule need not necessarily imply legal uncertainty: if the authority bases its decisions on publicly available data and makes its methods public, firms will be able to infer the decision the authority would make (regardless of whether they know the true nature of the action). Katsoulacos and Ulph (2014a) also show that, with exogenous penalties, there is no monotonic link between legal uncertainty and welfare. Indeed, welfare can be higher when there is some degree of legal uncertainty rather than none. When the additional condition is imposed that fines are set optimally,[23] however, a clear welfare ranking of decision rules does emerge: effects-based with partial legal uncertainty dominates effects-based with no legal uncertainty, which dominates effects-based with complete legal uncertainty, which in turn is welfare-equivalent to *per se*. So, in this setting, there is no situation in which a *per se* standard is optimal.[24]

As described more carefully in Section 1.4, while we do not go into questions relating to legal uncertainty in great detail, we can characterise the legal uncertainty setting in most of this thesis as one of partial legal uncertainty (Chapter 2 being the exception).

[23]Another interesting result is that, when there is partial legal uncertainty, the authority will set fines at such a level as to deter all firms from the harmful environment, while deterring none from the benign environment. Thus the view put forward by Schinkel and Tuinstra (2006, p.1274) that, "since imposing fines is assumed to involve next to no cost for the competition authority whereas investigation is costly, fine levels should in fact be set as high as possible, so that expected fines are high despite low detection efforts" (itself an expression of the "Becker Argument", see Immordino and Polo (2008), Becker (1968)) ignores the fact that too high a fine will deter too many benign firms (i.e. cause a type I deterrence error), which is revealed more clearly in this framework.

[24]These results are also proved at a greater level of generality in Katsoulacos and Ulph (2014b).

1.4 Research Questions and Contribution

Against the backdrop of this general framework, our starting point in this thesis is the following observation: there are important circumstances in which competition policy does not operate in insolation, but rather in the context of other important forms of regulation. In particular, we focus on intellectual property rights (as a means to incentivising innovation) and stability-focused banking regulation. In a broad sense, the question to be addressed in this thesis is: how should competition policy be enforced optimally in the presence of these competing regulatory aims?

1.4.1 Part I: Innovative Industries

In the innovation context, there is a vast literature exploring the links between competition and innovation incentives. A debate going back to Arrow (who argued that competition enhances innovation since a competitive firm will have greater incentives than a monopolist to innovate in order to avoid the pressures of competition) and Schumpeter (who argued that competition lowers the incentives to innovate by reducing the monopoly rents attainable by a successful innovator) has more recently emphasised that the relationship between competition and innovation may be non-monotonic, as in Aghion *et al.* (2005).[25]

In contrast to this literature, our focus is not on the competitiveness of the economic environment in a broad sense (as captured by the number of active firms, for example), but rather on the incidence of well-defined anti-competitive actions (that is, abuses of dominance). In particular, we will be interested in (i) the incentives of firms both to engage in anti-competitive conduct and to innovate, and (ii) the associated implications for optimal competition policy enforcement.

In Chapter 2 – "Welfare Effects of Compulsory Licensing" – we explore a specific type of potentially anti-competitive action, namely the refusal on the part of a dominant firm to license its intellectual property. The literature (reviewed in more detail in the introduction to Chapter 2) has so far emphasised the trade-off that competition authorities face when considering a compulsory licensing remedy: while such a policy will promote competition, it should also be expected to reduce the incentives for innovation by undermining the intellectual property rights of innovators. Yet, so far, there are no analytical results characterising the conditions under which welfare will rise or fall in response to compulsory licensing.

Chapter 2 presents a simple model that allows us to derive necessary and sufficient conditions for compulsory licensing to improve welfare. This chapter considers optimal policy from a welfare perspective (deterrence issues are key) and, moreover, covers both a consumer surplus and a total welfare standard.[26] From a legal uncertainty standpoint, the chapter compares two structural alter-

[25]See also Vives (2008), Boone (2000, 2001) and Schmutzler (2013) among many others.

[26]Furthermore, we also consider a 'foreclosure standard', under which the competition authority cares about protecting competition in the market *per se*, by preventing the dominant firm from foreclosing its less efficient rival.

natives for competition policy (voluntary vs. compulsory licensing), which may be interpreted as *per se* legality and *per se* illegality rules towards refusals to license intellectual property, respectively. Therefore, this is a setting in which there is no legal uncertainty.

We show that, when the risk-free rate of interest is low, compulsory licensing unambiguously increases consumer surplus, because it guarantees that the most preferred consumer outcome (that associated with technology transfer) is realised. The effect on total welfare is, in general, ambiguous, but is more likely to be positive when the industry in question is naturally less competitive. Compulsory licensing is also shown to be an effective measure to prevent leading firms foreclosing their less-efficient rivals, since such a policy guarantees that the technology gap between rival firms cannot exceed the critical level beyond which foreclosure occurs. These results are particularly significant given the controversy over several recent, high-profile refusal to license cases, discussed in Chapter 2.

The issue of refusals to license intellectual property and, relatedly, compulsory licensing is closely related to the broader issue of optimal competition policy enforcement in innovative industries. In general, there are two ways in which this question may be approached. Firstly, how should competition policy enforcement differ across industries, depending on their underlying degree of innovative intensity? Secondly, how should competition policy differentiate between offending firms within a *given* industry, depending on whether or not they have also innovated?[27] In both respects, the existing literature (as discussed in more detail in the introduction to Chapter 3) has so far stressed that innovation brings benefits to society, which necessarily makes the optimal policy more lenient in innovative industries, respectively towards firms that innovate in addition to engaging in some anti-competitive conduct.[28]

In Chapter 3 – "Competition Policy in Innovative Industries" – we subject this question to a more systematic analysis. We develop a framework that allows us to separate clearly a firm's decision to innovate from its decision to take some potentially anti-competitive action. This is important, as the firm's decision with respect to innovation falls completely outside the scope of competition policy. In that sense, we can think of the firm's decision as to whether or not to innovate, ignoring any potentially anti-competitive actions that it may take, as defining the appropriate counterfactual relative to which the harm from any competition offence should be calculated. Throughout the model, the setting is one of partial legal uncertainty, since firms are assumed to know the true harm implied by their action, but not the precise verdict that the competition authority would come to in case of an investigation.

The first contribution of Chapter 3 is to develop a notion of the 'true harm'

[27]In fact, as argued in Chapter 3, this distinction is not always clear in the existing literature, where innovative industries are often taken to be those where firms will always innovate if they take some anti-competitive action.

[28]See, e.g., Manne and Wright (2010), Spulber (2008).

that results from a given competition offence, which takes account of a firm's innovation behaviour in the counterfactual position, absent any anti-competitive conduct. In a decision error cost framework, we show that the optimal competition policy should in fact be more stringent towards firms that innovate in addition to taking some anti-competitive action, in the sense that the authority should base its decisions on a lower "liability standard" (reflecting a lower burden of proof). This follows because firms that innovate in addition to taking harmful actions are also more likely, *ceteris paribus*, to have innovated in the counterfactual position. In the context of a simple effects-based enforcement process, we show that this biases the authority's decision errors towards type II (acquittal) errors and away from type I (conviction) errors, in response to which the optimal liability standard should be lowered.

Finally, the framework also suggests that more innovative industries as a whole are more prone to type II errors, which goes against the view expressed (in largely informal terms) in the existing literature that more innovative industries are associated with a greater tendency towards type I errors (e.g. Manne and Wright (2010)). As such, the argument that more innovative industries should face a more lenient competition policy to mitigate this bias towards type I errors is also not supported in our framework.

1.4.2 Part II: The Banking Sector

Paralleling the debate around the interactions between competition and innovation incentives, there is an ongoing debate in the banking literature concerning the link between competition and the stability of banks (as reflected in the riskiness of the assets that they invest in, or the probability of bank runs, see Chapter 4). Influential papers, from Keeley's (1990) 'charter value hypothesis' onwards, have argued that excessive competition may be detrimental to stability, although, as in the innovation context, this result is highly dependent on the specific modelling assumptions (for example, whether competition takes place on the asset or liabilities side of banks' balance sheets). Besides the potentially negative impact that competition may have on stability, the banking literature has focused heavily on the effectiveness of various measures that may be employed to ensure the stability of banks, most importantly minimum capital requirements.[29]

This focus on banking stability, the means of safeguarding it, and in particular the damage that competition may cause to it, may be seen as part of a more general tendency among both regulators and economists to subordinate competition to stability objectives in the banking sector. Yet, as discussed in Chapter 4, there have been very recent and economically meaningful instances in which dominant banks have abused their market power to the detriment of consumers. The study of dominant banks' incentives to behave anti-competitively, and the influence that prudential regulation (in particular minimum capital requirements) has on these

[29] See, e.g., Furlong and Keeley (1989), Hellman *et al.* (2000).

incentives, is therefore highly relevant.

We address this question in Chapter 4 – "Competitive Effects of Bank Capital Regulation". Since this chapter deals with the incentives to behave anti-competitively, we are implicitly taking a deterrence view of optimal competition policy. In this banking context, the question of appropriate welfare standards takes on particular significance, since banks' customers typically include both small and medium-sized firms on the loans side, and individual customers on the deposit side.[30] As motivated more carefully in Chapter 4, we follow the approach taken by competition authorities in practice, by considering both customer groups to fall within the consumer surplus mandate of competition policy.[31] We then characterise generic abuse of dominance actions in both the loan and deposit markets,[32] and investigate the impact of higher capital requirements on the incentives of dominant banks to exploit their market power via these actions.[33]

In general, the effect of increasing capital requirements on the incentives for dominant banks to abuse their market position vis-à-vis its loans customers is shown to depend on the divergence in the equity funding cost between the incumbent and rival banks: when this is sufficiently large, higher capital requirements, by increasing the absolute loan volume of the incumbent, increase the incentives to act anti-competitively. The incentives to exploit depositors via the sale of ancillary financial products – the avenue by which we model abuses of dominance in the deposit markets – is also shown to depend on the magnitude of the equity funding cost differential, as well as on the slope of demand. In order for higher capital requirements to increase the incentives of dominant banks to exploit depositors, the equity cost gap must again be sufficiently large, and the demand curve must be sufficiently flat. Therefore, the central contribution of this chapter is to clarify the conditions under which stability-focused capital regulation conflicts with competition and consumer protection policy in the banking sector.

[30] We are thinking here of simple retail or commercial banks, rather than investment banks.

[31] The inclusion of banks' profits under a total welfare standard is another interesting avenue for research, which will not be explored in this thesis.

[32] Since, in the latter case, the mechanism operates via the sale of ancillary financial products to depositors, we are effectively considering both competition policy and consumer protection policy in this chapter.

[33] The legal uncertainty setting is again one of partial legal uncertainty.

Part I

Innovative Industries

Chapter 2

Welfare Effects of Compulsory Licensing

2.1 Introduction

It is well known that the unregulated exploitation by firms of their intellectual property (IP) rights can limit competition.[1] This chapter examines a particular type of anti-competitive conduct relating to a firm's use of its IP: the unilateral refusal by a dominant firm to license. As with the broader class of anti-competitive actions known as 'refusals to deal', such a refusal to license represents a potential abuse of a dominant position under competition law. A competition authority may therefore impose a compulsory licence – a legal obligation to share IP in exchange for fair, reasonable and non-discriminatory (FRAND) compensation[2] – on a firm that does not license its innovation voluntarily, in order to promote competition in the market. Of course, the argument against compulsory licensing is that, by undermining the IP protection of innovating firms, it reduces firms' incentives to innovate.[3] The impact of compulsory licensing on *welfare* is, therefore, ambiguous, since it promotes competition only at the expense of reduced innovation incentives. This chapter analyses these conflicting effects in a systematic fashion, and derives necessary and sufficient conditions for compulsory licensing to improve welfare.

The appropriate legal treatment of refusals to license IP has been a central issue in numerous high-profile competition cases. Notably, however, the US and European competition authorities have so far adopted quite different approaches to this question. While the US has consistently upheld the rights of IP holders

[1] See, e.g., Pate (2003).

[2] This was the remuneration principle implemented in the European *Microsoft* case. See Carlton and Shampine (2013) and Sidak (2013) for a wider discussion of the issues surrounding FRAND licensing.

[3] See, e.g., Feldman (2009).

by ruling against compulsory licensing – for example in *Xerox*[4] and *Kodak*[5] – the European Commission has imposed compulsory licensing in several landmark cases, most notably in *Microsoft*, but also in *IMS Health* and *Magill*.[6] Katsoulacos (2009) relates this divergence in approaches to the appropriate choice of legal standard by which refusals to license IP should be judged. The US approach in *Xerox* is equated to *per se* legality, while the Commission's legal standard in the *Microsoft* case is considered an example of a low-false-acquittals discriminating rule. The legal standard in the *Magill* and *IMS Health* cases, meanwhile, is argued to be a low-false-convictions test. In a welfare framework, the desirability of these competing legal standards is related to the underlying or average degree of harm associated with refusals to license IP. This average harm is, in turn, reflected in the 'presumption of legality', defined as the ratio of the expected benefit from refusals to license IP that are benign (that is, for which welfare falls if compulsory licensing is imposed) to the expected harm from refusals to license that are truly harmful (that is, for which compulsory licensing would improve welfare). The key insight is that the *per se* legality standard adopted in the US *Xerox* case is welfare-preferred to the discriminating rules (be they of the low-false-acquittals or low-false-convictions type) adopted by the Commission only if the presumption of legality is strong. However, the extent to which refusals to license IP should be viewed as presumptively legal is discussed only informally.

This chapter therefore also builds on Katsoulacos (2009), by investigating more carefully the presumption of legality that should apply to refusals to license IP. In particular, we take explicit account of innovation effects and investigate when compulsory licensing improves welfare, relative to the case where a dominant firm would refuse to license its innovation voluntarily.[7] Our innovation results are derived within the framework of a single innovation tournament model of R&D competition,[8] in which the imposition of compulsory licensing (by weakening the

[4] *CSU, LLC v. Xerox Corp.*, 203 F.3d 1322 (Fed. Cir. 2000).

[5] *Eastman Kodak Co. v. Image Technical Services Inc.*, 125 F.3d 1195 (9th Cir. 1997).

[6] *Microsoft v. Commission*, Case T201/04 (2007); *IMS Health and NDC Health v. Commission*, Case C418/01 (2004), ECR I-5039; and *Magill ITP, BBC and RTE v. Commission*, Cases C241/91 and C242/91 P (1995), ECR I-743.

[7] The welfare effects of compulsory licensing have previously been discussed in Chen (2014), Stavropoulou and Valletti (2013) and Bond and Saggi (2012). Our results extend Chen (2014), by treating innovation as a continuous rather than a binary variable. While the latter approach gives insights into the cases where innovation either falls to zero or remains unchanged following the imposition of compulsory licensing, our approach allows us to look at the intermediate cases where innovation rates may fall *somewhat* in response to compulsory licensing. Stavropoulou and Valletti (2013) and Bond and Saggi (2012) investigate the welfare effects of compulsory licensing in the specific context of North-South pharmaceutical trade, while our model is general.

[8] This is to be contrasted with the general class of "non-tournament" models of R&D. In tournament models, there can only be a single successful innovator, and firms invest in R&D in order to influence their likely date of success. The incentives to invest in R&D here depend on both a *profit incentive* (the difference in profits from innovating successfully and current profits) and the *competitive threat* (the difference in profits from innovating successfully and having the rival innovate successfully), with the relative magnitude of these effects determining the likely

IP protection of innovators) always lowers innovation incentives. While several models have shown that weakening IP protection can actually increase innovation rates,[9] we justify this modelling assumption as follows. The majority of competition authorities around the world, including in the US and EU, follow a consumer surplus standard.[10] In that context, were innovation rates to rise in response to a compulsory licence, such a policy would represent a win-win situation for consumers. To make the trade-off between innovation and competition real, we must therefore have a reduction in R&D incentives when compulsory licensing is imposed. While this may be achieved in more complex dynamic models,[11] the simplest such model is a one-shot tournament model.[12]

We derive our welfare results on the basis of both a consumer surplus and a total welfare standard, as well as in the case where the competition authority cares about protecting competition *per se* under a so-called foreclosure standard. We are able to show that, when the risk-free rate is low, consumer surplus is always higher when a dominant firm is forced to license via compulsory licensing, because this guarantees that the most preferred consumer outcome (that associated with technology transfer) is realised. This result therefore contradicts the view that refusals to license IP should be viewed as strongly presumptively legal, and consequently treated under a *per se* legality standard.[13] Instead, on the basis of Katsoulacos (2009), the discriminating rules adopted by the Commission appear more reasonable. The effect of compulsory licensing on total welfare is more complex, but is shown to be positive whenever the underlying degree of competitiveness in the industry is sufficiently low. We also show that compulsory licensing is an effective policy to protect competition *per se*, since it guarantees that the incumbent cannot foreclose its less-efficient rival.

While these results are derived in a baseline model in which the incumbent is

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innovator. (See the models of Loury (1979), Dasgupta and Stiglitz (1980), Lee and Wilde (1980), Reinganum (1982, 1983, 1985a,b), Harris and Vickers (1985).) In non-tournament models, there are multiple equivalent ways of attaining a new technology, so there can be multiple innovators. See Beath *et al.* (1989b) for a more extensive survey.

[9] See, e.g., Segal and Whinston (2007), who emphasise the *front-loading* effect, according to which weaker protection for innovative entrants may increase R&D, since it increases the incentives to innovate in order to replace the (more protected) incumbent. In models of sequential innovation, the *neck-and-neck* effect predicts that firms will invest more in R&D when they are closer together, so that the bunching of firms that is brought about by compulsory licensing may promote R&D spending in subsequent stages of innovation. See Aghion *et al.* (2001). These effects are discussed in more detail in Vickers (2010).

[10] Two exceptions are Canada and New Zealand, which follow a total welfare standard.

[11] See, e.g., Acemoglu and Akcigit (2012). They show that a so-called *trickle-down* effect makes a staggering of compulsory licensing fees optimal, whereby firms that are furthest behind pay more for the licence. While this mitigates the fall in innovation rates compared to a uniform compulsory licensing policy, innovation rates do still fall relative to the full IP protection benchmark.

[12] See also Gilbert and Shapiro (1996) and Kühn and Van Reenen (2008) for more general discussion of the R&D effects of compulsory licensing.

[13] Rather, this results suggests that refusals to license should be viewed as strongly presumptively *illegal* if consumer surplus is the relevant welfare measure.

the predicted winner of the innovation race – a scenario we refer to as *persistent dominance* – we also demonstrate their validity in an *action-reaction* setting, in which the less-efficient firm is predicted to overtake the incumbent by innovating successfully.[14] It is important to verify that the incentives for dominant firms to refuse to license, and the welfare effects of compulsory licensing carry over to the action-reaction setting, since here the dominance of the incumbent firm is, at least in the dynamic sense, weaker.[15]

The remainder of the chapter is organised as follows. Section 2.2 outlines the model. Section 2.3 discusses the innovation effects of compulsory licensing in the benchmark, persistent dominance case, while Section 2.4 derives the main welfare results. Section 2.5 discusses the action-reaction case before Section 2.6 concludes. All proofs that are not immediate from the context are collected in Appendix A.1.

2.2 The Model

We analyse a homogeneous-product industry in which firms produce under constant marginal costs. The model consists of three stages – innovation, fixed-fee licensing and production – and is solved by backward induction.

2.2.1 Stage 1 – Innovation

Consider an innovation race defined in terms of the gap between a given firm's marginal cost and an existing industry standard. Suppose there are just two firms: the follower has the technology that defines the existing industry standard, while the leader has a technology that is ahead of this industry standard as a result of some previous innovation, to be understood in the sense of lower cost. We write these gaps in the initial position as $g_F = 0$ and $g_L = G$, $0 < G < 1$, for the follower and leader, respectively, where the maximum conceivable gap has been normalised to 1. These gaps translate into marginal costs for firm i of $c_i = 1 - g_i$, so that the initial marginal cost levels are $c_F = 1$ and $c_L = 1 - G$ for the follower and leader, respectively. Firms invest in R&D in order to be the first to discover a new technology that, for whoever is the first to discover, will increase their gap over the industry standard by the amount g, $0 < g < 1 - G$.[16]

We adopt the approach taken elsewhere in the innovation literature by approximating a firm's choice of hazard rate (that is, its instantaneous innovation

[14]This follows Beath *et al.* (1995). See also Carlton and Gertner (2002), who argue that most R&D-intensive industries, such as the IT, pharmaceutical and chemical industries, are characterised by action-reaction competition.

[15]Another concern in the action-reaction setting is that dominant firms may refuse to license in an attempt to limit the innovative advantage that less efficient firms enjoy.

[16]Our set-up is also consistent with certain representations of product *quality*. For example, in Häckner (2000) (assuming homogeneous products), demand for firm i takes the form $p_i(Q) = \alpha_i - Q$, where Q is total output and α_i is firm i's quality parameter. Since costs are normalised to zero in that framework, this is equivalent to our demand environment in which costs vary and quality remains constant (see Section 2.2.3 below).

probability, conditional on no firm having innovated up to that point) by its *competitive threat*.[17] Let the hazard rate chosen by the leader be denoted by $x \geq 0$ and that of the follower by $y \geq 0$. To gain closed-form solutions, we further assume that the R&D costs are quadratic in hazard rates. In these circumstances, it is straightforward to show that the hazard rates chosen by the firms are[18]

$$x = \frac{1}{2r}(\pi_L^w - \pi_L^l) \quad \text{and} \quad y = \frac{1}{2r}(\pi_F^w - \pi_F^l), \tag{2.1}$$

where r is the risk-free rate of interest, and π_i^w and π_i^l denote the operating profits earned by firm $i = L, F$ as a result of winning and losing the innovation race, respectively.

For many of our results, it will be sufficient to consider the *rate-adjusted hazard rate*, which we define as $X = 2r \cdot x$ for the leader and $Y = 2r \cdot y$ for the follower. Note that these are independent of the risk-free rate r. The preceding discussion therefore implies that the leader is the predicted winner of the innovation race if and only if $X > Y$.

2.2.2 Stage 2 – Licensing

For compulsory licensing to be a meaningful policy, it must be the case that not all firms decide to license their innovations voluntarily. Several papers have shown that precisely such an equilibrium involving full diffusion of innovations will result when licensing is based (in whole or in part) on per-unit royalties.[19] Hence, in order for the refusal to license problem to arise, it is necessary to assume that licensing is based on fixed fees only.

In our model, firms bargain over the licence fee at which the technology is shared, and this is assumed to result in a Pareto-efficient outcome. This implies that licensing will only occur voluntarily if it increases the firms' joint profits. We define compulsory licensing as a licensing deal that is (i) imposed by the competition authority when voluntary licensing is not feasible and (ii) priced below the total economic benefit that the innovation brings to the non-innovator (FRAND).

[17] See, e.g., Ulph and Ulph (1998) and related literature. The reliance on the competitive threat as the sole determinant of firms' innovation incentives may also be justified by the following scenario. Suppose the innovator is in fact an outside firm, which auctions off any innovation it discovers. In this auction game, the producing firms' incentives to bid will be given exactly by their competitive threats, since one firm will inevitably acquire the patent rights. In this setting, the competitive threat represents an exact solution to the firms' R&D investment problem.

[18] See Beath *et al.* (1989a) for a more detailed derivation of these results.

[19] See Kamien and Tauman (1986) and Kamien *et al.* (1992) for licensing based purely on royalties, and Sen and Tauman (2007) for the case of optimally combined fixed fees and royalties. In Chen (2014), refusals to license may occur, even with royalties. In particular, in a vertically integrated industry, it is shown that the upstream monopolist may refuse to license in order to maintain vertical control when the upstream market becomes competitive. We will not deal with vertical integration as a motivation for refusals to license in this chapter.

2.2.3 Stage 3 – Production

We consider both a general demand environment, as well as a linear demand example where necessary for the results (see Section 2.2.4 below). At a general level, we suppose that competition takes the form of Cournot, with inverse demand given by twice continuously differentiable function $P(Q)$, with $P'(Q) < 0$ whenever $P(Q) > 0$, where $Q = q_L + q_F$ is aggregate output. Furthermore, we assume that $P(0) > 1$ and $P(Q) < 1 - (G + g)$ for Q sufficiently high. Finally, we make the standard assumption that $P'(Q) + QP''(Q) < 0$ for all $Q \geq 0$ with $P(Q) > 0$.[20] These assumptions ensure the existence and uniqueness of a Cournot equilibrium, with intuitive comparative static properties. In particular, letting $\pi_i(g_L, g_F)$ denote the operating profits of firm $i = L, F$ as a function of the cost gaps, we have $\frac{\partial \pi_i}{\partial g_i} > 0$ and $\frac{\partial \pi_i}{\partial g_k} < 0$, $k \neq i$.[21]

As is standard in homogeneous-product Cournot, equilibrium price, output and therefore consumer surplus depend only on the average cost (equivalently, cost gap). Consequently, in what follows, it is assumed that consumer surplus is a strictly increasing function of the combined cost gap, which we denote by $CS(g_L + g_F)$, with $CS' > 0$. Let

$$\Sigma(g_L, g_F) = \pi_L(g_L, g_F) + \pi_F(g_L, g_F)$$

denote industry profits associated with gaps (g_L, g_F). Finally, let the sum of consumer surplus and firm profits (that is, total welfare) be denoted by

$$TW(g_L, g_F) = \Sigma(g_L, g_F) + CS(g_L + g_F).$$

Unless otherwise stated, we consider a non-drastic innovation, so that both firms produce positive output, both before and after innovation has occurred.

2.2.4 Linear Demand Example

Many of the results to be derived in this chapter depend on the effect of discrete changes in the firms' marginal costs on industry profits. Whenever this rearrangement of costs is such that their sum (and therefore the average cost) remains constant, well-known results can be used to determine the profit effect for general demand functions.[22] However, the majority of cost changes we consider do not satisfy this requirement: not only do costs change across firms, the average cost is also affected. In this case, there are no general results that determine the sign of the aggregate profit effect associated with discrete cost changes.[23]

[20] Novshek (1985)

[21] Amir *et al.* (2013), Linnemer (2003)

[22] Because, in that simple case, aggregate output, price, industry revenue and consumer surplus are unaffected. See Salant and Shaffer (1999).

[23] Février and Linnemer (2004) develop general results for marginal cost changes. Since we are concerned with *discrete* cost changes, these results apply here only in the sense of first-order approximations. While the nature of the results is unchanged under the approximation method, we focus on the linear demand set-up for tractability.

We therefore introduce a simple linear-demand set-up to deal with this complication where it arises. Suppose then, for the sake of this example, that inverse demand is given by

$$P(Q) = (1+\epsilon) - Q, \qquad \epsilon > 0.$$

The benefit of this specification is that we can interpret the ϵ parameter as a measure that is inversely related to the 'competitiveness' of the market. This follows since, under the price-output combination $(P,Q) = (1,\epsilon)$ (that is, the one which prevails if price equals marginal cost under the initial industry standard),

$$\epsilon = -\frac{P'(Q)Q}{P(Q)}.$$

Therefore ϵ measures the inverse elasticity of demand at the competitive equilibrium corresponding to the initial industry standard.[24]

In a Cournot equilibrium, industry profits are symmetric and are given by

$$\Sigma(g_L, g_F) = \frac{1}{9}\left[(\epsilon + 2g_L - g_F)^2 + (\epsilon + 2g_F - g_L)^2\right],$$

while consumer surplus is equal to

$$CS(g_L + g_F) = \frac{1}{18}\left(2\epsilon + g_L + g_F\right)^2.$$

In terms of notation, we write z_i^{js} for the value of variable z that accrues to firm $i = L, F$ if the winner of the race is firm $j = L, F$, and if the degree of information sharing is $s = N, V, C$, where N denotes no licensing, V denotes a voluntary licensing regime and C denotes compulsory licensing. If a variable z is written without subscript i, it accrues to society as a whole rather than to either of the firms.

2.3 Innovation Effects of Compulsory Licensing

Having outlined the individual components of our modelling framework, this section considers the innovation effects of compulsory licensing, relative to a benchmark case in which firms are permitted to license voluntarily. As will be shown, compulsory licensing indeed imposes a cost by reducing aggregate R&D spending. Before deriving these results, it is useful to start by considering firms' innovation behaviour in the absence of licensing.

The predicted winner of the innovation race can be determined with reference to the rate-adjusted hazard rates, which depend solely on the difference in profits associated with winning and losing the innovation race. Noting that the cost gaps, conditional on the leader innovating, are $(g_L^{LN}, g_F^{LN}) = (G + g, 0)$, while, if the

[24] This measure of industry competitiveness is also used in Katsoulacos and Ulph (2013), for example. Measuring elasticity at the competitive equilibrium avoids the cellophane fallacy.

follower innovates, they are $(g_L^{FN}, g_F^{FN}) = (G, g)$, these rate-adjusted hazard rates are given by

$$X^N = \pi_L(G+g, 0) - \pi_L(G, g)$$

and

$$Y^N = \pi_F(G, g) - \pi_F(G+g, 0)$$

for the leader and follower, respectively. So, if there is no licensing, the leader has a strictly greater incentive to innovate if and only if $X^N > Y^N$, which is to say

$$\Sigma(G+g, 0) > \Sigma(G, g). \tag{2.2}$$

As proved in Lemma 1 below, this condition is always satisfied, even in our general demand environment. It follows that we are in a persistent dominance setting.

Lemma 1. *In the absence of licensing, the leader is the predicted winner of the innovation race,* $X^N > Y^N$.

Proof. Appendix A.1. □

2.3.1 Voluntary Licensing Benchmark

Now consider the incentives of each firm to license its innovation voluntarily, conditional on innovating successfully. The consequence of either firm's decision to license its discovery is that *both* firms' cost gaps will increase by an amount g following innovation. Therefore, if the leader wins and licenses, the cost gaps are equal to $(g_L^{LV}, g_F^{LV}) = (G+g, g)$. Conditional on the leader being the first to innovate, we can write the minimum price that the leader would be willing to accept for the licence and the maximum price that the follower would be willing to pay for the licence as

$$\underline{P}^L = \pi_L(G+g, 0) - \pi_L(G+g, g) \tag{2.3}$$

and

$$\overline{P}^L = \pi_F(G+g, g) - \pi_F(G+g, 0), \tag{2.4}$$

respectively. So, if the leader innovates, voluntary licensing will take place if and only if

$$\Sigma(G+g, g) > \Sigma(G+g, 0). \tag{2.5}$$

That is, voluntary licensing will occur if and only if such an agreement increases industry profits.

If the follower wins the innovation race and licenses, the cost gaps are also equal to $(g_L^{FV}, g_F^{FV}) = (G+g, g)$. Therefore, provided licensing takes place, operating profits and consumer surplus are the same, regardless of which firm makes the innovation. The minimum price that the follower would be willing to accept for the licence and the maximum price that the leader would be willing to pay are, respectively,

$$\underline{P}^F = \pi_F(G, g) - \pi_F(G + g, g) \tag{2.6}$$

and

$$\overline{P}^F = \pi_L(G + g, g) - \pi_L(G, g). \tag{2.7}$$

Therefore, if the follower innovates, licensing will take place if and only if

$$\Sigma(G + g, g) > \Sigma(G, g). \tag{2.8}$$

Notice that, given that (2.2) holds, it follows from (2.5) and (2.8) that if the leader licenses the innovation, then the follower certainly will. Conversely, if the follower does not license the discovery, then neither will the leader. For competition authorities to want to compel firms to license, it must be the case that at least one of the firms would choose not to license voluntarily. So it certainly has to be the case that the leader does not license. Consequently, in what follows, it will be assumed that[25]

$$\Sigma(G + g, g) < \Sigma(G + g, 0). \tag{2.9}$$

Since, if the follower licenses, both the average cost gap and the variance of costs increase, it is natural to assume that the follower *will* license, conditional on innovating.[26] Hence it is assumed that (2.8) holds, which in combination with (2.9) implies that

$$\Sigma(G + g, 0) > \Sigma(G + g, g) > \Sigma(G, g). \tag{2.10}$$

Let us denote the voluntary licence payment in case the follower discovers first and licenses by P^F, and write this as a weighted average of the reservation prices (2.6) and (2.7), so that

$$P^F = \sigma \left[\pi_F(G, g) - \pi_F(G + g, g)\right] + (1 - \sigma) \left[\pi_L(G + g, g) - \pi_L(G, g)\right].$$

Here σ, $0 < \sigma < 1$, is a parameter capturing the bargaining strength of the leader. Consequently, with voluntary licensing, the rate-adjusted hazard rates are given by

$$X^V = X^N - \sigma \left[\Sigma(G + g, g) - \Sigma(G, g)\right],$$
$$Y^V = Y^N + (1 - \sigma) \left[\Sigma(G + g, g) - \Sigma(G, g)\right].$$

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[25]In the context of our linear demand set-up, this condition is equivalent to the requirement that $2\epsilon < 3g + 8G$.

[26]See Salant and Shaffer (1999). In the context of our linear demand example, it is straightforward to verify that a sufficient condition for the follower to license is that $g < G$. This condition is far from being necessary, however. Indeed, the necessary and sufficient condition for the follower *not* to license is $3g > 2\epsilon + 10G$. In other words, a necessary condition for the follower to refuse to license is that the gap opened up by the new discovery is more than three times as large as the initial gap of the leader.

From (2.10) it follows that, if firms can license, this will reduce the hazard rate of the leader but raise the hazard rate of the follower.[27] Nonetheless, the leader still remains the predicted winner of the innovation race, since, by (2.10)

$$X^V - Y^V = \Sigma(G+g,0) - \Sigma(G+g,g) > 0. \tag{2.11}$$

In other words, the persistent dominance result in Lemma 1 is robust to the addition of voluntary licensing.

Before considering the innovation and welfare impacts of compulsory licensing, the following section discusses briefly the relevance of expectations and the "regulatory threat" for bargaining outcomes at the voluntary licensing stage. Importantly, the results presented in this section are robust to an alternative specification based on expectations.

2.3.2 Voluntary Licensing and the "Regulatory Threat"

So far, we have not taken explicit account of the fact that firms may anticipate a compulsory licence being imposed, in case no voluntary agreement is reached. One may think that the mere *threat* of regulatory intervention could spur firms to agree voluntary deals that would not be agreed in the absence of such a threat. In that case, the threat of a compulsory licence being imposed might resolve the refusal to license problem in and of itself. This is closely related to the issue of voluntary agreements in environmental regulation, where the regulatory threat can have precisely this effect.[28]

However, if we let θ^j, $0 \leq \theta^j \leq 1$, denote the (common) probability with which firms anticipate a compulsory licence being imposed on innovating firm $j = L, F$ in case no voluntary agreement is reached, it is possible to show that the licensing conditions (2.5) and (2.8) are unchanged when we allow for arbitrary expectations. Intuitively, a higher probability of compulsory licensing distorts the firms' reservation prices towards the expected, exogenous FRAND fee. Since this just represents a transfer between firms that does not affect industry profits, the licensing condition is still determined on the basis of (2.5) and (2.8). Hence the threat of compulsory licensing alone cannot solve the underlying refusal to license problem (see Appendix A.2 for details).

[27] This replicates the result of Katz and Shapiro (1985) and others, who show that voluntary licensing has an ambiguous effect on industry-wide innovation incentives, relative to no licensing. As in that paper, aggregate innovation incentives will rise if the bargaining strength of the licensor (here: the follower) is high, specifically if $\sigma < \frac{1}{2}$.

[28] See, e.g., Manzini and Mariotti (2003), Árguedas (2005) and Segerson and Miceli (1998). A notable difference in the bargaining context analysed in those papers is that all firms lose out as a result of environmental regulation. In the compulsory licensing context, the non-innovator actually benefits when compulsory licensing is imposed.

2.3.3 Compulsory Licensing

Having developed this benchmark voluntary licensing case, we now consider the innovation effects of compulsory licensing. Under a policy of compulsory licensing, the leader will be obliged by the competition authority to share its discovery at FRAND prices if it innovates successfully. Moreover, firms will take this into account when investing in R&D. As discussed in Section 2.2, we assume that such a FRAND licence must be priced below the economic benefit that the innovation brings to the non-innovator. This implies that the FRAND licence price must satisfy[29]

$$P^{FRAND} \leq \pi_F(G+g,g) - \pi_F(G+g,0),$$

which we can write more conveniently as

$$P^{FRAND} = \phi \left[\pi_F(G+g,g) - \pi_F(G+g,0)\right], \tag{2.12}$$

where ϕ is a constant in the interval $[0,1]$. This FRAND price is, moreover, assumed to be commmon knowledge. By simple algebraic comparison, it then follows that the hazard rates of the firms are always identical under compulsory licensing. Therefore the outcome of the innovation race becomes indeterminate.

Lemma 2. *Under compulsory licensing, the hazard rates of the leader and follower are identical,* $X^C = Y^C = P^{FRAND} + P^F$.

The intuition for this result is clear. Regardless of whether a given firm wins or loses the innovation race, its operating profits will be constant because the innovation is shared in either case. Since what matters in determining the hazard rates is the difference in profits from winning and losing the innovation race, the incentives of the leader (to win so as to earn the FRAND fee and avoid paying under the voluntary licensing deal if the follower wins) are now exactly equal to those of the follower (to win so as to earn the voluntary licensing fee and avoid paying the FRAND price). Note also that this result is independent of the precise *level* at which the FRAND licence price is set.

The next result summarises the innovation incentives of firms across the voluntary and compulsory licensing regimes under persistent dominance.[30]

Lemma 3. *The (rate-adjusted) hazard rates of the firms are ranked as follows,* $X^V > Y^V \geq X^C = Y^C$.

Proof. Appendix A.1. □

This result therefore confirms the cost side of the welfare trade-off discussed in the introduction: compulsory licensing reduces industry-wide innovation incentives.

[29] Note that the FRAND requirement is therefore equivalent to the requirement that (see (2.4)) $P^{FRAND} \leq \overline{P}^L$. That is, the FRAND price must be below the total willingness of the non-innovator to pay for the licence in a voluntary licensing scenario.

[30] Since the focus of the chapter is the effect of compulsory licensing relative to a voluntary licensing benchmark, we exclude for brevity the no-licensing regime from these comparisons.

2.4 Welfare Effects of Compulsory Licensing

This section presents the main results of the chapter, relating to the welfare effect of compulsory licensing when the costs of reduced innovation incentives (demonstrated in Lemma 3) are balanced against the pro-competitive benefits (in the form of increased industry output) of technology transfer. We consider in turn three welfare standards: consumer surplus, total welfare, and foreclosure.

2.4.1 Consumer Surplus

As a first step towards a full welfare analysis of compulsory licensing on the basis of a consumer surplus standard, we derive an expression for the expected present discounted value of consumer surplus, which accounts for R&D effects. Let $v(x, y)$ denote this present discounted consumer surplus, given hazard rates x and y. We know that consumer surplus before an innovation occurs is given by $CS(G)$, while consumer surplus following an innovation by firm $j = L, F$ and given licensing regime $s = V, C$ is denoted by CS^{js}. We can then write the present discounted value of consumer surplus as[31]

$$v(x^s, y^s) = \frac{x^s \frac{CS^{Ls}}{r} + y^s \frac{CS^F}{r} + CS(G)}{x^s + y^s + r}. \tag{2.13}$$

The necessary and sufficient condition for consumer surplus to be higher under compulsory licensing than under voluntary licensing is

$$v(x^C, y^C) > v(x^V, y^V).$$

In order to isolate the effect of the risk-free interest rate r, we can write the above condition in terms of rate-adjusted hazard rates as

$$\begin{aligned} \frac{X^C X^V}{r^2} \left[CS(G + 2g) - CS(G + g)\right] + CS(G) \left(X^V + Y^V - 2X^C\right) \\ > X^V CS(G + g) - CS(G + 2g) \left(2X^C - Y^V\right). \end{aligned} \tag{2.14}$$

This expression may be interpreted as follows. The first term is positive and reflects the fact that, post-innovation, consumers will on average enjoy a higher level of surplus under compulsory licensing than under voluntary licensing, because the possibility that the leader will innovate and refuse to license is removed. The second term is positive because, as shown in Lemma 3, aggregate innovation rates are lower under compulsory licensing, which implies that consumers will enjoy the status quo surplus for longer in expectation. Hence the inequality can only fail on account of the terms on the second line, the sign of which is ambiguous. On average, consumers will jump to a higher level of consumer surplus sooner under

[31]The derivation of this expression parallels the derivation of present discounted profits in Grossman and Shapiro (1987, p. 374) and Beath *et al.* (1989, p. 165), for example.

voluntary licensing since innovation rates are higher. On the other hand, the level of surplus that consumers will enjoy post-innovation under voluntary licensing is lower than that which they would enjoy post-innovation under compulsory licensing, due to the technology transfer effect.

In what follows, we will simplify the problem by considering an economic environment in which the risk-free rate r is 'low'.[32] Multiplying (2.14) through by r^2 and letting $r \to 0$, the consumer surplus effect is then positive if and only if [33]

$$CS(G+2g) - CS(G+g) > 0, \tag{2.15}$$

which is clearly satisfied. Hence we have the following welfare result.

Proposition 1. *When the risk-free rate is low, compulsory licensing increases consumer surplus, even when dynamic incentive effects are taken into account,* $v(x^C, y^C) > v(x^V, y^V)$.

Intuitively, when the risk-free rate is low, consumers are more concerned with the identity of the innovating firm and the associated licensing outcome than the precise timing of the innovation.[34] Since both firms' innovations result in a cost reduction of magnitude g, forcing the leader to license via compulsory licence is equivalent here (from a consumer surplus point of view) to the follower licensing voluntarily. Therefore, compulsory licensing guarantees that the most preferred consumer outcome (that associated with technology transfer) is achieved with certainty,[35] making it unambiguously preferred to voluntary licensing in consumer surplus terms.

It also follows that the presumption of legality that applies to refusals to license IP, as judged by a consumer surplus standard, is extremely weak in these circumstances. We next consider the implications of compulsory licensing for total welfare.

[32] Note that, since the risk-free rate scales the magnitude of the competitive threats in (2.1), the assumption of low r is also implicit in the assumption that the competitive threats dominate firms' innovation decisions, as in Ulph and Ulph (1998). The economic implication of this assumption is that dynamic concerns relating to the likely identity of the innovating firm take precedence over the precise timing of the innovation. This assumption is therefore most reasonable in high-tech industries, where the rate of innovation is relatively high.

[33] Note that the limit argument is adopted for convenience only. Collecting the terms in (2.14) that are discounted by r^2 in a new term, call it A, and those that are not in another term, call it B, so that (2.14) can be written as $\frac{A}{r^2} + B > 0$, what is strictly required in order for the risk-free rate to be considered "low" in the sense we have in mind here is that $r < \sqrt{A/|B|}$ whenever $B < 0$.

[34] Of course, if $B > 0$ in the preceding footnote (a sufficient condition for which is that $CS(G+2g)\left(2X^C - Y^V\right) > CS(G+g)X^V$) then Proposition 1 also holds for arbitrarily large r.

[35] This is an important difference to the action-reaction case analysed in Section 2.5, where the identity of the innovating firm does still matter under compulsory licensing.

2.4.2 Total Welfare

Using analogous notation to that in Section 2.4.1, we can write the present discounted total welfare resulting from hazard rates x and y, given information sharing regime $s = V, C$, as

$$W(x^s, y^s) = \frac{1}{x^s + y^s + r} \left\{ \begin{array}{l} x^s \left(\dfrac{TW^{Ls}}{r} \right) + y^s \left(\dfrac{TW^F}{r} \right) \\ + TW(G, 0) - (x^s)^2 - (y^s)^2 \end{array} \right\}. \tag{2.16}$$

In terms of total welfare, compulsory licensing will be preferred to voluntary licensing if and only if

$$W(x^C, y^C) > W(x^V, y^V). \tag{2.17}$$

When the risk-free rate is low, the condition implied by (2.17) can be written as

$$X^C X^V \Delta_{TW} + \Delta_c > 0,$$

where

$$\Delta_{TW} = [\Sigma(G+g, g) - \Sigma(G+g, 0)] + [CS(G+2g) - CS(G+g)] \tag{2.18}$$

captures the difference in total welfare levels, absent R&D costs, and $\Delta_c > 0$ is a term capturing the R&D cost savings under compulsory licensing relative to voluntary licensing. The term Δ_{TW} is made up of both a negative (see (2.10)) profit effect and a positive consumer surplus effect. Since, moreover, we can say on the basis of our linear demand example that Δ_{TW} is increasing in ϵ (that is, the degree to which the market is uncompetitive) and positive whenever[36]

$$8\epsilon > 3g + 14G, \tag{2.19}$$

we have the following result.[37]

Proposition 2. *When the risk-free rate is low, the total welfare effect of compulsory licensing is positive whenever the underlying degree of competitiveness in the industry is sufficiently low.*

Therefore, in industries that are uncompetitive, the consumer gain from increased output associated with compulsory licensing will outweigh the loss in terms of aggregate profits suffered by firms. If, on the other hand, the industry is sufficiently competitive, it is total welfare improving to allow the dominant firm to refuse to license, rather than imposing a compulsory licence.

[36] This follows because $\Delta_{TW} = \frac{g}{18}(8\epsilon - 3g - 14G)$.

[37] It is well known that tournament models provide incentives for socially excessive investment in R&D (see, e.g., Beath *et al.* (1995)). It should be noted in this regard that our results are robust to the inclusion of spillovers (by which innovation incentives can be made arbitrarily small) and, as such, they are not driven by this average over-investment issue. See Appendix A.3 for details.

2.4.3 Foreclosure

We now consider the final welfare standard that a competition authority may implement: a foreclosure standard. This is motivated by the concern that a refusal to license by the dominant firm may result in the follower exiting the market. Relaxing the assumption of a non-drastic innovation for this section, we can see that, in our linear demand example, foreclosure will occur whenever

$$g_L > \widehat{g}_L\left(g_F\right) \equiv \epsilon + 2g_F. \tag{2.20}$$

It follows that forcing the leader to share its innovation guarantees that its lead over the follower will not exceed the critical level $\widehat{g}_L\left(g_F\right)$ defined in (2.20).

This result holds far more generally, however. In homogeneous-product Cournot with constant marginal costs, each firm's output necessarily increases in response to a cost shock that reduces all firms' costs symmetrically.[38] For our purposes, we can restate this existing result as follows.

Proposition 3. *If both firms are active before any innovation occurs, compulsory licensing guarantees that both firms remain active post-innovation.*

Compulsory licensing is therefore an effective policy to protect competition *per se*.

In the remainder of the chapter, we explore the robustness of our welfare results by considering an alternative R&D setting, in which, rather than the leader being the predicted winner of the innovation race (*persistent dominance*), the follower is predicted to innovate, and this innovation allows the follower to overtake the leader's technology (*action-reaction*). As will be shown, our welfare results continue to hold under this alternative setting of R&D competition.

2.5 Action-Reaction R&D Competition

2.5.1 Innovation Effects of Compulsory Licensing

In order to generate action-reaction, assume from now on that, if the follower innovates, its cost gap will increase by an amount $G + g$, while if the leader innovates, its gap will increase by g. This implies that both firms are now racing to achieve a post-innovation gap of $G + g$. In the absence of licensing, it is then straightforward to show that the rate-adjusted hazard rates of the firms can be written as

$$X^N = \pi_L(G + g, 0) - \pi_L(G, G + g),$$

$$Y^N = \pi_F(G, G + g) - \pi_F(G + g, 0).$$

It follows that the necessary and sufficient condition for the *follower* to be the predicted winner of the innovation race is

$$\Sigma(G, G + g) > \Sigma(G + g, 0), \tag{2.21}$$

[38] See, e.g., Février and Linnemer (2004).

which, in the context of our linear Cournot example, requires that

$$2\epsilon > 8g + 3G. \tag{2.22}$$

Thus action-reaction will occur in industries in which the baseline level of competitiveness is sufficiently low. Since we are interested in investigating the innovation and welfare effects of compulsory licensing in action-reaction industries, we assume that (2.21), and therefore (2.22), are satisfied.

Voluntary Licensing Benchmark

Turning to the firms' voluntary licensing decisions, note that the cost gaps, conditional on the leader innovating and licensing, are $(g_L^{LV}, g_F^{LV}) = (G + g, g)$. Hence the minimum price that the leader would accept in order to sell the licence and the maximum price that the follower would be willing to pay are as in (2.3) and (2.4), which in turn implies that the leader will again license if and only if

$$\Sigma(G + g, g) > \Sigma(G + g, 0). \tag{2.23}$$

If the follower innovates and licenses, then $(g_L^{FV}, g_F^{FV}) = (2G + g, G + g)$. Hence the minimum price that the follower would accept for the licence, and the maximum price that the leader would be willing to pay are now

$$\underline{P}^F = \pi_F(G, G + g) - \pi_F(2G + g, G + g), \tag{2.24}$$

and

$$\overline{P}^F = \pi_L(2G + g, G + g) - \pi_L(G, G + g), \tag{2.25}$$

respectively, and so licensing will take place if and only if

$$\Sigma(2G + g, G + g) > \Sigma(G, G + g). \tag{2.26}$$

Now, on the basis of our linear demand example, (2.23) holds if and only if $2\epsilon > 3g + 8G$, while (2.26) holds if and only if $2\epsilon > 3g - 7G$. So it will again be the case that if the leader chooses to license, the follower certainly will, while if the follower chooses not to license, then neither will the leader. Note, moreover, that condition (2.22) guarantees that the follower *will* license, conditional on innovating. We therefore assume that (2.26) is satisfied while (2.23) is not, and instead we have

$$\Sigma(G + g, 0) > \Sigma(G + g, g). \tag{2.27}$$

As in the persistent dominance case, this implies that only the follower will license its discovery voluntarily.

Writing the voluntary licence payment in case the follower innovates as a weighted average of the reservation prices (2.24) and (2.25), this licence payment is equal to

$$\begin{aligned} P^F = &\sigma \left[\pi_F(G, G + g) - \pi_F(2G + g, G + g)\right] \\ &+ (1 - \sigma) \left[\pi_L(2G + g, G + g) - \pi_L(G, G + g)\right], \end{aligned}$$

where σ, $0 < \sigma < 1$, is again the bargaining strength of the leader. The hazard rates under voluntary licensing then follow as

$$X^V = X^N - \sigma \left[\Sigma(2G + g, G + g) - \Sigma(G, G + g) \right],$$

$$Y^V = Y^N + (1 - \sigma) \left[\Sigma(2G + g, G + g) - \Sigma(G, G + g) \right].$$

With reference to (2.26), we can see that, despite the follower having been more likely to innovate in the first place, introducing voluntary licensing increases the hazard rate of the follower and decreases the hazard rate of the leader.[39]

Compulsory Licensing

Following the same definition of FRAND licensing given in Section 2.2, the FRAND licence fee must again satisfy

$$P^{FRAND} = \phi \left[\pi_F(G + g, g) - \pi_F(G + g, 0) \right],$$

with $0 \leq \phi \leq 1$. Unlike in the persistent dominance scenario, however, the operating profits of a given firm associated with winning and losing the innovation race are not equal under compulsory licensing, because the magnitude of the cost saving now depends on the identity of the innovating firm. As the next Lemma shows, this in turn implies that, under action-reaction, the innovation incentives are not equalised when compulsory licensing is imposed.

Lemma 4. *Under action-reaction, the follower remains the predicted winner of the innovation race when compulsory licensing is imposed, $Y^C > X^C$.*

Proof. Appendix A.1. □

Nonetheless, despite the fact that compulsory licensing does not equalise the hazard rates, since it reduces the hazard rate of the leader and (weakly) reduces the hazard rate of the follower, it will again reduce the industry-wide innovation incentives relative to the voluntary licensing benchmark. Therefore the cost of compulsory licensing in terms of reduced innovation rates remains, as summarised in the next result.

Lemma 5. *Under action-reaction, compulsory licensing reduces aggregate R&D incentives relative to a voluntary licensing regime, $X^V + Y^V > X^C + Y^C$.*

Proof. Appendix A.1. □

Finally, denoting the absolute magnitudes of the changes in hazard rates by $\Delta X = X^V - X^C > 0$ and $\Delta Y = Y^V - Y^C \geq 0$, it is also possible to show that $\Delta X > \Delta Y$ whenever $\Sigma(G + g, 0) > \Sigma(G + g, g)$, which, given (2.27), is satisfied. Hence we have the following result.[40]

[39] Of course, this also implies that the follower will remain the predicted winner of the race. By (2.21) and (2.26), we have $X^V - Y^V = \Sigma(G + g, 0) - \Sigma(2G + g, G + g) < 0$.

[40] In this sense, the refusal by the leader to license voluntarily can also be seen as an attempt to limit the extent of action-reaction in the market.

Lemma 6. *The imposition of compulsory licensing further strengthens the action-reaction properties of the innovation race, since $\Delta X > \Delta Y$.*

We may now consider the welfare effects of compulsory licensing under action-reaction, as judged both by a consumer surplus standard and a total welfare standard.[41]

2.5.2 Welfare Effects of Compulsory Licensing

Consumer Surplus

In order to assess the consumer surplus implications of compulsory licensing, first consider the consumer surplus levels associated with the various outcomes of the innovation race. Let $CS^F = CS(3G+2g)$ denote the level of consumer surplus that results if the follower innovates under either voluntary or compulsory licensing, $CS^{LC} = CS(G+2g)$ denote the level of surplus that results if the leader innovates under compulsory licensing, and $CS^{LV} = CS(G+g)$ the level of surplus that results if the leader innovates (and refuses to license) under voluntary licensing. Since $CS' > 0$, we know that $CS^F > CS^{LC} > CS^{LV}$.

We know that compulsory licensing will be consumer surplus preferred to voluntary licensing if and only if

$$v(x^C, y^C) > v(x^V, y^V).$$

With reference to (2.1) and (2.13), and assuming that the risk-free rate is low, this condition holds if and only if

$$X^C X^V (CS^{LC} - CS^{LV}) + X^V Y^C (CS^F - CS^{LV}) - X^C Y^V (CS^F - CS^{LC}) > 0. \tag{2.28}$$

Relative to the corresponding expression in the persistent dominance case (see (2.15)), the condition now includes a negative term. This reflects the fact that compulsory licensing no longer guarantees the most preferred consumer outcome: there is a chance now that the leader will innovate under compulsory licensing, yielding CS^{LC}, while under voluntary licensing it would have been the follower that innovates, yielding $CS^F > CS^{LC}$ (this occurs with probability $x^C y^V$). Compared to the persistent dominance case, this makes compulsory licensing relatively less attractive when we have action-reaction.

Nonetheless, compulsory licensing must still be preferred to voluntary licensing in a probabilistic sense. This follows because compulsory licensing strengthens the relative likelihood that the follower will innovate, yielding the more valuable innovation to consumers (Lemma 6), while, if the leader were to innovate, the innovation will still be shared by compulsory licensing.

[41] The results from the foreclosure standard carry over unchanged to the action-reaction setting.

Formally, bearing in mind that $CS^{LC} > CS^{LV}$, a sufficient condition for (2.28) to hold is

$$X^V Y^C > X^C Y^V,$$

which can be rewritten as

$$1 + \frac{\Delta X}{X^C} > 1 + \frac{\Delta Y}{Y^C}. \tag{2.29}$$

Since $\Delta X > \Delta Y$ (Lemma 6) and $X^C < Y^C$ (Lemma 4), this is always satisfied. Hence we have the following result.

Proposition 4. *When the risk-free rate is low, compulsory licensing increases consumer surplus under action-reaction,* $v(x^C, y^C) > v(x^V, y^V)$.

This section also makes clear that, even when r is low, dynamic effects could still make the consumer surplus impact of compulsory licensing ambiguous. This is true whenever such a policy shifts the innovation probabilities in favour of those firms that make less significant innovations. The effect is unambiguous here because compulsory licensing makes it relatively *less* likely that the leader will innovate.

Total Welfare

In this section, we let $\Sigma^F = \Sigma(2G+g, G+g)$ denote industry profits if the follower innovates under either voluntary or compulsory licensing, $\Sigma^{LC} = \Sigma(G+g, g)$ denote industry profits if the leader innovates under compulsory licensing, and $\Sigma^{LV} = \Sigma(G+g, 0)$ denote profits if the leader innovates (and refuses to license) under voluntary licensing. We know from (2.21), (2.26) and (2.27) that $\Sigma^F > \Sigma^{LV} > \Sigma^{LC}$. Given the ranking of consumer surplus outcomes in Section 2.5.2, this also implies that $TW^F > \max\left[TW^{LC}, TW^{LV}\right]$.

The necessary and sufficient condition for compulsory licensing to be total welfare preferred to voluntary licensing is

$$W(x^C, y^C) > W(x^V, y^V),$$

where the W function is given in (2.16). When the risk-free rate is low and excluding the cost savings term for simplicity,[42] this condition can be written in terms of rate-adjusted hazard rates as

$$\begin{aligned} X^C X^V \left[TW^{LC} - TW^{LV}\right] + X^V Y^C \left[TW^F - TW^{LV}\right] \\ - X^C Y^V \left[TW^F - TW^{LC}\right] > 0. \end{aligned} \tag{2.30}$$

Therefore, if $TW^{LC} > TW^{LV}$, so that compulsory licensing would increase total welfare in a persistent dominance scenario, then this will also hold under

[42] These would of course tend to favour compulsory licensing over voluntary licensing in the total welfare comparison.

action-reaction (since $X^V Y^C > X^C Y^V$, see (2.29)). If, on the other hand, TW^{LV} exceeds TW^{LC} to a sufficient degree, then the expression in (2.30) may turn negative. Given that, in the context of our linear demand example, the difference $TW^{LC} - TW^{LV}$ is increasing in ϵ (that is, the degree to which the industry is uncompetitive, see (2.19)), this leads to our final welfare result.

Proposition 5. *When the risk-free rate is low, the total welfare effect of compulsory licensing is positive under action-reaction whenever the underlying degree of competitiveness in the industry is sufficiently low.*

Moreover, given that (2.30) still holds when $TW^{LC} = TW^{LV}$, it follows that the threshold degree of "un-competitiveness" above which the total welfare effect is definitely positive is lower in the case of action-reaction that under persistent dominance. In other words, the total welfare effect of compulsory licensing is in fact more likely to be positive under action-reaction than under persistent dominance.

2.6 Conclusion

This chapter has developed a framework that clarifies the trade-off between competition and innovation incentives that competition authorities face when considering a compulsory licensing remedy. Our welfare results show that, despite the fact that innovation incentives fall when compulsory licensing is imposed, such a policy nonetheless increases consumer surplus when the risk-free rate is low. It follows that the presumption of legality surrounding refusals to license IP, assuming a consumer surplus standard, is not strong. This result therefore supports the approach taken by the European Commission in *Microsoft*, *IMS Health* and *Magill*, in which it ruled in favour of compulsory licensing on the basis of discriminating decision rules, rather than upholding the rights of IP holders by implementing a *per se* legality standard, as in the US *Xerox* case.[43] The imposition of compulsory licensing was also shown to be justified if the competition authority follows a foreclosure standard, since it guarantees that the dominant firm cannot foreclose its less-efficient rival.

The total welfare effect of compulsory licensing, meanwhile, depends on the underlying degree of competitiveness of the industry, and is more likely to be positive when the industry in question is naturally less competitive. This result (abstracting from any conflicts with the stated consumer surplus goal of US competition policy) gives qualified support to the position adopted by the Federal Circuit in the landmark *Xerox* case, namely that refusals to license should be viewed as presumptively legal. Provided the underlying degree of competitiveness characterising the relevant industries is sufficiently high, allowing a dominant firm to refuse to license is superior to compulsory licensing in total welfare terms.

[43]See Katsoulacos (2009).

Chapter 3

Competition Policy in Innovative Industries

3.1 Introduction

There are two ways in which the question of optimal competition policy enforcement in innovative industries may be approached.[1] Firstly, by asking how optimal competition policy should vary between industries that differ in their underlying degree of innovative intensity. Secondly, we may ask how optimal policy should differentiate between firms within a given industry, depending on whether or not a competition offence has occurred in isolation or in combination with socially beneficial innovation.[2] In both respects, the existing literature has so far emphasised that innovation brings benefits that will make the optimal competition policy more lenient in more innovative industries, respectively towards firms that innovate besides taking some anti-competitive action.[3] This chapter develops a framework that is primarily targeted at the latter of these approaches: how does the stringency of optimal competition policy differ according to whether or not competition law infringements occur in combination with innovation? In contrast to the existing literature, we show that there is a sense in which the optimal stringency of competition policy will be harsher when competition infringements occur

[1]Our notion of optimality throughout this chapter will be based on decision-theoretic concerns, which focus on the costs of decision errors of type I (false convictions) and type II (false acquittals). This approach to competition law enforcement was first developed by Easterbrook (1984), and is also used in Hylton and Salinger (2001) and Ahlborn *et al.* (2004, 2005), for example. For more general discussion of the issues around competition policy and innovation, see Katz and Shelanski (2007), Shapiro (2002) and Encaoua and Hollander (2002).

[2]As will be discussed, this distinction is not always clear in the existing literature, where "innovative industries" are frequently treated as those where firms *always* innovate if they take an anti-competitive action.

[3]Manne and Wright (2010) argue that competition policy should be more lenient in innovative industries, so as to recognise the benefits of innovation and avoid costly type I (conviction) errors. Spulber (2008) puts forward the view that competition policy should not be too harsh, so as not to deter innovation.

in combination with innovation, rather than in isolation.[4] The idea behind this result is that the authority should implement a lower burden of proof or "liability standard" (implying a more stringent policy) for firms that have innovated besides taking some anti-competitive action, to account for the fact that such firms are also more likely, *ceteris paribus*, to innovate in the counterfactual situation.

In practice, the issue of how to treat competition infringements when firms may also innovate has been central to numerous high-profile competition cases. The view that innovation should lead to a more lenient policy has featured prominently, though arguably more so in the US than in the EU. In *Jerrold*,[5] for example, the court evaluated alleged tying conduct under a rule of reason approach, rather than convicting on the basis of *per se* illegality, ostensibly in recognition of the important role that *Jerrold* had played in innovating to create the market in the first place. In several cases involving refusals to license intellectual property, the US has consistently rejected calls for compulsory licensing on the grounds that this would diminish the incentives for innovation, notably in *Xerox*,[6] as well as in the long list of cases detailed in American Bar Association (2003). In Europe, on the other hand, the Commission has made clear on several occasions that a refusal to license could violate competition law, most notably in *Microsoft*, but also in *IMS Health* and *Magill*.[7]

This variation in approaches may in part be explained by the lack of formal economic models that clarify what role innovation should play in competition cases. Two recent papers which have looked at this question are Hylton and Lin (2014) and Immordino *et al.* (2011), both of which conclude that taking innovation into account will result in a more lenient optimal policy. Indeed, in Hylton and Lin (2014) it may even be optimal to reward the anti-competitive action of a firm if that firm has also innovated.

However, these results are, at least in part, a consequence of the fact that the two actions – innovation on the one hand and some anti-competitive action on the other – are not truly separated from one another. In Hylton and Lin (2014), the firm's decision to innovate is undertaken, conditional on the expected profits from taking a secondary, anti-competitive action. That is, there is no explicit consideration of a case in which the firm may innovate *without* taking an anti-competitive action, and without the associated risk of antitrust intervention. This has two main implications. Firstly, in such a context, any policy that deters the

[4]In fact, our framework can also shed light on the first approach to optimal competition policy. We show that, to the extent that an industry is more "innovative" (in a sense to be made clear) it will in fact be prone to type II (acquittal) errors, in contrast to what the literature has emphasised to-date (see previous footnote).

[5]*United States v. Jerrold Electronics Corp.*, 365 US 567 (1961). This case is discussed in Hylton and Lin (2014), who argue that it in fact represents an exception to the usual approach in exclusionary conduct cases in the US, which typically do not compensate for innovation.

[6]*CSU, LLC v. Xerox Corp.*, 203 F.3d 1322 (Fed. Cir. 2000).

[7]*Microsoft v. Commission*, Case T201/04 (2007); *IMS Health and NDC Health v. Commission*, Case C418/01 (2004), ECR I-5039; and *Magill ITP, BBC and RTE v. Commission*, Cases C241/91 and C242/91 P (1995), ECR I-743. See Vickers (2010) for further details.

anti-competitive action will necessarily deter innovation, since there is no scope for the firm to innovate without taking the anti-competitive action. Secondly, the harm from taking the anti-competitive action is always calculated net of the benefit brought about by innovation. This is consistent with a story where innovation cannot occur without anti-competitive actions. If for some parameter values, however, the firm did have profitable innovation opportunities absent the anti-competitive action, it is not appropriate to attribute the innovation benefit to the firm having undertaken the anti-competitive action.

In Immordino *et al.* (2011), innovation is similarly bundled with a secondary, potentially anti-competitive action, in the sense that the profits from innovation are realised only via taking the secondary action. There is no separate profit and welfare effect of innovation, which might render it a profitable venture in isolation.[8] Again, the results suggest that the optimal policies in innovative industries should be softer, in order to encourage costly investments in R&D.[9,10]

Relative to this existing literature, a major contribution of this chapter is to unpack the decision of a given firm to innovate from that to take a secondary, potentially anti-competitive action. This is important since a firm's decision as to whether or not to innovate (ignoring any potentially anti-competitive actions that it may take) falls completely outside the scope of competition policy. As such, we can think of the firm's decision with respect to innovation as defining the appropriate counterfactual on which to base a calculation of the 'harm' resulting from any competition offence.[11]

We first develop a very general framework, in which the firm faces a choice over two actions – innovation and some potentially anti-competitive action – that are specified in a generic way. In particular, the profit and consumer surplus outcomes associated with each action are assumed to depend on an underlying random parameter, capturing the idea that the effect of any given action may vary to some extent randomly, depending on the precise circumstances in which it is

[8]The framework is extended in a working paper (Immordino and Polo (2012)) in which innovation does bring about a stand-alone profit and welfare effect. There the innovation decision is still implicitly tied to anti-competitive conduct, however, because innovation always brings about the potential for competition authority intervention and related fines.

[9]Another paper that explores competition policy in innovative industries is Segal and Whinston (2007), who look at policies that restrict incumbent behaviour towards new entrants. When only the potential entrant can innovate, stronger protection from the incumbent increases entrant profits, but at the same time reduces the incentives to take the incumbent's place by investing in R&D. Nonetheless there are cases in which stronger competition policy unambiguously increases innovation incentives.

[10]This chapter is also related to the extensive literature on the relationship between competition and innovation, as in Vives (2008), Aghion *et al.* (2005), Boone (2000, 2001) and Schmutzler (2013), among many others. The distinction lies in the fact that, whereas these papers focus on the competitiveness of the economic environment, we are considering specific, potentially anti-competitive *actions*.

[11]In this chapter, we will consider only the case in which the authority uses a consumer surplus standard to judge competition infringements, so that the harm of any given competition offence is equal to the associated change in consumer surplus.

taken. The firm is assumed to observe the realisation of all random parameters, allowing it to choose the most profitable action accordingly. Importantly, the firm may also decide to innovate and take the anti-competitive action simultaneously.

The competition authority, on the other hand, is assumed to be able to observe the situation that prevails after the potentially anti-competitive action is taken. Conditional on this action having been taken, it can also observe whether or not it was accompanied by innovation. This corresponds to a scenario in which potentially anti-competitive actions are always reported to the authority by consumers or other market participants, for example, at which point the authority can also observe whether or not the firm has innovated. The authority does *not* know the realised value of the random parameters corresponding to either the anti-competitive action or innovation, however. Since these action parameters determine the effect of any action relative to the counterfactual scenario, this is equivalent to saying that the authority does not observe the counterfactual on the basis of which to calculate harm.

In this context, the authority is assumed to implement an effects-based decision rule, under which it launches a competition investigation whenever the firm takes the potentially anti-competitive action (irrespective of whether this occurs in isolation or in combination with innovation). This investigation allows the authority to form an estimate of harm, and we assume that the authority will ban the action whenever this harm estimate exceeds its specified 'liability standard'. Since the authority can observe whether or not the potentially anti-competitive action was undertaken in combination with innovation or not, it can in principle condition the liability standard it implements on the observed action choice of the firm. Indeed, we take the level of the liability standard that should be implemented in each case as our measure of stringency: a lower liability standard, corresponding to a lower burden of proof, representing a harsher policy.

Since firms that innovate in addition to taking the potentially anti-competitive action are also more likely to innovate in the counterfactual,[12] we show that it will be optimal from a decision error cost point of view to set a more stringent competition policy (a lower liability standard) when the firm is observed as innovating besides taking the potentially anti-competitive action. This reflects that fact that, to the extent that a firm would innovate in the counterfactual, the authority's estimate of harm will be biased downward, leading to an increase in type II (acquittal) errors unless the liability standard is also lowered.

The remainder of the chapter is organised as follows. In Section 3.2, we develop our general model. We describe the information setting and the investigative process employed by the competition authority, and derive the main results relating to the optimal stringency of competition policy. Section 3.3 presents a

[12]This fact is, in the first instance, ensured by an appropriate assumption on the correlation between the profits from the various actions. This assumption, which represents the main working assumption of the general framework, is later verified in the context of a more specific micro-founded example.

specific micro-founded example, which underpins the key working assumptions of our general model. In Section 3.4, some further implications of our micro-founded example concerning the role of innovation in competition cases, and potential extensions to a deterrence framework are discussed. Section 3.5 concludes.

3.2 A General Model

3.2.1 The Economic Setting

Consider a firm with constant marginal costs of production, which operates in a market subject to inverse demand curve $p(X)$, $p' < 0$, where p is price and X is output. We collect all relevant parameters of this demand function (such as the price elasticity of demand), as well as any parameters describing the competitive environment (such as the threat of entry) in the vector $\boldsymbol{\omega}$. These $\boldsymbol{\omega}$ parameters are treated as constants at the level of any given industry, although they may in general vary from one industry to another.

We denote the level of consumer surplus associated with any given equilibrium price p_e and associated output X_e by

$$CS(p_e) = \int_0^{X_e} [\, p(u) - p_e \,]\, du,$$

from which it follows that $CS' < 0$.

Finally, we suppose that in the initial equilibrium, before any actions are taken, marginal costs are equal to $c_0 > 0$, while price and output are equal to p_0 and X_0, respectively (these will generally depend on c_0 and $\boldsymbol{\omega}$). This in turn implies revenue and profits in the initial equilibrium equal to

$$R_0 = p_0 \cdot X_0 \quad \text{and} \quad \pi_0 = (p_0 - c_0)X_0,$$

respectively.

3.2.2 Actions and Firm Behaviour

Our focus in this chapter will be on the choices that this firm makes over actions that may impact the initial equilibrium. We denote the set of feasible actions by $\mathcal{A}$, with generic element $a \in \mathcal{A}$. We assume that $\mathcal{A}$ always includes the *trivial* action $a = 0$ of doing nothing and remaining in the initial equilibrium. Since this initial equilibrium as captured in $(p_0, X_0, c_0, R_0, \pi_0)$ will be the baseline relative to which all random effects are measured, we treat these variables as constants from now on.

We will, however, only consider cases in which the set $\mathcal{A}$ also includes at least one *non-trivial* action. In particular, as we are interested in the enforcement of competition policy in innovative industries, the non-trivial actions that we will explore in some detail in this chapter are (i) innovation and (ii) a generic abuse of a dominant position. These non-trivial actions will, depending on the precise circumstances in which they are taken, exert a particular effect on the initial equilibrium. We capture this fact by relating the effect of any non-trivial action $a \neq 0$ in $\mathcal{A}$ on the equilibrium variables $(p_0, X_0, c_0, R_0, \pi_0)$ to one random parameter Ψ_a, the realisation of which ψ_a is drawn from a suitably defined density on support $D_a \subseteq \mathbb{R}$. Therefore, the precise equilibrium that prevails following any non-trivial action depends on the realisation of the relevant random variable.[13] These Ψ_a variables are, moreover, assumed to be distributed independently of one another. By relating the impact of each non-trivial action to a random parameter, we ensure that there will be random variation in firm profits (and other equilibrium variables) *within* an industry.[14]

Of course, whenever the firm faces a choice of multiple actions that may be profitable in isolation, it may be profit maximising to choose a combination of these actions (i.e. to innovate and take the abusive action simultaneously). We therefore also allow the firm to choose combinations of actions in $\mathcal{A}$.[15] This raises the prospect that certain action choices that the firm could make will have random parameters in common, causing the profits (and consumer surplus outcomes) of these actions to be correlated. Indeed, the form of this correlation between the profits of various actions will turn out to be key for the analysis in Section 3.2.4.

In terms of notation, we denote the profit function for any non-trivial action $a \neq 0$ in $\mathcal{A}$ by $\pi_a : D_a \longrightarrow \mathbb{R}$. We can think of these profit functions yielding both a random profit variable $\pi_a(\Psi_a)$ and a realised value of profits $\pi_a(\psi_a)$ for all $\psi_a \in D_a$. The profit from taking any two non-trivial actions a and a' in $\mathcal{A}$ in combination will similarly be written as $\pi_{a+a'} : D_a \times D_{a'} \to \mathbb{R}$.[16] We also make the following assumption concerning the firm's choice over actions.

Assumption 1. *The firm knows the precise realisation of the random parameters Ψ_a, and chooses the most profitable action or combination of actions on that basis.*

Finally, besides this economic distinction between trivial and non-trivial actions, it will also be useful to differentiate between non-trivial actions according to the following *legal criterion.* We have in mind that some actions, despite the impact they have on the initial equilibrium, will never be the focus of competi-

[13] In the micro-founded example of Section 3.3, the random parameters are assumed to impact the firm's marginal cost.

[14] As opposed to the variation *between* industries generated by the $\boldsymbol{\omega}$ variables. In general, it is not important to associate each non-trivial action with only one random parameter. This assumption merely makes the exposition clearer. In other work (e.g. Katsoulacos and Ulph (2009, 2014a)), distributions for benefit and harm are often directly assumed. In our framework, relating the distribution of harm to these underlying random parameters will be helpful when it comes to a discussion of the decision errors that the competition authority may make.

[15] Therefore, we could also think of the firm choosing subsets of actions from the power set $\mathcal{P}(\mathcal{A})$.

[16] We will not go into great detail concerning the distribution of profits in this chapter. In particular, we do take the approach of defining a transformation function and finding the derived density function of profits, as we will do in relation to harm in Section 3.2.3.

tion policy intervention. We refer to such actions as '*per se* legal' and, in our set-up, innovation will belong to this class of actions. All actions that are not *per se* legal are assumed to represent potential abuses of competition law, for which reason we refer to such actions as 'potentially illegal actions'. Examples of this type of action include refusals to deal, bundling and other abuses of a dominant position. The point is that the economic impact of any non-trivial action is not the only relevant factor for competition policy. Whether or not the action satisfies the legal criterion which determines whether or not it can be investigated by the competition authority also matters.

Before considering the enforcement of competition policy in innovative industries, we first develop a benchmark case in which the only non-trivial action is a generic abuse of a dominant position (a potentially illegal action). This will allow us to describe the competition policy setting and develop a benchmark for the cost of decision errors before we move on to the innovative industry case in Section 3.2.4.

3.2.3 A Benchmark Case

Consider a case where the set of actions is composed of only one non-trivial action A, which is a potentially illegal action. Therefore $\mathcal{A} = \{0, A\}$. While we do not impose any restrictions on the impact that this action has on price, so that it may in general be either harmful or benign from the viewpoint of consumers, we make the following assumption concerning the profitability of the action.[17]

$$\pi_A(\psi_A) > \pi_0 \quad \text{for all} \quad \psi_A \in D_A.$$

This ensures that the action is economically meaningful in the sense that, in the absence of any competition policy intervention, there is a strict profit incentive for the firm to take the action.

Throughout the chapter, it is assumed that the competition authority follows a consumer surplus standard.[18] Consequently the 'harm'[19] that results from this potentially anti-competitive action A can be written as

$$H = t(\Psi_A) = CS(p_0) - CS\Big[\, p_A(\Psi_A) \,\Big], \tag{3.1}$$

where we refer to t as the 'transformation function', and where $p_A(\Psi_A)$ denotes the post-action price as a function of the random variable.[20] It will also be convenient to make the following assumption concerning this transformation function t.

[17] As part of the micro-founded example presented in Section 3.3, we specify in detail a potentially harmful action that satisfies this condition.

[18] This is by far the most common approach adopted by competition authorities in practice, including in the EU and US.

[19] This 'harm' could also be negative, i.e. a benefit, if the post-action price is lower than that in the initial equilibrium, $p_A < p_0$.

[20] In general, we take it as given throughout this chapter that the price that prevails following any non-trivial action depends on the random parameters, and suppress this dependence in our notation. Therefore, we generally write p_a for $p_a(\Psi_a)$ for all $a \neq 0$ in $\mathcal{A}$.

Assumption 2. *The function $t : D_A \to B$ is a monotonic, differentiable function of the random variable Ψ_A, mapping domain $D_A \subseteq \mathbb{R}$ one-to-one onto range $B \subseteq \mathbb{R}$.*

Notice that, since the harm in (3.1) is a function of the underlying random parameter Ψ_A, it represents a random variable in its own right. More specifically, letting H denote the random harm variable and h a given realisation of harm, we can denote the density function of harm by[21]

$$\nu_H(h) \quad \text{for all} \quad h \in B. \tag{3.2}$$

Competition Policy Enforcement

We will assume that the competition authority recognises that harm is given by (3.1), and that it can observe accurately and without cost what has happened, given that the firm has taken the action, that is $(p_A, X_A, c_A, R_A, \pi_A)$. This may be the result of any potentially illegal action coming to the authority's attention via complaints from consumers, for example. However, the authority does not observe the variables $(p_0, X_0, c_0, R_0, \pi_0)$ corresponding to the initial equilibrium. In other words, the authority, unlike the firm, does not observe the parameters of the action. Thus the uncertainty about the harm from this action on the part of the competition authority surrounds the counterfactual position of the firm.[22]

In this context, we assume that the authority uses an effects-based enforcement procedure, so that, in any particular case, it first conducts an investigation of the likely harm caused by the action. On the basis of this investigation, the authority forms an estimate of harm, which, for any $h \in B$, is equal to

$$\tilde{h} = h + \epsilon,$$

where ϵ is the estimation error. In what follows, this estimation error ϵ will be treated (for all actions) as uniformly distributed on $[-E, E]$, $E > 0$, where E is exogenous.[23]

We further suppose that the decision rule used by the authority is the following: ban any action for which the estimate of harm exceeds its specified *liability standard*, denoted by λ.[24] This means that the authority will ban the potentially illegal action whenever $\tilde{h} > \lambda$. We can therefore also think of λ as a measure that

[21]Assumption 2 ensures that this derived density function can be obtained by a simple application of the *change of variables* technique. See, e.g., Grimmet and Stirzaker (1982).

[22]In general, the industry-specific characteristics $\boldsymbol{\omega}$ may represent a further source of uncertainty for the competition authority.

[23]Our results should extend readily to more general error distributions. Our motivation for using a uniform distribution is to gain explicit solutions, which will simplify the analysis in Section 3.2.4.

[24]While our representation of the competition authority is close to existing work, e.g. Katsoulacos and Ulph (2009, 2014a, 2014b), our approach differs in that we do not normalise this liability standard to zero.

is inversely related to the stringency of competition policy – indeed all our results relating to the stringency of competition policy will be based on the optimal level for the liability standard λ.

This decision rule implies that any action with realised harm level equal to h will be approved by the competition authority with probability

$$\alpha(h|\lambda, E) = \begin{cases} 1 & \text{if } h < \lambda - E, \\ \dfrac{E - (h - \lambda)}{2E} & \text{if } h \in [\lambda - E, \lambda + E], \\ 0 & \text{if } h > \lambda + E. \end{cases} \tag{3.3}$$

In keeping with our notion that λ is inversely related to the stringency of competition policy, it is straightforward to verify that $\frac{\partial \alpha}{\partial \lambda} \geq 0$ (strictly so whenever h is in the interval $[\lambda - E, \lambda + E]$).

Noting that a type I error (false conviction) will occur whenever $\tilde{h} > \lambda$ and $h < 0$, while a type II error (false acquittal) occurs when $\tilde{h} < \lambda$ and $h > 0$, we can write the expected cost of type I and II decision errors across all potential actions of this type that the authority may be called to investigate as

$$C1 = \int_{\lambda - E}^{0} \left[\frac{E + (h - \lambda)}{2E} \right] (-h)\ \nu_H(h)\, dh \tag{3.4}$$

and

$$C2 = \int_{0}^{\lambda + E} \left[\frac{E - (h - \lambda)}{2E} \right] h\ \nu_H(h)\, dh, \tag{3.5}$$

respectively, where $\nu_H(h)$ is the probability density function given in (3.2). It follows that, if competition policy is extremely lenient, so that $\lambda > E$, the cost of type I decision errors is zero, while, if competition policy is very harsh, so that $\lambda < -E$, there is zero cost of type II decision errors.

Some further comparative statics results for these decision error cost expressions are given in the following lemma.

Lemma 7. *For all $\lambda < E$, $C1$ is decreasing and strictly convex in λ. For all $\lambda > -E$, $C2$ is increasing and strictly convex in λ.*

Proof. Straightforward differentiation under the integral in (3.4) and (3.5). □

Decision error cost expressions of this form will be the basis for determining the optimal level of stringency λ^* in the innovative industry setting, which we analyse in the following section.[25]

[25]As described in Section 3.2.4, we will consider two scenarios in this chapter, which differ in terms of how the optimal stringency level is chosen. First, we consider the case where λ^* is chosen to equalise the probability of type I and II decision errors. Secondly, we consider the case where λ^* is chosen to minimise the total cost of decision errors $C = C1 + C2$.

3.2.4 Innovative Industries

We now turn to the main focus of the chapter: the enforcement of competition policy when firms may also innovate. To that end, we suppose that the set of potential actions $\mathcal{A}$ now includes cost-reducing innovation, in addition to the trivial action and the same non-trivial, potentially illegal action A discussed in the benchmark case. Innovation is represented by the element $I \in \mathcal{A}$ and, as discussed in Section 3.2.2, this is assumed to represent a *per se* legal action. We will maintain the assumption that, while the potentially illegal action $k = A$ may in general be either harmful or benign, innovation is unambiguously beneficial to consumers, in the sense that[26]

$$p_I(\psi_I) < p_0 \quad \text{for all} \quad \psi_I \in D_I. \tag{3.6}$$

The full set of actions is therefore now given by $\mathcal{A} = \{0, I, A\}$. For our purposes, it will be useful to partition this set into *per se* legal and potentially illegal actions, so that

$$\mathcal{A} = \{\{0, I\}, \{A\}\}.$$

In what follows, we will identify variables corresponding to a *per se* legal action by a subscript $j \in \{0, I\}$ and variables corresponding to a potentially illegal action (bearing in mind that actions can also be taken in combination) by a subscript $k \in \{A, I + A\}$, where $I + A$ indicates that innovation I and the potentially anti-competitive action A are taken simultaneously. It is important to note that the combination of a *per se* legal action and a potentially illegal action is therefore also considered to be potentially illegal. This is plausible, as the authority is likely to be concerned that the harm from any potentially illegal action will outweigh the benefit from the *per se* legal action.

Firm Behaviour

The first point to note with respect to the firm's choice over actions is that it now faces a choice over *per se* legal actions (innovate or remain in initial equilibrium), which is completely outside the scope of competition policy. We may therefore consider the firm's decision as to whether or not to innovate, ignoring the potentially harmful action A, as defining its *counterfactual position.*[27] Unlike in the benchmark case, it follows that there are now two potential counterfactual scenarios. We introduce the following definition to differentiate between firms according to their counterfactual behaviour.

[26] This is a very weak assumption that, in the context of process innovation, is satisfied in all standard oligopoly models. Under product innovation, a further interesting issue that arises is that, even if the counterfactual situation were observable, errors could be made in estimating harm, due to the fact that price increases for the product may have occurred simultaneously with (unobservable) increases in product quality. We do not explore this issue in this chapter.

[27] This counterfactual can therefore also be thought of as specifying which action the firm would choose, were it banned from undertaking any potentially illegal actions.

Definition 1 (Innovative Firms)**.** *A firm is* innovative *if it faces profitable innovation opportunities in the absence of any potentially illegal actions, that is if* ψ_I *is such that* $\pi_I(\psi_I) > \pi_0$*. Otherwise, the firm is referred to as* non-innovative*.*

It should be clear that, since the innovation profits depend on the random component Ψ_I, there will generally be a whole range of realisations of this random parameter for which the firm would choose to innovate. Therefore, this classification of firms according to their innovativeness does not pin down a unique firm type as such, but rather identifies a *class* of firms. In what follows, we will denote the (unconditional) probability that the firm is innovative by θ, and assume that $0 < \theta < 1$, so that there is always some probability *ex ante* that the firm will be innovative or not.

We are now in a position to make two important assumptions regarding profits.[28] The first ensures that, irrespective of the counterfactual behaviour, the firm will always decide to engage in a potentially illegal action (be it with or without also innovating) in the absence of any competition policy interventions. Therefore, these potentially illegal actions indexed by $k \in \{A, I+A\}$ are still economically meaningful.

Assumption 3. $\max[\pi_A(\psi_A), \pi_{I+A}(\psi_I, \psi_A)] > \max[\pi_I(\psi_I), \pi_0]$ *for all* $\psi_A \in D_A$ *and* $\psi_I \in D_I$*.*

The second assumption, which is key for our results, states that firms that innovate as part of any potentially illegal action are also more likely to innovate in the counterfactual position.

Assumption 4. $\text{corr}\Big[\,(\pi_I(\Psi_I) - \pi_0)\,,(\pi_{I+A}(\Psi_I, \Psi_A) - \pi_A(\Psi_A))\,\Big] > 0$

An important implication of Assumption 4 is that, *conditional* on action $I+A$ being chosen over A, the probability that the firm is innovative is greater than in the converse case. Letting $\hat{\theta}_k$ denote the probability of the firm being high-tech, conditional on the chosen action being $k \in \{A, I+A\}$, it follows that

$$\hat{\theta}_{I+A} > \hat{\theta}_A. \tag{3.7}$$

Competition Policy Enforcement

We carry over the assumptions concerning the enforcement of competition policy from the benchmark case. In particular, we assume that the authority is again able to observe the situation that prevails once any potentially illegal action is taken, that is $(p_k, X_k, c_k, R_k, \pi_k)$, $k \in \{A, I+A\}$. Therefore, irrespective of whether the potentially illegal action was undertaken in isolation or in combination with innovation, the competition authority can observe the vector of equilibrium variables that results. Moreover, we assume that the authority can differentiate between

[28]Both will be verified in the context of our micro-founded example in Section 3.3.

potentially illegal actions, so that, if the potentially harmful action A comes to its attention, it is also able to determine whether or not this was undertaken in combination with innovation. Nonetheless, the authority again does not know what the firm's counterfactual behaviour would have been. Therefore, despite being able to identify the potentially illegal actions that were taken, the parameters of these actions are unknown to the competition authority.

The authority follows an effects-based procedure that is identical to that described in the benchmark case, up to a relabelling of actions. That is, irrespective of which potentially illegal action is undertaken, the authority is able to arrive at an estimate of harm, which is always calculated relative to the initial equilibrium. In other words, the counterfactual price used by the authority in arriving at its harm estimate is always p_0.[29] This estimate differs from the actual harm by an estimation error ϵ, which is uniformly distributed on $[-E, E]$, which in turn implies that the probability that any potentially illegal action will be approved is again given by (3.3).

The decision rule of the authority is to ban any action for which its harm estimate exceeds its liability standard. However, since the authority can observe whether or not the potentially harmful action A was accompanied by innovation, it can in principle implement two different liability standards, depending on which potentially illegal action is observed. We denote the liability standard for action $k \in \{A, I + A\}$ by λ_k. Our main results will focus on how the optimal choice of liability standard differs between potentially illegal actions.

True Harm and Mis-measured Harm

In order to get at an expression for the cost of decision errors in innovative industries, on the basis of which to draw conclusions about optimal stringency levels, we first need to consider the distribution of harm. In evaluating the harm implied by any potentially illegal activity, it is clear that proper account must be taken of the firm's counterfactual position. We introduce the following notion to make this more explicit.

Definition 2 (True Harm). *True harm, denoted by $H_{j,k}$, is the change in consumer surplus implied by a firm choosing potentially illegal action $k \in \{A, I + A\}$ when, in the counterfactual position, it would have chosen* per se *legal action $j \in \{0, I\}$.*

It follows that there are now four true harm variables, which we can write generically as

$$H_{j,k} = CS(p_j) - CS(p_k),$$

[29]This corresponds to a setting in which the authority, though able to observe whether or not a potentially harmful action was accompanied by innovation, cannot disentangle the effects of these two actions, but rather estimates harm relative to a counterfactual where no actions were taken.

$j \in \{0, I\}$, $k \in \{A, I + A\}$. These harm functions will generally be defined on a domain covering all realisations of the random parameters (Ψ_I, Ψ_A) that are consistent with the action choices implied by that harm variable: let $D_{j,k} \subseteq \mathbb{R}^2$ denote this domain.[30] Furthermore, let $B_{j,k} \subseteq \mathbb{R}$ denote the range of each respective harm function.

As functions of the underlying random variables, it again follows that these true harm variables are random variables in their own right. We denote the marginal probability density function true harm variable by[31]

$$\nu_{H_{j,k}}(h_{j,k}) \quad \text{for all} \quad h_{j,k} \in B_{j,k}. \tag{3.8}$$

Given the enforcement process specified for the competition authority, however, these true harms are not the only relevant variables in the innovative industry context. Since the authority cannot observe the counterfactual and, in our simple framework, receives a signal about harm that is calculated relative to the initial equilibrium price p_0, the authority's estimate of harm is based on the wrong counterfactual whenever the firm in question is truly innovative. We therefore introduce the following notion of mis-measured harm.

Definition 3 (Mis-measured Harm)**.** *Mis-measured harm, denoted by $H'_{I,k}$, is the calculated change in consumer surplus when an* innovative *firm chooses action $k \in \{A, I + A\}$, but the harm calculation is based on counterfactual price p_0.*

It follows that, whenever the firm is innovative, the authority arrives at an estimate of mis-measured harm as a result of its investigation, rather than true harm. Given (3.6), moreover, the counterfactual consumer surplus is (stochastically) higher when the firm is innovative rather than not. Therefore, basing inferences on mis-measured rather than true harm will tend to under-estimate the true harm. Formally,

$$H'_{I,k} = CS(p_0) - CS(p_k) < CS(p_I) - CS(p_k) = H_{I,k}, \tag{3.9}$$

$k \in \{A, I+A\}$. Thus we have two mis-measured harm variables, each corresponding to one of the potentially illegal activities, which cover the cases in which the authority relies on its harm estimate relative to p_0, but the firm is truly innovative.

To capture the idea that each value of true harm may be associated with a range of mis-measured harm (and vice versa) due to the additional random variation in the counterfactual price p_I, we need to consider the joint distribution between these variables. For each potentially illegal activity $k \in \{A, I + A\}$,

[30] That is, the domain covers those realisations of the random variables for which the profit maximising choices by the firm imply the correct counterfactual and potentially illegal action. For now, we assume that these domains are non-empty, so that $D_{j,k} \neq \emptyset$ for all j, k. This implies that the firm, irrespective of whether it is innovative or not, will prefer to undertake either potentially illegal action for at least some realisations of the random variables. We again verify this assumption in the context of our micro-founded example in Section 3.3.

[31] The derivation of these marginal density functions is discussed below.

the true and mis-measured harm variables corresponding to an innovative firm will be defined on the domain that corresponds to the true harm variable, that is $D_{I,k} \subseteq \mathbb{R}^2$. We assume that the transformations $T_k : (\psi_A, \psi_I) \mapsto (h_{I,k}, h'_{I,k})$, which, for each action $k \in \{A, I+A\}$, map from the pair of random variables to the pair of true and mis-measured harms are one-to-one from domain $D_{I,k}$ onto range $B^2_{I,k} \subseteq \mathbb{R}^2$.[32] Then, provided the *Jacobian* determinant applied to the inverse transformation T^{-1} satisfies standard conditions,[33] the joint density of true harm $H_{I,k}$ and mis-measured harm $H'_{I,k}$ can again be derived via a straightforward change of variables. We denote this joint density by

$$\nu_{H_{I,k},H'_{I,k}}(h_{I,k}, h'_{I,k}) \quad \text{for all} \quad (h_{I,k}, h'_{I,k}) \in B^2_{I,k}, \tag{3.10}$$

$k \in \{A, I+A\}$. The marginal density in (3.8) may be found simply by integrating out mis-measured harm $H'_{I,k}$, while the marginal density for mis-measured harm, which we denote $\nu_{H'_{I,k}}(h'_{I,k})$, is found by integrating out true harm.

Cost of Decision Errors

Working on the basis of these notions of true harm, mis-measured harm, and the relationship between them as captured by the joint density in (3.10), we may now explore the decision errors that the authority is expected to make across all potential actions that may come to its attention. We present the arguments for general $k \in \{A, I+A\}$, since they apply equally to both potentially illegal actions.

The first case to consider is that in which the firm that comes to the authority's attention, having undertaken some potentially illegal action, is non-innovative. In that case, for a given liability standard λ_k, the cost of decision errors follows in standard form, based on the marginal density of true harm variable $H_{0,k}$. The decision error cost expressions parallel (3.4) and (3.5), and can be written as

$$C1_k = \int_{\lambda_k - E}^{0} \left[\frac{E + (h_{0,k} - \lambda_k)}{2E} \right] (-h_{0,k}) \; \nu_{H_{0,k}}(h_{0,k}) \, dh_{0,k} \tag{3.11}$$

and

$$C2_k = \int_{0}^{\lambda_k + E} \left[\frac{E - (h_{0,k} - \lambda_k)}{2E} \right] h_{0,k} \; \nu_{H_{0,k}}(h_{0,k}) \, dh_{0,k}, \tag{3.12}$$

$k \in \{A, I+A\}$.

The more interesting case is that in which the action that comes to the authority's attention was undertaken by a firm that is innovative. In that case, since inferences are based on a mis-measured harm variable that under-estimates harm, there will be a bias towards type II errors and away from type I errors. Consider type II errors first. We suppose that for each realisation of mis-measured harm

[32] We use B^2 notation to differentiate this from the range of true harm $B_{I,k} \subseteq \mathbb{R}$.

[33] See Grimmet and Stirzaker (1982) for details.

$h'_{I,k}$, true harm may take values (as governed by the joint density in (3.10)) in the range

$$h_{I,k} \in \left[\underline{h}(h'_{I,k}) \, , \, \overline{h}(h'_{I,k}) \right].$$

This captures the idea that a given value of mis-measured harm need not be associated with a unique value for true harm, due to the additional random variation in the counterfactual price p_I (see (3.9)).[34] The conditions for a type II error (false acquittal) are now that

$$\tilde{h}'_{I,k} < \lambda_k \quad \text{and} \quad h_{I,k} > 0.$$

Note that the probability of an acquittal on the basis of mis-measured harm $H'_{I,k}$ (that is, the first half of our condition for a type II error to occur) is given by

$$\begin{aligned} Pr[\tilde{h}' < \lambda_k] = & \int_{-\infty}^{\lambda_k - E} 1 \cdot \nu_{H'}(h') \; dh' \\ & + \int_{\lambda_k - E}^{\lambda_k + E} \left[\frac{E - (h' - \lambda_k)}{2E} \right] \nu_{H'}(h') \; dh', \end{aligned}$$

where we have dropped the I, k subscripts from harm variables throughout. As long as $\overline{h}(h'_{I,k}) > 0$, there is still a chance that a given acquittal on the basis of mis-measured harm $h'_{I,k}$ will be false (even if the mis-measured harm that is erroneously being estimated is itself negative). Nonetheless, if we define $X < 0$ as the threshold level of $h'_{I,k}$ such that, for all $h'_{I,k} < X$ we have $\overline{h}(h'_{I,k}) < 0$, then we know there can be no false acquittal on the basis of $\tilde{h}'_{I,k}$ when $h'_{I,k} < X$. Hence we can write the type II error component in the case of an innovative firm (dropping the I, k subscripts for all harm variables) as

$$\begin{aligned} C2'_k = & \int_{X}^{\lambda_k - E} \int_{0}^{\overline{h}(h')} h \; \nu_{H,H'}(h, h') \; dh \; dh' \\ & + \int_{\lambda_k - E}^{\lambda_k + E} \int_{0}^{\overline{h}(h')} \left[\frac{E - (h' - \lambda_k)}{2E} \right] h \; \nu_{H,H'}(h, h') \; dh \; dh'. \end{aligned}$$

It follows the cost of decision errors of type II is therefore distorted, relative to the hypothetical case in which inferences were based on an estimate of true harm rather than mis-measured harm (see (3.12)). This follows because (i) false acquittals can occur for the same range of true harm $\lambda_k + E < h_{I,k} < \lambda_k + E$, but,

[34] In fact, when the action chosen is $k = I + A$, the post-action price is a function of both Ψ_A and Ψ_I, implying that a given p_{I+A} will pin down a unique value for p_I, and therefore a given value of mis-measured harm will be associated with a unique value of true harm, rather than a range. This difference notwithstanding, the intuition underlying Lemmas 8 and 9 below is the same for both actions. The difference is that the second integral term can be dropped from the decision error cost expressions when the action chosen is $k = I + A$, and, in that case, we can integrate over the marginal density of $H'_{I,k}$.

in each case, the decision is based on a mis-measured harm variable $h'_{I,k} < h_{I,k}$ that makes acquittals more likely, and (ii) the range of true harm for which an acquittal may now occur is expanded to include $h_{I,k} > \lambda_k + E$. Thus we have the following result.

Lemma 8. *For a given liability standard λ_k, the competition authority's enforcement process leads to an inflation in the expected cost of type II decision errors when the firm is innovative, relative to the hypothetical case in which inferences were based on true harm.*

Now consider the expected cost of type I errors when the firm is innovative. A type I error is now defined by the conditions that

$$\tilde{h}'_{I,k} > \lambda_k \quad \text{and} \quad h_{I,k} < 0.$$

Note that there can be no false conviction when $h'_{I,k} > 0$, since $h_{I,k} > h'_{I,k}$. The probability of conviction based on mis-measured harm estimate $\tilde{h}'_{I,k}$ is equal to (again omitting the repeated subscripts for clarity)

$$\begin{aligned} Pr[\tilde{h}' > \lambda_k] = &\int_{\lambda_k - E}^{\lambda_k + E} \left[\frac{E + (h' - \lambda_k)}{2E} \right] \nu_{H'}(h')\ dh' \\ &+ \int_{\lambda_k + E}^{\infty} 1 \cdot \nu_{H'}(h')\ dh'. \end{aligned}$$

Bearing in mind that there can be no false conviction when $h'_{I,k} > 0$, the cost of type I decision errors can therefore be written as

$$C1'_k = \int_{\lambda_k - E}^{0} \int_{\min[\underline{h}(h'),0]}^{0} \left[\frac{E + (h' - \lambda_k)}{2E} \right] (-h)\ \nu_{H,H'}(h, h')\ dh\ dh'.$$

Hence the cost of type I decision errors falls relative to the hypothetical case in which inferences were based on true rather than mis-measured harm (see (3.11)). This follows because (i) the range of true harm for which an error can occur is reduced, and (ii) for those values of true harm for which where a false conviction can occur, the decision is based on an estimate of mis-measured harm $h'_{I,k} < h_{I,k}$ that makes convictions less likely.

Lemma 9. *For a given liability standard λ_k, the competition authority's enforcement process leads to a reduction in the expected cost of type I decision errors when the firm is innovative, relative to the hypothetical case in which inferences were based on true harm.*

We close this section by noting some comparative statics results concerning the cost of decision error terms when the firm is truly innovative. Firstly, it is clear that the expected cost of type I errors is again decreasing in the magnitude of the liability standard, while the expected cost of type II errors is increasing in the magnitude of the liability standard. In other words,

$$\frac{\partial C1'_k}{\partial \lambda_k} \leq 0 \quad \text{and} \quad \frac{\partial C2'_k}{\partial \lambda_k} \geq 0.$$

It may also be verified that $C1'_k$ is unambiguously convex in λ_k, while $C2'_k$ is convex in λ_k whenever (dropping the I, k subscripts from harm variables for clarity)

$$\int_0^{\overline{h}(\lambda_k+E)} h\ \nu_{H|H'}(h|\lambda_k + E)\ dh > \int_0^{\overline{h}(\lambda_k-E)} h\ \nu_{H|H'}(h|\lambda_k - E)\ dh, \qquad (3.13)$$

where $\nu_{H|H'}(h|h')$ denotes the density of $H_{I,k}$, conditional on $H'_{I,k} = h'_{I,k}$. While the limits of the integrals in this expression certainly suggest it will be satisfied, we have to respect the difference between the conditional density functions. Throughout the remainder of the chapter, we will maintain the assumption that (3.13) is always satisfied, implying that decision error costs are (as in the benchmark case) convex in the liability standard.

Assumption 5. *$C1'_k$ is convex and decreasing in λ_k, while $C2'_k$ is convex and increasing in λ_k.*

In what follows, we will base our inferences on the incidence of these distortions to the decision error costs when the firm is innovative. In doing so, we will not go into the precise magnitude of these distortions across actions.[35] Rather, we will consider $C1'_k$ to be "small" relative to $C1_k$, and $C2'_k$ to be "large" relative to $C2_k$ for both $k = A, I + A$.

Discussion and Results

The discussion in the previous section shows that we can write the expected cost of decision errors when the potentially illegal action that is observed by the competition authority is $k \in \{A, I + A\}$ as

$$C_k = \hat{\theta}_k\Big(C1'_k + C2'_k\Big) + (1 - \hat{\theta}_k)\Big(C1_k + C2_k\Big), \qquad (3.14)$$

where $\hat{\theta}_k$ is the conditional probability defined in Section 3.2.4. We are now in a position to answer the question of how the optimal stringency of competition policy varies according to the firm's innovation behaviour.

As a preliminary observation, we can see that our framework does not agree with the view expressed in the literature that innovative industries are associated with a greater risk of type I errors.[36] Instead, if we suppose that more innovative

[35] A judgement as to the precise magnitude of these distortions is not analytically possible at this level of generality.

[36] For example, Manne and Wright (2010) argue that an imperfect understanding of the benefits engendered in any given innovation raise the prospect of type I errors.

industries are associated with higher (conditional) probabilities of firms being innovative (that is, higher θ_k for both k), then, with reference to (3.14), there will be more weight on the distortions towards type II errors and away from type I errors in more innovative industries. Thus we have the following result.

Proposition 6. *More innovative industries are characterised by a greater tendency towards type II errors.*

Now consider how the stringency of competition policy should differentiate according to whether or not competition law infringements occur in combination with innovation or in isolation. This is equivalent to the question of how the optimal liability standards λ_k^* should differ between potentially illegal actions. To answer this question, we will consider two cases, which differ according to how the optimal liability standard is chosen: in the first case, we suppose that the authority cares about equalising the probability of making errors of both type I and II,[37] while, in the second case, we assume that λ_k^* is chosen simply to minimise the total cost of decision errors.

Given that the probability of the firm being innovative is greater when the observed action is $k = I + A$ rather than $k = A$ (see (3.7): $\hat{\theta}_{I+A} > \hat{\theta}_A$), there will be a greater tendency towards type II errors when the observed action includes an innovation component. If the aim is to equalise the probability of type I and II errors for each action $k \in \{A, I + A\}$, it follows from the fact that the cost of type I (respectively, type II) errors is decreasing (respectively, increasing) in λ_k that the optimal liability standard will be lower when the observed action is $k = I + A$, rather than $k = A$. Hence we have the following.

Proposition 7. *When the liability standard is chosen to equalise error probabilities, the optimal competition policy is harsher towards firms that innovate beside taking some potentially anti-competitive action than it is towards firms that do not innovate,* $\lambda_{I+A}^* < \lambda_A^*$.

We may check the robustness of this result by considering a second scenario, in which the liability standard is chosen to minimise the total cost of decision errors. In this case, it is the marginal cost of decision errors that matter. Nonetheless, given that decision error costs are assumed to be convex, whenever they are *sufficiently* convex, so that at the higher level of type II decision error costs associated with the mis-identification case the marginal cost saving brought about by reducing the liability standard is also large (conversely for type I errors), the same result holds. Because the conditional probability of the firm being innovative is greater when $k = I + A$, there is more emphasis on that part of the decision error cost expression where the *marginal* cost of type II decision errors is large and where the marginal cost of type I errors is small (or indeed zero). Therefore, to

[37] This approach is consistent with Manne and Wright (2010), for example, who propose a series of rules that lower the level of type I errors (at the expense of higher type II errors) to counter the supposed bias towards type I errors in innovative industries.

minimise the total cost of decision errors, the optimal liability standard will again be lower for a firm that is observed as taking action $k = I + A$ rather than $k = A$.

Proposition 8. *When the liability standard is chosen to minimise the total cost of decision errors, and provided costs are sufficiently convex, the optimal competition policy is harsher towards firms that innovate beside taking some potentially anti-competitive action than it is towards firms that do not innovate,* $\lambda^*_{I+A} < \lambda^*_A$.

Therefore both Propositions 7 and 8 contradict the view that optimal competition policy should necessarily be more lenient towards firms that innovate besides taking some potentially harmful action. The idea underlying our results is that the competition authority should implement a harsher liability standard for firms that innovate as part of some potentially illegal action, in order to reflect the fact that such firms are also more likely to have innovated in the counterfactual position.

3.3 Micro-founded Example

It is clear that the results presented in the preceding section rely on the divergence in conditional probabilities $\hat{\theta}_k$. This divergence is, in turn, a direct consequence of Assumption 4. At this stage, we therefore consider a specific, micro-founded example, in which we assume a particular demand function and characterise specific non-trivial actions, to verify this and other working assumptions of our general model.

3.3.1 The Market & Initial Equilibrium

For the purpose of this example, consider a market in which demand is given by

$$p = X^{-\frac{1}{\eta}},$$

where p and X are again price and output, respectively, and $\eta > 1$ is the point elasticity of demand. For any given price $p > 0$, consumer surplus is therefore equal to

$$CS(p) = \frac{p^{1-\eta}}{\eta - 1}.$$

We characterise the initial equilibrium as follows. Suppose that, in the absence of any non-trivial actions being taken, and given initial costs of $c_0 > 0$, the ratio of price to marginal cost in this market is

$$\frac{p_0}{c_0} = 1 + \frac{\mu}{\eta - 1}. \tag{3.15}$$

In this expression, μ, $0 \leq \mu \leq 1$, provides a measure of the underlying degree of monopolisation of the industry in the absence of any explicitly anti-competitive action: $\mu = 0$ corresponds to perfect competition and $\mu = 1$ to monopoly.[38] The industry-level parameters may therefore be summarised here as $\boldsymbol{\omega} = (\eta, \mu)$.

In this initial equilibrium, the firm would earn operating profits of

$$\pi_0 = \sigma R_0,$$

where

$$\sigma = \frac{\mu}{\mu + \eta - 1}, \quad 0 \leq \sigma < 1, \tag{3.16}$$

measures the share of revenue that is accounted for by profits (equivalently, the ratio of profits to revenue) and $R_0 = (p_0)^{1-\eta}$ denotes revenue in the initial equilibrium.

3.3.2 Characterising Actions

We consider the innovative industry case in which $\mathcal{A} = \{0, I, A\}$. First, we describe a particular characterisation for both the potentially illegal action A and innovation I, before moving on to verify the working assumptions of our general framework.

Potentially Illegal Action

We suppose that the potentially illegal action A, if undertaken, will exert two effects relative to the initial equilibrium. Firstly, it raises the ratio of price to marginal cost from the value captured in (3.15) to

$$\left(1 + \frac{\mu}{\eta - 1}\right)(1 + \delta_m), \ \delta_m > 0.$$

Secondly, it generates a potential efficiency gain which lowers marginal costs from c_0 to[39]

$$c_A = \frac{c_0}{1 + \Delta_{c_A}}, \ \Delta_{c_A} \geq 0.\text{[40]}$$

So a potentially anti-competitive action is defined by the pair (δ_m, Δ_{c_A}) and is characterised by the conditions that $\delta_m > 0$, $\Delta_{c_A} \geq 0$.

Of course, it is natural to require that the price-cost margin that emerges after the action has been taken should not exceed that under monopoly. This requires that

$$\delta_m \leq \frac{1 - \mu}{\mu + \eta - 1}. \tag{3.17}$$

[38] In this single firm set-up, we may consider this parameter as capturing the threat of entry into the market, for example.

[39] For example, in the bundling context, this cost saving may be thought of as capturing bundling or selling synergies. See, e.g., Salinger (1995) and Nalebuff (2004).

[40] Therefore Δ_{c_A} measures the efficiency gain as a percentage of the marginal costs the firm would have if it takes the action.

Therefore, in what follows, it will be assumed that the bound on δ_m given in (3.17) always holds. Notice that the more competitive the baseline situation is (that is, the lower is μ), the more scope there is for taking an anti-competitive action that raises the price-cost margin.

The price that prevails if the if the firm takes the action is then

$$p_A = p_0 \left(\frac{1 + \delta_m}{1 + \Delta_{c_A}} \right). \tag{3.18}$$

With reference to (3.18), it is clear that if $\delta_m > \Delta_{c_A}$ the action is harmful, and otherwise it is benign. To reflect the fact that the harm from this particular action may depend on the precise circumstances in which it is taken (i.e. vary to some degree randomly within an industry), it is sufficient to consider *either* of the parameters δ_m or Δ_{c_A} to be random variables. In what follows, we will therefore proceed by considering Δ_{c_A} to be the relevant random parameter (corresponding to Ψ_A in the general model), while δ_m is treated as non-random.[41] The particular realisation of this random cost-saving variable is denoted δ_{c_A}, which is drawn from a suitably defined density on support $D_A = \mathbb{R}_+$.

Innovation

Innovation is assumed to bring about (with certainty) a cost saving equal to $\Delta_{c_I} \geq 0$ at a fixed R&D cost to the firm of $z > 0$. This implies that if the firm takes action $I \in \mathcal{A}$ in isolation, marginal costs will be equal to[42]

$$c_I = \frac{c_0}{1 + \Delta_{c_I}}.$$

The price that prevails if the firm innovates is in turn given by

$$p_I = \frac{p_0}{1 + \Delta_{c_I}} < p_0, \tag{3.19}$$

from which it follows that innovation is indeed beneficial for consumers. Therefore, (3.6) is always satisfied in this context.

Similarly to the treatment of Δ_{c_A}, we assume that Δ_{c_I} is itself distributed randomly in the industry. In particular, the realisation of innovation cost savings

[41] It should be emphasised that our results do not depend on this assumption. As argued in the context of the general model, a distribution for harm may also be found when both δ_m and Δ_{c_A} vary randomly. From an economic viewpoint, our set-up corresponds to a scenario in which the price-raising effect of a potentially anti-competitive action can, on the basis of economic models available to the authority, be determined accurately, but the presence of unobserved, random efficiencies causes uncertainty about the true level of harm.

[42] It is worthwhile emphasising the difference between this marginal cost saving achieved as a result of innovation and that realised as a by-product of the anti-competitive action (that is, Δ_{c_A}). While, in the former case, the firm faces a private cost of innovation for which it realises a private benefit, in the latter case, the cost of the marginal cost reduction is effectively borne by consumers via δ_m.

δ_{c_I} for the firm is obtained as the result of a random draw from a suitably defined density function on support $D_I = \mathbb{R}_+$. (Therefore, Δ_{c_I} corresponds to Ψ_I in the general framework.) As in the general set-up, we assume that these random variables $(\Delta_{c_I}, \Delta_{c_A})$ are distributed independently of one another.

Finally, we denote the marginal cost saving relative to the status quo cost level c_0 that occurs if the potentially illegal action and innovation are undertaken simultaneously by $\delta_{c_{I+A}}$. Specifically, we assume that cost reductions are cumulative, in the sense that

$$\frac{1}{(1+\delta_{c_{I+A}})} = \frac{1}{(1+\delta_{c_A})(1+\delta_{c_I})} \tag{3.20}$$

for all $\delta_{c_A} \in D_A$ and $\delta_{c_I} \in D_I$.

3.3.3 Counterfactual Behaviour

In order to determine the relevant counterfactual behaviour of the firm, we need to consider its decision as to whether or not to innovate in the absence of any potentially illegal actions. On the basis of Definition 1, we know that the firm will be innovative whenever the realised cost saving is such that $\pi_I(\delta_{c_I}) > \pi_0$. Since the profits from innovating can be written for any $\delta_{c_I} \in D_I$ (and using a first-order approximation for revenue[43]) as

$$\pi_I(\delta_{c_I}) = \sigma R_0 \left[1 + (\eta - 1)\frac{\delta_{c_I}}{1+\delta_{c_I}}\right] - z, \tag{3.21}$$

this condition is satisfied whenever the realised innovation benefit δ_{c_I} is sufficiently large, specifically whenever

$$\delta_{c_I} > \delta^*_{c_I} \equiv \frac{z}{\sigma R_0(\eta-1) - z}. \tag{3.22}$$

3.3.4 Action Choices

We are now in a position to evaluate the firms choice over potentially illegal actions. Firstly, we will show that, as postulated in Assumption 3, these potentially illegal actions are always economically meaningful, in the sense that the firm will always have a strict profit incentive to take its preferred action, irrespective of its counterfactual behaviour. Secondly, we will verify Assumption 4, namely that firms that innovate as part of any potentially illegal action are, *ceteris paribus*, also more likely to do so in the counterfactual.

Using a first-order approximation for revenue, the profits associated with each potentially illegal action $k \in \{A, I+A\}$ can be written as

$$\pi_A(\delta_{c_A}) = R_0 \left(\frac{\sigma + \delta_m}{1+\delta_m}\right) \left[1 - (\eta - 1)\left(\frac{\delta_m - \delta_{c_A}}{1+\delta_{c_A}}\right)\right] \tag{3.23}$$

[43]That is, writing $R_I = (p_0 + \Delta p_I)^{1-\eta} \approx R_0 \left[1 - (\eta-1)\left(\frac{\Delta p_I}{p_0}\right)\right]$.

and

$$\pi_{I+A}(\delta_{c_A}, \delta_{c_I}) = R_0 \left(\frac{\sigma + \delta_m}{1 + \delta_m} \right) \left[1 - (\eta - 1) \left(\frac{\delta_m - \delta_{c_{I+A}}}{1 + \delta_{c_{I+A}}} \right) \right] - z \tag{3.24}$$

for all $\delta_{c_A} \in D_A$ and $\delta_{c_I} \in D_I$ and where $\delta_{c_{I+A}}$ is defined in (3.20). We are now able to prove the following result, which confirms Assumption 3 from the general framework.

Lemma 10. *There is always at least one profitable anti-competitive action that the firm can take, irrespective of whether or not it is innovative.*

Proof. See Appendix B.1. □

Before demonstrating that Assumption 4 is satisfied in this specific framework, it is worth confirming the assumption that was made implicitly throughout the general analysis, namely that the domains $D_{j,k}$ are non-empty for all combinations of j and k (see footnote 30). This implies that the firm will choose both potentially illegal actions with positive probability, irrespective of whether or not it would innovate in the counterfactual.

Lemma 11. *Irrespective of whether the firm would innovate in the counterfactual position or not, the firm may choose either action $k = A$ or $k = I + A$, depending on the precise realisation of the random variables Δ_{c_I} and Δ_{c_A}.*

Proof. Appendix B.2. □

Finally, we can now prove that Assumption 4 is satisfied in this specific context, ensuring that firms observed engaging in potentially illegal action $k = I + A$ are indeed more likely to innovate in the counterfactual position, and that consequently (3.7) holds.

Lemma 12. *The firm is more likely to choose to innovate as part of any anti-competitive action it chooses if it is high-tech rather than low-tech.*

Proof. See Appendix B.3. □

3.4 Discussion & Extensions

Before concluding, we discuss some further implications that emerge from this work, drawing on both the general framework and micro-founded example as indicated.

3.4.1 The Role of Innovation in Competition Law

A first point of interest concerns the role that innovation should play in competition cases at a general level. As discussed in the introduction, existing work has so far emphasised the benefits that innovation brings, and used this as the basis for arguing that the 'harm' from any given competition offence should be offset by any innovation benefits that the infringing firm has also created. In our framework, in which we take explicit account of the firm's behaviour in the counterfactual position, it is clear that this argument only holds to the extent that the firm is non-innovative. To the extent that the firm would have innovated in the counterfactual position, it is not appropriate to attribute the innovation benefits it creates to its decision to engage in some potentially harmful action. This is the reason why it is important to adjust the counterfactual price to account for the firm's innovation decisions in the counterfactual position.

We can illustrate the distinction between these two approaches using our micro-founded example. There, the price that prevails following any potentially illegal action is given by

$$p_k = p_0 \frac{1+\delta_m}{1+\delta_{c_k}},$$

while the price under innovation is given in (3.19).

It therefore follows that when the firm is non-innovative, and any innovation was therefore undertaken *conditional* on also realising the profits from the potentially illegal action, the innovation benefits may, in some circumstances, overturn the anti-competitive harm associated with the action. In other words it is possible that

$$H_{0,A} = CS(p_0) - CS\left[p_0\left(\frac{1+\delta_m}{1+\delta_{c_A}}\right)\right] > 0 \tag{3.25}$$

but

$$H_{0,I+A} = CS(p_0) - CS\left[p_0\left(\frac{1+\delta_m}{1+\delta_{c_{I+A}}}\right)\right] < 0,$$

which will be true when the realised δ_{c_I} is sufficiently large.[44] Thus the existing view expressed in the literature is still reflected in our framework.

Nonetheless, it is also true that if the action $k = A$ is harmful in isolation ($H_{0,A} > 0$), there will be no potentially illegal action $k \in \{A, I+A\}$ that an innovative firm could take for which true harm is negative. This follows since (3.25) implies that

$$H_{I,I+A} = CS\left(\frac{p_0}{1+\delta_{c_I}}\right) - CS\left[p_0\left(\frac{1+\delta_m}{1+\delta_{c_{I+A}}}\right)\right] > 0.$$

Therefore this framework makes clear exactly when the existing view of innovation in competition cases is justified (namely when the firm in question is

[44]Respecting also the constraint that $\delta_{c_I} < \delta^*_{c_I}$ implied by the fact that the firm is non-innovative.

non-innovative), while also demonstrating that innovation cannot represent a mitigating factor that may overturn the harm from a given competition infringement for a firm that is innovative, once proper account is taken of the counterfactual behaviour.

3.4.2 Deterrence

In this chapter, we have focused exclusively on the cost of decision errors as the basis for determining the optimal stringency levels as captured in λ_k^*. This approach only considers the authority's ability to adjudicate correctly in the cases that may come to its attention, and therefore does not take account of the fact that competition policy may influence the types of actions that firms are willing to undertake in the first place – that is, it ignores deterrence effects.

While the intuition developed in this chapter should carry over at a general level to a deterrence setting (in determining the extent to which a more stringent policy deters innovation, we have to consider the extent to which firms have profitable innovation opportunities in the absence of any potentially harmful actions) this raises several modelling difficulties. Firstly, the key to determining the optimal policy when deterrence effects are included is the correlation between profits and harm: as the stringency of competition policy is increased, is it the most harmful or the least harmful actions that are deterred at the margin? When considering deterrence effects in an innovative industry setting, however, the relationship between profits and harm need not be monotone. As such, it may be difficult to calibrate the stringency of competition policy to deter all harmful actions. The precise assumptions that are reasonable concerning the joint density of profits and harm represent one difficulty in extending this framework to a deterrence setting.[45]

Moreover, in addition to deterrence effects relating to the firm's choice as to whether or not to take a given action, there are now *differential* deterrence effects to consider, which may alter the firm's choice as to *which* potentially illegal action to undertake when the stringency of competition policy changes. Therefore, to the extent that a more stringent policy would encourage firms to take less harmful actions (i.e. to choose $k = I+A$ over $k = A$), such a policy may actually encourage innovation. However, this also implies that the set of realisations of the random parameters for which a given action is preferred will generally change when the stringency of competition policy changes. This means, in turn, that the domains of the true harm variables $D_{j,k}$ are not constant, moving this problem outside the scope of our present framework.

[45]Nonetheless, we can argue that the assumption that is typically made in the literature, namely that profits and harm are distributed independently, is certain not to be true when we relate the random variation in these variables to common underlying random parameters.

3.5 Conclusion

This chapter has developed a very general framework for the study of competition policy enforcement in innovative industries, the principal working assumptions of which were also verified in the context of a more specific, micro-founded example. In contrast to existing work exploring the implications of innovation for the enforcement of competition policy, we allow the firm's decision with respect to innovation to vary in the counterfactual position. This allows us to develop a notion of the 'true harm' resulting from competition offences, which takes the offender's counterfactual behaviour into account.

The principal result of the chapter is that the stringency of competition policy, as reflected in the liability standard according to which the competition authority bans potentially harmful actions, should be lower (corresponding to a harsher policy) for competition infringements that occur together with innovation rather than in isolation. This follows since firms that are observed as innovating in combination with some potentially harmful action are also more likely to innovate in the (unobserved) counterfactual position. Since the authority's simple estimate of harm will be biased downward to the extent that the firm would have innovated in the counterfactual, the optimal liability standard will be lower to compensate for this.

Part II

The Banking Sector

Chapter 4

Competitive Effects of Bank Capital Regulation

4.1 Introduction

In the banking sector, the promotion of competition may conflict with the objective of maintaining financial stability. An early and well-known theory formalising the idea that excessive competition among banks promotes instability is the 'charter value hypothesis', according to which banks that have their future earnings potential (as reflected in their charter value) eroded by competition pursue more risky asset-allocation strategies.[1] More intense competition may also increase the probability of bank runs.[2] Since, moreover, the substantial costs of financial instability are well documented,[3] while the efficiency benefits of competition are inherently difficult to quantify, it may be argued that stability concerns override competition objectives for bank regulators.[4]

The implications of this are twofold. Firstly, competition infringements may be tolerated in order to bolster charter values, avoid bank runs and therefore safeguard stability.[5] Secondly, policies may be put in place to promote stability, without regard to their effect on the competitive behaviour of banks. Key among such stability-enhancing policies has been the imposition of minimum bank cap-

[1] Keeley (1990). This result has subsequently been contested by extending the notion of competition beyond deposit markets to loan markets (see, e.g., Boyd and De Nicoló (2005) and Caminal and Matutes (2002)) and interbank lending markets (see, e.g., Allen and Gale (2004)).

[2] See Vives (2013) and literature cited therein.

[3] The Basel Committee on Banking Supervision (BCBS) estimates the net present value cost to output from financial crises at 19%-163%, with a median value of 63%. See BCBS (2010).

[4] For example, Carletti and Vives (2008, p.12) note that, even before the 2008 crisis, "central banks in Europe were too complacent with collusion agreements among banks and even fostered them." See also Vives (2011) and Allen and Gale (2004).

[5] As noted by Carletti and Hartmann (2002, p.12) in the context of mergers, "it may be that the very influential 'charter value hypothesis' [...] has convinced some countries to counterbalance the competition-oriented antitrust review with a stability-oriented supervisory review of bank mergers."

ital requirements.[6] This chapter addresses these twin concerns by developing a framework for competition policy in the banking sector (which is so far lacking in the literature), which takes explicit account of capital regulation.[7]

As such, this chapter is most closely related to the literature on the strategic effects of capital structure. Brander and Lewis (1986) show that capital structure choices can affect the nature of competition between standard producing (non-bank) firms. Higher debt levels commit a given firm to producing more output in response to any output produced by its rivals. This corresponds to a "riskier" strategy, since it increases the variance of the firm's profit streams.[8] Since the effect of such commitments is to increase output, however, they can be viewed as pro-competitive. Similar pro-competitive effects of debt have been found in the context of collusive agreements. Maksimovic (1988) shows that firm owners prefer to break collusive agreements and cash-in on the short-term gains from deviation when the debt level is sufficiently high, due to limited liability.[9] It follows that, even in the context of standard producing firms, there is a sense in which high levels of equity capital (by reducing debt levels) may be associated with anti-competitive effects.

The most important difference when considering banks rather than standard producing firms (besides the obvious difference in the nature of business operations) is that, in the presence of binding capital requirements, the capital structure may not be freely chosen and adjusted by banks. Chami and Cosimano (2010) show that capital requirements can strengthen the incentives of banks to *sustain* collusion, since they impose a limit on the total volume of loans that a bank can issue, and therefore also limit the extent to which any bank can steal rival banks' loan business by deviating from the collusive lending rate. However, the decision by banks to enter into collusive behaviour in the first place is not modelled endogenously. Finally, Schliephake and Kirstein (2013) show that, when adjustments to the capital structure are costly, capital requirements represent an imperfect pre-commitment to a particular loan capacity, which transforms the outcome of the competitive process from Bertrand towards Cournot.[10] In other

[6] As reflected in the most recent Basel III Accord, for example. The economic literature concerning the effectiveness of such capital requirements in mitigating risk-taking incentives is vast. See, e.g., Furlong and Keeley (1989), Hellman *et al.* (2000), Hakenes and Schnabel (2011) and Besanko and Kanatas (1994).

[7] In fact, owing to the nature of the harmful actions we consider, the implications of our framework cover both competition and consumer protection policy.

[8] As such, this can be viewed as an instance of the asset-substitution moral hazard problem first discussed in Jensen and Meckling (1976).

[9] See also Stenbacka (1994) and Hege (1998) for similar results. This result has been contested in Spagnolo (2000), however, who shows that, when firms hire conservative managers (with high reputational costs of bankruptcy) in order to mitigate the asset-substitution moral hazard problem, collusion becomes *more* sustainable for highly leveraged firms when credit markets are concentrated.

[10] As noted by the authors, this effect may be taken to represent tacit collusion, but not explicit collusion.

words, capital requirements can soften the competitive environment (as rigid capacity constraints for standard producing firms were previously shown to do by Kreps and Scheinkman (1983)).

This chapter is also concerned with the competitive effects of capital regulation in the banking sector. However, in focusing on competitive outcomes, it is important to differentiate between the notions of (1) the competitive *environment* within which banks operate (as reflected, for example, in the number of active banks, Cournot vs. Bertrand etc.[11]) and (2) anti-competitive *actions* that banks operating in a given competitive environment may take.[12] Our results will touch upon both notions of competition and show that, in the first instance, an increase in the capital requirement increases the market concentration. Since, in our model, larger banks enjoy lower costs of raising equity,[13] an increase in the capital requirement can be viewed an asymmetric cost shock that impacts the marginal costs of initially high-cost banks most strongly. Therefore, there is a strong sense in which higher capital requirements diminish the degree of competitive intensity in the market as a whole.

Nonetheless, our results show that this decrease in the competitiveness of the market overall does not necessarily translate into increased incentives to take anti-competitive *actions*. In the loan market, we represent a generic abuse of a dominant position via a shock that increases lending rates.[14] This may be considered a reduced form representation of a variety of competition-infringing behaviours that occur in the corporate bank lending markets. For example, banks have been found to obstruct SMEs in their attempts to switch loans to alternative finance providers through delays in waiving claims over collateral and completing

[11] Boone (2001) provides an axiomatic treatment of measures of the competitive environment.

[12] For concreteness, by anti-competitive actions we mean an unspecified abuse of a dominant position, rather than cartels or mergers. The supposition that some banks enjoy sufficient market power in their interactions with small and medium-sized enterprises (SMEs) to abuse a dominant position is supported by the findings of the Office of Fair Trading (UK) (since taken over by the newly-formed Competition and Markets Authority), which highlights barriers to entry and difficulty for SMEs in differentiating providers as key reasons why banks enjoy significant market power. See OFT (2014).

[13] This is backed up by Witmer and Zorn (2007), for example, who find empirical evidence that the cost of equity is inversely related to firm size for a sample of North American firms. In the context of banks, lower equity costs for larger banks may further be explained by implicit government guarantees associated with banks that are "too big to fail". Gandhi and Lustig (2010) find that government guarantees do indeed reduce the cost of equity for large US banks.

[14] An important underlying question in the banking context concerns the appropriate welfare standard. In this chapter, we will follow the approach taken by the majority of competition authorities around the world (including in the US and EU) by using a consumer surplus standard. Moreover, in the banking context, where customers include both individual consumers on the deposit side and small and medium enterprises on the loans side, we consider both customer groups to fall within the consumer surplus mandate of the competition authority. This is the approach taken by the Financial Conduct Authority, for example, which states (see FCA (2013, p.5)): "Our responsibilities extend to all consumers, [...] whether an individual, small company or a major participant in the wholesale market."

documentation.[15] Furthermore, banks were identified as far back as 2002 by the then Competition Commission (UK) as bundling business current accounts with loans.[16] More recently, the new competition and consumer protection body for the banking sector in the UK, the Financial Conduct Authority, has launched a 'skilled persons review' into alleged abusive conduct on the part of a major British highstreet bank towards firms in financial difficulty.[17]

Our results show that, especially when allowing for the sale of ancillary financial products to depositors, the difference in equity funding costs between banks must be sufficiently large in order for increases in the capital requirement to increase the incentives of a dominant bank to act anti-competitively. This is due to the fact that the incentive effect is proportional to the size of a bank's loan book. While higher capital requirements increase the market share of the dominant bank, they also reduce the market size overall, because equity is assumed to be costly relative to debt for both banks. Hence the market share effect must be not just positive, but also large enough to offset the market size effect in order for the incentives for anti-competitive conduct to increase.

In considering anti-competitive actions on the deposit side, we wish to extend the notion of competition policy beyond the traditional objective of 'protecting competition in the interests of consumers', to a direct concern for consumer welfare. In particular, we examine the incentives that banks face to exploit depositors via the sale of ancillary financial products. In so doing, we view deposit accounts as a type of *gateway product*,[18] which banks can exploit as a channel via which to sell more profitable ancillary products.[19] In this context, a dominant bank may abuse its position to misinform and more generally obstruct the switching process of depositors looking for rival deals in the market. This is what the Financial Conduct Authority has termed a *situational monopoly*: "situational monopolies can arise, where intermediaries sell add-on products at monopoly prices because consumers do not shop around for better offers at the point of sale."[20] A well-known episode of such mis-selling in the UK centred on payment protection insurance (PPI) contracts.[21]

In this context, we show that the only switching that will occur in equilibrium

[15] OFT (2014)

[16] Further details available at http://www.oft.gov.uk/OFTwork/markets-work/SME-banking-review/#.U1pPHvlSbpR.

[17] See http://www.fca.org.uk/news/update-on-independent-review-of-rbs-treatment-of-business-customers-in-financial-difficulty for details.

[18] See, e.g., Armstrong and Zhou (2011, p.F386)

[19] This view of current accounts is also reflected in policy circles. The Financial Conduct Authority, for example, notes that "[t]here is evidence that personal current accounts help banks to sell a range of more profitable products." See http://www.fca.org.uk/news/research-shows-many-consumers-paying-too-much-for-overdrafts.

[20] Erta *et al.* (2013, p.22)

[21] Lloyds, the worst offender in the UK market, had by December 2013 set aside £8 billion to cover PPI compensation claims (which might serve as a proxy for consumer harm) and also faced a £28 million fine from the UK Financial Conduct Authority. See Financial Times (2013).

is from the dominant bank (which charges a higher price for the ancillary financial product) to the rival bank. Therefore, only the magnitude of the dominant bank's switching costs will matter. A natural characterisation of a harmful action in the deposit market is, therefore, an unanticipated increase in the switching cost that depositors of the incumbent bank face, once they have already deposited their funds.[22] We show that the effect of increases in the capital requirement on the incentives of the dominant bank to exploit consumers depends on both the magnitude of the equity funding cost difference, and the slope of the demand curve.

The remainder of the chapter is organised as follows. Section 4.2 develops a benchmark model, in which banks compete in the loan market by raising equity and deposits. We describe the competition policy setting and derive initial results on the effect of capital regulation on the nature of the equilibrium, and on the incentives of the incumbent bank to abuse its dominant position in the loan market. Section 4.3 expands the model to two stages. Following the first stage loan market competition, banks offer ancillary financial products for sale in the second period, to depositors who exhibit a degree of inertia in switching to the rival bank. We first characterise a subgame perfect Nash equilibrium in which we again have a dominant bank, before exploring the effects of increasing capital requirements on the market structure and incentives for anti-competitive conduct. Section 4.4 concludes.

4.2 A Benchmark Model

4.2.1 Basic Model Set-up

Consider a banking duopoly consisting of an incumbent bank and a new entrant, which we index with subscripts $i = I, N$, respectively. Banks are assumed to invest in an amount l of loans that are of an equivalent risk class,[23] and their operations are funded by a combination of deposits d (assumed to be insured, at a premium normalised to zero) and equity e. Throughout this chapter, we will suppose that the balance sheet identity always holds for each bank as

$$l_i = d_i + e_i. \tag{4.1}$$

In this benchmark setting without ancillary financial products, this is guaranteed to hold if cash on balance sheet yields no return, for example.

In this banking market, we assume that exogenously determined capital regulation requires each bank to hold a minimum fraction equal to δ, $0 < \delta < 1$, of their total assets (that is, loans) in the form of equity. To ensure that this constraint

[22]As will also be shown, to the extent that this increase in switching costs is anticipated by other market participants, there will never be an incentive for the dominant bank to take this action.

[23]This removes considerations related to risk-weighting of assets.

on equity levels δ is always binding, and that increases in the minimum capital requirement are consequently economically meaningful, we adopt the approach taken elsewhere in the literature by assuming that equity is "costly" relative to debt (that is, deposits).[24] Specifically, we assume that there is an infinite mass of potential depositors, each of whom holds a unit of funds that they are willing to deposit at a rate no lower than $\gamma > 0$. This implies that banks face a horizontal supply of deposits schedule at a cost of deposits equal to $r_i^D = \gamma$ for both i.[25] Equity is costly relative to deposits in the sense that each bank has to pay an equity funding premium of $\rho_i > 0$ per unit over the cost of deposits in order to attract equity investors. Thus we can write bank i's marginal equity funding cost as $r_i^E = \gamma + \rho_i$. We make the further assumption that banks are asymmetric in the dimension of their equity funding premium. In particular, we suppose that the incumbent, for reasons such as its established market reputation and access to internal loan databases,[26] faces a lower equity funding premium than does the new entrant.

Assumption 6. $\rho_I < \rho_N$

This assumption will be the source of dominance in our model.[27] We further assume that each bank faces constant marginal resource costs of loan monitoring, equal to $c_i^L > 0$ for bank i. In the absence of compelling *a priori* arguments to the contrary, we suppose that banks are initially symmetric in this dimension, so that $c_I^L = c_N^L = c^L$.[28] Taken together, these assumptions imply that banks operate subject to constant marginal costs of issuing loans (equivalently, of raising funds), equal for bank i to

$$r_i = \delta\, r_i^E + (1-\delta)\, r_i^D + c^L = \gamma + \delta\rho_i + c^L. \tag{4.2}$$

[24]See, e.g., Schliephake and Kirstein (2013). Hellmann *et al.* (2000) and Gorton and Winton (1997) offer theoretical justifications for considering equity to be "costly" in this sense.

[25]In other words, banks are assumed to be price-takers in the deposit market.

[26]Basel III regulations grant banks that use internal loan databases to create models to assess the riskiness of their loans a reduction on their capital requirement. New banks have neither the access to historic data nor the experience to make use of the advanced approaches, see ICB (2011, §7.26). Thus, the difference in marginal equity costs can more broadly be considered to reflect this "discount" that established banks can achieve on the *amount* of equity they need to raise. According to the ICB (2011, §7.27) "a small bank using a standardised approach could need to hold more than three times as much capital against a good-quality mortgage book as a large diversified bank using an advanced internal ratings-based (IRB) approach." Finally, new entrants may also be more reliant on costly venture capital as a source of funds.

[27]Note that this will also be consistent with a story where larger banks enjoy lower equity costs due to implicit guarantees associated with being "too big to fail". In the interests of simplicity, we do not make the equity funding premium a function of bank size, however. All we require for our results is that, in equilibrium, the dominant bank enjoys a lower equity funding cost. While there are other ways in which a bank might achieve dominance, which in turn affect its equity cost in a way that is consistent with Assumption 6, the approach described here is sufficiently rich for the results that we derive in this chapter.

[28]Resource costs related to debt and equity financing are normalised to zero.

From Assumption 6, it therefore follows that $r_I < r_N$.

Banks are assumed to compete in the loan market in a Cournot fashion. Letting upper-case letters denote aggregate variables, the inverse demand for loans function is assumed to relate the lending rate r^L to total loan volumes L via the following linear specification,[29]

$$r^L(L) = a - bL,$$

where $a, b > 0$. Moreover a is assumed to satisfy

$$a > \gamma + c^L + \delta(2\rho_N - \rho_I),$$

which ensures that both banks are active in equilibrium.

4.2.2 Initial Equilibrium

The assumption that equity is costly guarantees that the capital constraint δ always binds. Denoting equilibrium values with stars, it follows that, in any equilibrium,

$$e_i^* = \delta\, l_i^* \quad \text{and} \quad d_i^* = (1-\delta)\, l_i^*$$

for $i = I, N$. In combination with the balance sheet identity (4.1), either bank's optimisation problem can therefore be solved equivalently for l_i, d_i or e_i. Letting the choice variable be loans with no loss in generality, equilibrium loan rates are determined as the Cournot-Nash outcomes, when each bank maximises profits

$$\pi_i(l_i) = l_i \left[a - bL - r_i\right],$$

with respect to its own loan volumes, taking the rival's loan volumes as given. From this, the Cournot equilibrium values for the market share and profits of bank $i = I, N$ follow straightforwardly as

$$s_i^* = \frac{1}{2} + \frac{3\delta}{4}\left(\frac{\rho_j - \rho_i}{a - \gamma - c^L - \delta\overline{\rho}}\right), \; j \neq i, \tag{4.3}$$

and

$$\pi_i^* = \frac{(l_i^*)^2}{b}, \tag{4.4}$$

respectively, where $\overline{\rho} = \frac{1}{2}(\rho_I + \rho_N)$ is the average equity funding premium and

$$l_i^* = \frac{a - \gamma - c^L - \delta(2\rho_i - \rho_j)}{3b}, \; j \neq i,$$

is the equilibrium loan volume. Hence it follows from Assumption 6 that $s_I > \frac{1}{2}$.

[29] In Appendix C.1, we extend the results of this benchmark setting to more general demand functions.

4.2.3 Capital Regulation

Now consider the impact of a marginal increase in the capital requirement δ on this initial equilibrium. From (4.2),

$$\frac{\partial r_i}{\partial \delta} = \rho_i. \tag{4.5}$$

Therefore the effect of raising the capital requirement is to raise the marginal funding cost of both banks. Moreover, due to Assumption 6 ($\rho_I < \rho_N$), this effect is asymmetric and exerts a greater impact on the marginal cost of the new entrant. From (4.3), it is straightforward to see that the incumbent's market share is increasing in δ if and only if $\rho_N > \rho_I$, which holds due to Assumption 6. Therefore, using the Herfindahl index $H = \sum_i (s_i^*)^2$ as our measure of market concentration, we have the following result.

Lemma 13. *Marginal increases in the capital requirement δ lead to a more concentrated market equilibrium, in the sense that the Herfindahl index rises.*

Since the relevant derivative is positive for all feasible parameter values,[30] this result also holds for discrete changes in the capital requirement.[31]

Corollary 1. *Lemma 13 also holds for discrete changes in the capital requirement δ.*

Therefore, we have identified a first sense in which higher capital requirements may bring about anti-competitive effects. Since we can view an increase in the capital requirement as a cost shock that impacts banks with higher equity funding costs more strongly, such an increase results in a less competitive market environment, in the sense that the market concentration rises.

We next explore whether, in addition to this effect on the competitive environment, increases in the capital requirement necessarily increase the incentives of the dominant bank to engage in a generic anti-competitive action in the loan market.

4.2.4 Competition Policy Setting

Before characterising the anti-competitive action that banks may take in the loan market, it is worth considering the competition policy setting. This will be kept very simple. Throughout the chapter, we have in mind that any bank that takes a harmful action faces an exogenous probability of being caught by the competition authority, and fined a fixed amount. Moreover, the probability of being caught is

[30] This follows since $\frac{\partial s_I^*}{\partial \delta} = \frac{3}{4} \frac{(\rho_N - \rho_I)(a - \gamma - c^L)}{(a - \gamma - c^L - \delta\overline{\rho})^2}$.

[31] In Appendix C.1, we demonstrate that Lemma 13 and Corollary 1 are robust results, in the sense that they hold for a broad class of both concave and convex demand functions, in addition to linear demand.

assumed to be independent of the precise characteristics (such as market share) of the bank that takes the action. This implies that the incentive for any bank to take a given action depends solely on the profit effect of doing so.

4.2.5 Anti-competitive Actions – Loan Market

We begin by identifying three conditions that any anti-competitive action (abuse of dominance) should satisfy in the context of this simple banking duopoly.

C1. The action is 'harmful', in the sense that it lowers consumer surplus.

C2. The action is necessarily profitable for the bank that takes the action (abstracting from the possibility of competition policy intervention).

C3. The action necessarily lowers the profits of the bank that does not take the action.

A natural candidate to represent this generic anti-competitive action is therefore a shock to the marginal costs of the bank that does not take the action. More generally, this can also be interpreted as a negative demand shock.[32] That is, the effects of this anti-competitive action as captured in *C1*-*C3* are *as if* the marginal cost of the small bank had increased. Moreover, as will be shown, the profit effect from taking this action will be proportional to a given bank's equilibrium loan volumes, which renders it a natural candidate to represent an abuse of dominance. We therefore define an anti-competitive action in the loan market as follows.

Definition 4 (Anti-competitive action in loan market)**.** *An anti-competitive action in the loan market taken by bank i entails a cost shock that increases marginally the funding cost r_j, $j \neq i$, of the rival bank.*

Without loss in generality, we may consider this increase in funding cost to operate via the resource costs of loan monitoring, so that, if the action were taken by bank $i = I, N$, post-shock we have $c_i^L < c_j^L$, $j \neq i$. Clearly, from (4.4), and rewriting equilibrium loan volumes to account for asymmetric costs as

$$l_i^* = \frac{a - \gamma - (2c_i^L - c_j^L) - \delta(2\rho_i - \rho_j)}{3b}, \ \ j \neq i,$$

the effect of this action will be to increase the profits of the firm taking the action, since

$$\frac{\partial \pi_i^*}{\partial c_j^L} = \frac{2}{3b^2} l_i^* > 0.$$

That is, in the absence of competition policy intervention, there is a profit incentive to take the action, which, moreover, is proportional to the equilibrium

[32]For example, supposing that each bank faces a loan rate $r_i^L(L) = a_i - bL$, the assumption could be that the action, if taken by bank i, causes the parameter a_j, $j \neq i$, to fall. This is the approach to modelling abuses of dominance taken in Katsoulacos (2014), for example.

loan volume of the bank taking the action. Therefore, there is always a greater incentive for the dominant incumbent to take the action than for the new entrant.

The effect of increasing capital requirements on the incentive to engage in this anti-competitive action is then simply determined by the cross-partial derivative[33]

$$\frac{\partial^2 \pi_i^*}{\partial \delta \partial c_j^L} = \frac{2}{9b^3}(\rho_j - 2\rho_i).$$

It follows that an increase in the capital requirement will always decrease the incentive of the new entrant to take the anti-competitive action. This follows because such an increase will cause aggregate loan volumes to fall[34] and, moreover, causes the share of the new entrant in the total market to fall. Since the profit effect is proportional to the own loan volumes, the effect of increasing δ is always to reduce the incentive of the new entrant to take the action. For the incumbent, it is clear that the reduction in the total loan market size will be offset by the increase in its share in the market, that is $\partial l_I^*/\partial \delta > 0$, if and only if

$$\rho_N > 2\rho_I.$$

Hence we have the following result.

Proposition 9. *The necessary and sufficient condition for increases in the capital requirement δ to increase the incentives for the incumbent bank to take the anti-competitive action is that $\rho_N > 2\rho_I$.*

Therefore, despite the fact that increases in the capital requirement always increases the market concentration (that is, reduces the intensity of competition in the market overall) it does not necessarily increase the incentives of the dominant bank to behave anti-competitively, and always reduces the incentives of the new entrant to act anti-competitively. This follows because, as well as making the market more concentrated, it reduces the size of the overall loan market.[35]

Having established this simplified benchmark case, we now move on to a richer setting in which banks also compete to sell ancillary financial products to depositors. In this case, we can explore the incentives of banks to behave anti-competitively or, more generally, in a way that is harmful to customers, both in the loan market and via the sale of ancillary financial products.

4.3 Model with Ancillary Product Sales

4.3.1 Extended Model Set-up

Suppose now that, as motivated in the introduction, banks can use the provision of a current account to depositors as a *gateway* via which to target depositors with

[33]Again, this effect also holds for discrete changes in δ when demand is linear.

[34]This follows since total equilibrium loan volumes can be written as $L^* = \frac{2}{3b}(a - \gamma - \overline{c}^L - \delta\overline{\rho})$, where $\overline{c}^L$ and $\overline{\rho}$ are average loan monitoring cost and equity funding premium, respectively.

[35]In Appendix C.1, corresponding results are discussed for the case of general demand.

the sale of ancillary financial products. We now assume that banks and depositors interact in a two-stage game. In the first stage, banks compete in the loan market by issuing deposits and equity, as described in the basic set-up of Section 4.2.1. In the second stage, banks compete to sell a homogeneous ancillary financial product (such as an insurance contract, personal loan etc.) to depositors.

Each depositor is assumed to have inelastic unit demand for one unit of this product, which is valued at common reservation value $v > 0$. Depositors, however, are assumed to display inertia in their switching behaviour. Moreover, depositors are differentiated with respect to their switching cost. While any depositor that purchases the ancillary financial product from the bank that provides their deposit account incurs no costs in addition to the sale price, a switching cost equal to σ is incurred when they purchase from the rival bank. This σ is determined at the start of the second period as the result of a random draw from a uniform density on the interval $[0, \lambda]$, where $\lambda < v$.[36] The cost of offering this ancillary financial product for the banks is normalised to zero.

As in Section 4.2, dominance in our model will result from an asymmetry in the equity funding premium of the two banks. In particular, we shall now assume that this difference in equity funding premia is sufficiently large, so that

$$\rho_N - \rho_I > \frac{(1-\delta)}{\delta}\frac{5\lambda}{18}. \tag{4.6}$$

Thus we require that the difference in equity funding premia be sufficiently large relative to the upper bound on the feasible search costs λ, and that the capital requirement δ be high enough for this difference to matter.

Finally, we again assume that cash on balance sheet yields zero return, and, furthermore, that deposits are always costly for banks (that is, depositors will never pay to deposit their funds at a bank).[37] This implies that the balance sheet identity given in (4.1) again holds for both banks.

4.3.2 Initial Equilibrium

Let the price charged by bank $i = I, N$ for this ancillary financial product in the second stage be denoted by p_i, and the associated quantity sold by q_i. We will consider a subgame perfect Nash equilibrium in which, as before, we have a dominant bank that enjoys a lower equity funding cost that its rival.[38]

[36] As discounting between the two periods will not be important for our results, we do not include a discount factor in the model. Our modelling of switching costs is close to standard frameworks. See, e.g., Chen (1997).

[37] This is a fairly weak assumption. If we allowed for positive costs for banks of offering this ancillary financial product, it will always hold when these costs are sufficiently high, for example.

[38] That is, our aim is not to characterise the full range of possible equilibria in this game, but rather we restrict our attention to a dominant bank equilibrium that is the counterpart to the one-stage equilibrium analysed in Section 4.2.

Stage 2 – Ancillary Product Sales

We begin by considering the second stage competition for the sale of the ancillary financial product. At this stage, we take the first-stage choices of loans (equivalently: deposits or equity) as given. Assume, moreover, that in this dominant-bank equilibrium, the first stage deposit volumes satisfy[39]

$$d_I > d_N. \tag{4.7}$$

We posit, moreover, that the dominant bank will charge a higher price in this second stage equilibrium, that is

$$p_I > p_N. \tag{4.8}$$

Given that depositors face a cost of switching, (4.8) implies that switching can only occur from the incumbent to the new entrant. A depositor whose deposits are held by the incumbent will be indifferent between switching and not switching if

$$v - p_I = v - p_N + \sigma,$$

which in turn implies that the quantity sold by the incumbent in the second stage will be

$$q_I = d_I \left[1 - \frac{(p_I - p_N)}{\lambda} \right].$$

In other words, the incumbent will sell the ancillary product to that fraction of its depositor base that does not have profitable switching opportunities. Hence it follows that the quantity sold by the new entrant in the second period will be equal to its own depositor base (none of whom will switch since we posit that $p_N < p_I$) plus the share of the incumbent's depositors that switch, so that

$$q_N = d_N + d_I \left(\frac{p_I - p_N}{\lambda} \right).$$

Given that the marginal costs of providing this ancillary product for the banks are normalised to zero, second-period profits of the banks can be written as

$$\pi_{I2} = p_I d_I \left[1 - \frac{(p_I - p_N)}{\lambda} \right], \tag{4.9}$$

$$\pi_{N2} = p_N \left[d_N + d_I \left(\frac{p_I - p_N}{\lambda} \right) \right]. \tag{4.10}$$

Maximising each profit function with respect to own price, the unique solution for second period prices that satisfies the second-order conditions can then be solved

[39] We later show this is guaranteed to hold, given (4.6).

as

$$p_I^* = \frac{\lambda(2d_I + d_N)}{3d_I} = \frac{\lambda(2l_I + l_N)}{3l_I}, \tag{4.11}$$

$$p_N^* = \frac{\lambda(2d_N + d_I)}{3d_I} = \frac{\lambda(2l_N + l_I)}{3l_I}. \tag{4.12}$$

Clearly, optimal second period prices will depend on the outcome of the first period deposit (equivalently, loan) market competition. Note also that optimal prices do not depend on the value of the product v. The degree to which banks can move away from the Bertrand outcome at the second stage depends solely on the magnitude of switching costs, as reflected in λ. Moreover, we see that $p_I^* > p_N^*$ if and only if $d_I > d_N$.[40] Therefore, the dominant bank will indeed always charge a higher price in the second-stage equilibrium. The one maintained assumption that we are carrying forward is therefore that $d_I > d_N$.

Substituting (4.11) and (4.12) into the profit expressions and expressing everything in terms of loans rather than deposit volumes, second period equilibrium profits are then equal to

$$\pi_{I2}^* = (1-\delta)\lambda\frac{(2l_I + l_N)^2}{9l_I}, \tag{4.13}$$

$$\pi_{N2}^* = (1-\delta)\lambda\frac{(2l_N + l_I)^2}{9l_I}. \tag{4.14}$$

Stage 1 – Loan Market Competition

In a subgame perfect equilibrium, each agent will be optimising, given the strategies of the other players. This means that depositors must be indifferent between depositing their funds with either bank in the first period, given the expected surplus derived from ancillary product sales in the second period. Since every potential depositor has a reservation return of γ, each bank will offer a deposit rate in period 1 that makes depositors indifferent between depositing and not depositing.

The total expected surplus of a depositor who deposits their funds with the incumbent in period 1 is equal to

$$r_I^D + \left[v - \int_{p_I^*-p_N^*}^{\lambda} \frac{p_I^*}{\lambda}\, d\sigma - \int_0^{p_I^*-p_N^*} \frac{p_N^*+\sigma}{\lambda}\, d\sigma\right].$$

[40] For completeness, to rule out the undercutting case where $d_I > d_N$ and $p_I < p_N$, note that, if $p_I < p_N$, second-period profits can be written as $\pi_{I2} = p_I\left[d_I + d_N(p_N - p_I)/\lambda\right]$ and $\pi_{N2} = p_N d_N\left[1 - (p_N - p_I)/\lambda\right]$ for the incumbent and new entrant, respectively. Maximising these with respect to price returns the same optimal prices as in (4.11) and (4.12), except that we have d_N in the denominator rather than d_I. Nonetheless, $d_I > d_N \Rightarrow p_I^* > p_N^*$, thereby contradicting the premise of this undercutting case.

Solving this and setting it equal to the reservation rate of γ, we can solve for the required deposit rate for the incumbent as

$$r_I^D(p_I^*, p_N^*) = \gamma - v + p_I^* - \frac{(p_I^* - p_N^*)^2}{2\lambda}.$$

Thus the required rate of return paid to depositors of the incumbent (that is, the incumbent's *average* cost of deposits) is increasing in the reservation rate γ and decreasing in the value of the ancillary product sold in the second period. The additive p_I^* term reflects the fact that, if consumers are charged a higher price in the second period, they will have to be compensated more for depositing their funds in the first period. The last term reflects the fact that, the greater the extent of divergence between the prices, the more opportunities depositors will have to switch in the second period, so the less they care about higher prices charged by the incumbent.

Similarly, the average cost of raising deposits for the new entrant is equal to

$$r_N^D(p_N^*) = \gamma - v + p_N^*.$$

Notice that the divergence between prices does not matter for the new entrant, since there will never be switching from the new entrant to the incumbent when $p_I^* > p_N^*$ (equivalent, $l_I > l_N$).

Substituting in the expressions for optimal second period prices, see (4.11) and (4.12), the required return per depositor (that is, the average cost of deposits) can be expressed as a function of loans as

$$r_I^D(l_I, l_N) = \gamma - v + \frac{\lambda}{3l_I}\left[2l_I + l_N - \frac{1}{6l_I}(l_I - l_N)^2\right], \tag{4.15}$$

$$r_N^D(l_I, l_N) = \gamma - v + \frac{\lambda}{3l_I}(2l_N + l_I). \tag{4.16}$$

Therefore, we can write the *total* cost of deposits for the two banks as a function of loan volumes as

$$C_I^D(l_I, l_N) = (1-\delta)l_I\left\{\gamma - v + \frac{\lambda}{3l_I}\left[2l_I + l_N - \frac{1}{6l_I}(l_I - l_N)^2\right]\right\}, \tag{4.17}$$

$$C_N^D(l_I, l_N) = (1-\delta)l_N\left\{\gamma - v + \frac{\lambda}{3l_I}(2l_N + l_I)\right\}. \tag{4.18}$$

We can then express each bank's total profits across the two periods as a function of the chosen loan volumes as

$$\Pi_I(l_I, l_N) = l_I[a - bL - \delta r_I^E - c^L] - C_I^D(l_I, l_N) + \pi_{I2}^*(l_I, l_N), \tag{4.19}$$

$$\Pi_N(l_I, l_N) = l_N[a - bL - \delta r_N^E - c^L] - C_N^D(l_I, l_N) + \pi_{N2}^*(l_I, l_N). \tag{4.20}$$

Before considering the new Cournot-Nash outcome of maximising these profits, we will make some simplifications to the respective objective functions, based on the nature of the dominant bank equilibrium we are exploring. Before considering the first-order condition of (4.19) with respect to l_I, consider first the derivative of the total cost of deposits function for the incumbent. This is equal to

$$\frac{\partial C_I^D(l_I, l_N)}{\partial l_I} = (1-\delta)\left\{\gamma - v + \frac{\lambda}{18}\left[11 + \left(\frac{l_N}{l_I}\right)^2\right]\right\}.$$

Therefore, when the degree of dominance is large (so that the ratio l_N/l_I is small) the cost of deposits function quickly approaches a linear function. Graphically, the marginal cost of deposits function can be drawn for illustrative parameter values as in Figure 4.1, above. Notice that, when $l_I > 1$, it converges to a constant very quickly.

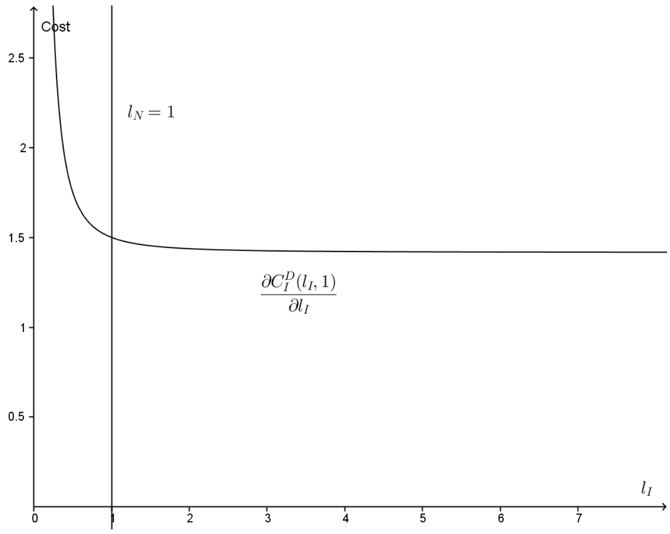

Figure 4.1: Marginal Cost of Deposits when $\delta = \frac{1}{2}$, $\gamma = 5$, $v = 4$, $\theta = 3$, $l_N = 1$.

Given that we are investigating a dominant bank equilibrium, in which indeed $l_I > l_N$, it is therefore a natural simplification to approximate the cost of deposits function at a point where the degree of dominance is large (that is, where $(l_N/l_I) \approx 0$), so that it becomes a linear function. Formally, this equivalent to a first-order approximation of $C_I^D(l_I, l_N)$ around the point where $l_N = 0$.

Similarly, the first derivative of the incumbent's second-period profits is approximately constant when the degree of dominance is large, since

$$\frac{\partial \pi_{I2}^*}{\partial l_I} = (1-\delta)\frac{\lambda}{9}\left[4 - \left(\frac{l_N}{l_I}\right)^2\right].$$

So again, the second period profits will be approximated well by a linear function whenever the degree of dominance is large.

Similar results hold for the new entrant's cost of deposits term $C_N^D(l_I, l_N)$ and second period profits $\pi^*_{N2}(l_I, l_N)$. In each case, the first derivatives with respect to l_N will depend on the endogenous variables l_N and l_I only via the ratio l_N/l_I. In a dominant bank equilibrium such as we are describing here, it is therefore again a natural simplification to approximate these functions at a point where the degree of dominance is large (again, where $(l_N/l_I) \approx 0$).

Using, therefore, first-order approximations around $l_N = 0$ for the cost of deposits functions and second-period profits, (4.19) and (4.20) can be written as

$$\Pi_I(l_I, l_N) = l_I \left[a - bL - (\delta\rho_I + \gamma + c^L) + (1-\delta)\left(v - \frac{\lambda}{6}\right)\right], \tag{4.21}$$

$$\begin{aligned}\Pi_N(l_I, l_N) = &\, l_N \left[a - bL - (\delta\rho_N + \gamma + c^L) + (1-\delta)\left(v + \frac{\lambda}{9}\right)\right] \\ &+ l_I(1-\delta)\frac{\lambda}{9}.\end{aligned} \tag{4.22}$$

These profits are straightforward to maximise, yielding unique solutions for first period loan volumes equal to

$$l_I^* = \frac{a - \gamma - \delta(2\rho_I - \rho_N) - c^L + (1-\delta)\left(v - \frac{4\lambda}{9}\right)}{3b}, \tag{4.23}$$

$$l_N^* = \frac{a - \gamma - \delta(2\rho_N - \rho_I) - c^L + (1-\delta)\left(v + \frac{7\lambda}{18}\right)}{3b}. \tag{4.24}$$

Notice, finally, that our maintained assumption that $l_I^* > l_N^*$ will hold whenever (4.6) holds, which closes the description of this dominant bank equilibrium.

The final terms in these expressions represent the change in net profitability of issuing deposits, which is positive for both banks because they can now pay a return on deposits below the reservation return γ (since depositors anticipate surplus in period 2), and also earn profits directly from their depositors in the second period. Therefore, the cost advantage of funding via deposits rather than equity is strengthened.

Substituting these equilibrium loan values into (4.19) and (4.20), total equilibrium profits are equal to

$$\Pi_I^* = \frac{(l_I^*)^2}{b}, \tag{4.25}$$

$$\Pi_N^* = \frac{(l_N^*)^2}{b} + l_I^*(1-\delta)\frac{\lambda}{9}. \tag{4.26}$$

4.3.3 Capital Regulation

We are now in a position to consider the marginal effect of increases in the capital requirement δ on this initial subgame perfect dominant bank equilibrium. Note that the market share of the incumbent bank can now be written as

$$s_I^* = \frac{1}{2} + \frac{3\left[\delta(\rho_N - \rho_I) - (1-\delta)\left(\dfrac{5\lambda}{18}\right)\right]}{4\left[a - \gamma - \delta\overline{\rho} - c^L + (1-\delta)\left(v - \dfrac{\lambda}{36}\right)\right]}.$$

By inspection, since the numerator of the second additive term is increasing in δ and the denominator is decreasing in δ, higher capital requirement will again increase the market concentration. Moreover, there is now an additional effect relative to the benchmark case. Not only does higher δ give greater importance to equity as a source of funds (for which, as we know, the incumbent enjoys a cost advantage). Given the second-stage competition in which the incumbent charges higher prices due to its dominant position, and the fact that depositors anticipate this in the first stage, the cost of *deposits* is now *higher* for the incumbent than for the new entrant.[41] Therefore, a higher capital requirement also makes that source of funds (namely, deposits) for which the incumbent is at a cost disadvantage less significant.

4.3.4 Anti-competitive Actions – Loan Market

So again, increases in the deposit rate increase the market concentration. We may now consider the effect of an increase in the capital requirement on the incentives of the incumbent[42] to engage in anti-competitive conduct in the loan market, as described in Section 4.2.5. Allowing for asymmetry in c_i^L in (4.25), the incentive to take the anti-competitive action in the loan market is equal to the profit effect, in turn determined by

$$\frac{\partial \Pi_I^*}{\partial c_N^L} = \frac{2l_I^*}{3b^2} > 0.$$

It follows that the incentive to take this anti-competitive action is again proportional to the size of the dominant bank. Considering now the effect of increases in the capital requirement on the incentives to take this action, note that

$$\frac{\partial^2 \Pi_I^*}{\partial \delta \partial c_N^L} = \frac{2}{9b^3}\left[(\rho_N - 2\rho_I) - \left(v - \frac{4\lambda}{9}\right)\right].$$

As before, the effect of increasing δ on the incentives to take the action will depend on its effect on l_I^*, since the profits from this action are proportional to loan volumes. Since we know that banks pay a cost above γ for equity and a cost below γ for deposits, a shift in the funding mix towards more costly equity is now more likely to decrease loan volumes in absolute terms (even if they rise

[41] This follows since the marginal cost of deposits can be written (to an approximation) as $c_I^D(l_I, l_N) = \gamma - v + (11\lambda/18)$ and $c_N^D(l_I, l_N) = \gamma - v + (\lambda/3)$ for the incumbent and new entrant, respectively.

[42] In this section, we focus on the incentives of the dominant bank to behave anti-competitively.

in relative terms) than when the difference in funding costs was solely due to the equity funding premia ρ_i. In order for l_I^* to rise when the funding requirement shifts in favour of more costly equity, we now require the difference in funding premia to be sufficiently large also to offset the increase in costs that occurs due to the opportunity cost of reduced deposits.

Proposition 10. *Allowing for second stage ancillary product sales, the necessary and sufficient condition for increases in the capital requirement to increase the incentives of the incumbent to take the anti-competitive action in the loan market is*

$$\rho_N > 2\rho_I + \left(v - \frac{4\lambda}{9}\right).$$

Hence, due to the additional profit opportunities associated with deposits in this two-stage game, higher capital requirements are less likely to increase the incentives of the incumbent to act anti-competitively.

4.3.5 Anti-competitive Actions – Deposit Market

We now consider the final avenue for anti-competitive actions, namely exploiting depositors directly via the sale of ancillary financial products in the second period. First notice that, to the extent that depositors' switching costs differ depending on which bank they have deposited their funds with, only the incumbent's switching costs will matter in equilibrium, since the only switching that will ever occur in this dominant bank equilibrium is from the incumbent to the new entrant. A natural avenue for an abuse of dominance relating to the sale of ancillary financial products is, therefore, an increase in the switching costs of the incumbent's depositors.[43]

An important distinction here will be whether or not this increase in switching costs (formally, an increase in the upper bound on the switching cost distribution, λ) is *anticipated* by the other market participants. To the extent that the increase in λ is anticipated, it follows from (4.25) and (4.23) that this will always reduce equilibrium profits of the incumbent, since

$$\frac{\partial \Pi_I^*}{\partial \lambda} = -l_I^*(1-\delta)\frac{8}{27b^2} < 0.$$

We therefore have to refine the model slightly to accommodate an increase in the switching costs in the second period, that is not anticipated by depositors or the new entrant in the first period.[44] This means that depositors will not demand

[43] For example, the incumbent may hide disadvantageous terms in the small print or offer misleading advice to consumers concerning the product of the rival bank. This corresponds to a classic consumer protection issue.

[44] This assumption of myopic agents appears reasonable, since we are modelling an action that exploits consumers. In this case, the action is exploitative precisely because consumers do not have the opportunity to factor this increase in switching costs into their decision about where to deposit their funds in the first period. This assumption is also realistic, when one bears in mind the complexity of many financial products and the many potentially unforeseen ways in which banks might exploit this complexity in order to obstruct depositors' attempts to switch.

a corresponding increase in the return on deposits in order to be compensated for the expected higher prices for the ancillary prices in period 2, and the new entrant will not anticipate the increased profitability of deposits in period 2, and therefore will compete less strongly for deposits in period 1.

Suppose, therefore, that depositors and the new entrant expect in period 1 that the switching costs will be determined as a random draw from a uniform density function on $[0, \lambda]$, where λ is, in a sense, the fair value of switching costs (in the sense that this is the cost that people face of switching when they are not otherwise obstructed). However, suppose that the incumbent knows that it can somehow obstruct its depositors from switching by increasing (unexpectedly) at the start of period 2 the true upper bound on the switching costs to $\lambda + \Delta$. Given that depositors do not anticipate this increase in period 1, the cost of deposits is unaffected for both banks. Moreover, the new entrant will maximise total profits in period 1 on the basis of expected switching costs λ. Hence the objective functions of the two banks can now be written as

$$\widehat{\Pi}_I(l_I, l_N) = l_I \left[a - bL - \delta\rho_I - \gamma - c^L + (1-\delta)\left(v - \frac{\lambda}{6} + \frac{4\Delta}{9} \right) \right] + l_N(1-\delta)\left(\frac{4\Delta}{9} \right), \tag{4.27}$$

$$\widehat{\Pi}_N(l_I, l_N) = l_N \left[a - bL - (\delta\rho_N + \gamma + c^L) + (1-\delta)\left(v + \frac{\lambda}{9} \right) \right] + l_I(1-\delta)\frac{\lambda}{9}. \tag{4.28}$$

Setting $\Delta = 0$ returns the two standard profit functions (see (4.21) and (4.22)).

Notice that there is now an additional l_N term in the incumbent's objective function. The reason is that, the higher is the new entrant's loan volume, the more closely aligned will be the second period prices of the two banks, and therefore the lower will be the degree of switching when the incumbent marginally increases switching costs via Δ (holding this l_N fixed).

Maximising each objective function with respect to the corresponding loan variable and solving simultaneously, the unique solution that satisfies the second-order conditions is now

$$\hat{l}_I^* = \frac{a - \gamma - \delta(2\rho_I - \rho_N) - c^L + (1-\delta)\left(v - \frac{4\lambda}{9} + \frac{8\Delta}{9} \right)}{3b},$$

$$\hat{l}_N^* = \frac{a - \gamma - \delta(2\rho_N - \rho_I) - c^L + (1-\delta)\left(v + \frac{7\lambda}{18} - \frac{8\Delta}{9} \right)}{3b}.$$

Notice that the increase in switching cost, to the extent this is unanticipated, represents a pure market stealing effect from the new entrant to the incumbent.

Substituting these equilibrium loan values into the profit expression (4.27) yields equilibrium profits of the incumbent equal to

$$\widehat{\Pi}_I^* = \frac{(\hat{l}_I^*)^2}{b} + \hat{l}_N^*(1-\delta)\left(\frac{4\Delta}{27}\right).$$

We are now in a position to investigate the incentives for the incumbent to increase marginally the switching costs above expectations. This incentive effect is determined by

$$\left.\frac{\partial \widehat{\Pi}_I^*}{\partial \Delta}\right|_{\Delta=0} = (1-\delta)\frac{4}{27}\left(\frac{4}{b^2}\hat{l}_I^* + \hat{l}_N^*\right) > 0,$$

where all equilibrium terms on the right hand side are evaluated at $\Delta = 0$. Therefore we have the following intermediate result.

Lemma 14. *A marginal increase in the incumbent's switching cost is strictly profitable for the incumbent when such an increase is not anticipated by the other market participants (that is, depositors and the new entrant).*

Now consider the effect of an increase in the capital requirement on this incentive to increase the switching costs.

$$\left.\frac{\partial^2 \widehat{\Pi}_I^*}{\partial \delta \partial \Delta}\right|_{\Delta=0} = -\frac{4}{27}\left(\frac{4}{b^2}\hat{l}_I^* + \hat{l}_N^*\right) + (1-\delta)\left(\frac{4}{b^2}\frac{\partial \hat{l}_I^*}{\partial \delta} + \frac{\partial \hat{l}_N^*}{\partial \delta}\right),$$

where, again, everything on the right-hand side is evaluated at $\Delta = 0$. The first term is clearly negative and reflects the direct effect of an increase in the capital requirement. This will reduce the amount of deposits in favour of equity, which will necessarily reduce the profitability of increasing the switching costs for those depositors that remain.

The more interesting term is the second. This captures the changes in the *relative* amounts of deposits of the two banks. As noted, the profits of the incumbent now also depend on the new entrant's loan (equivalently, deposit) volumes, since these determine the potential for switching when the costs of doing so are increased. Writing this indirect effect out in full, we see that it is equal to

$$\frac{(1-\delta)}{3b^3}\left[\rho_I(b^2-8) - \rho_N(2b^2-4) - 4\left(v - \frac{4\lambda}{9}\right) - b^2\left(v + \frac{7\lambda}{18}\right)\right],$$

from which it follows that a sufficient condition for the indirect effect to be negative is

$$\rho_I(b^2-8) < \rho_N(2b^2-4).$$

This is satisfied whenever the slope of demand is sufficiently steep, so that $b > \sqrt{2}$. Therefore, despite the fact that increasing the switching cost increases the incumbent's loan volume $\hat{l}_I^*$, the fact that the new entrant's loan volumes $\hat{l}_N^*$ fall may cause the net indirect effect to be negative when demand is sufficiently steep.

On the other hand, if demand is flat ($b < \sqrt{2}$), then the indirect effect may turn positive if the difference in equity funding premia is sufficiently large, in which case an increase in the capital requirement may *increase* the incentives to exploit consumers. This will be especially true if the capital requirement is raised from an initially very low level (so that $(1-\delta)$ is close to unity). Hence we have the following.

Proposition 11. *Increases in the capital requirement δ will decrease the incentives for the incumbent to exploit depositors when demand is sufficiently steep, but may increase the incentives when demand is flat and the difference in equity funding premia $\rho_N - \rho_I$ is sufficiently large.*

Therefore, the degree to which we have a conflict between capital regulation and consumer protection depends on the slope of demand and the magnitude of the difference in equity funding premia.[45]

4.4 Conclusion

This chapter has addressed the following question: when do increases in stability-oriented capital requirements conflict with competition and consumer protection objectives in the banking sector. While higher capital requirements increase the market concentration, they do not necessarily increase the incentives for banks to behave in a way that harms consumers. The incentive of the incumbent to engage in a generic abuse of dominance in the loan market was shown to increase only if the difference in equity funding cost relative to the new entrant was sufficiently large. On the deposit side, the incentive to exploit consumers via an unanticipated increase in switching cost will *decrease* when capital requirements are raised, unless the equity funding costs are sufficiently divergent, and the slope of demand is sufficiently flat. Thus capital regulation, in the present framework, appears more likely to conflict with competition policy than consumer protection policy.

Extensions to this work should consider in more detail the appropriate remedies that a competition and consumer protection authority should implement to correct for the incentive effects of capital regulation. Our modelling of the competition authority was kept very brief in this chapter, to allow the analysis to focus on the profit effect of various harmful actions. The question of optimal enforcement (including optimal fines, the appropriate *base* on which to levy fines etc.) becomes particularly interesting when consumers are boundedly rational. In this case, existing work has already shown that there may be conflicts between

[45]Note that this unanticipated increase in the switching cost has an ambiguous effect on the new entrant's profits. While the new entrant's loan volumes clearly fall, it nonetheless benefits from the realised higher switching costs in the second period, irrespective of the fact that these were not anticipated. It can be shown that a sufficient condition for the new entrant's profits to increase when the switching costs are raised marginally is $b^2 > (1-\delta)\frac{2}{27}$.

competition and consumer policy.[46] This issue is left as the subject of future work.

Finally, it should be noted that some aspects of this model may also describe other settings in which regulation has a differential effect on competing firms' marginal costs (e.g. environmental regulation). The specific framework we develop here, with costly equity, binding capital constraints and gateway products that imply switching costs, is specific to the banking sector, however.

[46] Armstrong (2008)

Chapter 5

Concluding Remarks

This thesis has studied the optimal enforcement of competition policy in innovative industries and in the banking sector. In both cases, it was argued that the presence of important, competing regulatory aims (the promotion of innovation incentives in the former and the maintenance of stability in the latter) complicate the enforcement of competition policy.

Part I of the thesis focused on the case of innovative industries. In the context of unilateral refusals to license intellectual property, Chapter 2 investigated the welfare impact of a compulsory licensing policy. While the model does exhibit the trade-off between innovation incentives and increased competition that has been discussed in the existing literature, it also offers a simple mechanism via which the trade-off can be resolved: whenever the risk free rate of interest is sufficiently low, the benefits of increased competition will outweigh the reduction in innovation incentives from a consumer surplus point of view. In terms of total welfare, the impact of compulsory licensing was further related to a parameter capturing the "competitiveness" of the industry within which firms are competing. Provided the industry is sufficiently uncompetitive, compulsory licensing was shown to be a beneficial policy in total welfare terms. Finally, compulsory licensing was shown to be an effective policy if the competition authority follows a structural competition objective, which aims to prevent foreclosure in the market. Since compulsory licensing guarantees that the technological gap between the competing firms remains constant, it ensures that the leader cannot foreclose its less efficient rival by innovating successfully. These results are particularly relevant, given the differing views that competition authorities in the US and EU have taken of compulsory licensing in numerous high-profile refusal to license cases.

In Chapter 3, we explored the enforcement of competition policy in the context of a much more generally defined abuse of dominance. The aim of this chapter was to explore the extent to which the stringency of competition policy should differ, according to whether the abusive conduct was carried out in isolation or in combination with innovation. On this point, the existing literature has so far emphasised that recognising the benefits of innovation always leads to a more lenient policy when competition infringements occur with innovation, rather than in isolation.

In our model, the firm's decision to engage in this potentially anti-competitive abuse of dominance was treated separately from its decision to innovate. Since the firm's decision with respect to innovation falls outside the scope of competition policy, this effectively defines a firm's counterfactual behaviour. On that basis, we were able to develop a concept of 'true harm' that takes explicit account of a firm's innovation behaviour in the counterfactual position. In a decision error cost framework, we then demonstrated a particular sense in which the optimal stringency of competition policy should be harsher towards firms that innovate in addition to taking the anti-competitive action. This followed because firms that are observed as innovating as part of a competition infringement were also shown to be more likely to innovate in the counterfactual. This implies that the competition authority's estimate of harm, in each case calculated relative to the status quo position in which the firm would simply have done nothing, is more likely to be biased downwards (thereby inflating type II (acquittal) and deflating type I (conviction) errors) when firms innovate as part of a competition offence. The optimal liability standard, a measure inversely related to the stringency of competition policy, was therefore shown to be lower for such firms.

In Part II of the thesis, we considered the implications of prudential regulation, in particular in the form of minimum capital requirements, for competition and consumer protection policy in the banking sector. It was argued that, despite recent instances in which dominant banks have abused their market position to the detriment of customers on both the loans and deposits side, the main focus of regulators and academics (in particular in the wake of the recent financial crisis) has been on stability objectives. In that context, we derived a very robust result, showing that increases in the capital requirement increase the market concentration. In a sense, capital requirements therefore exert a negative effect on the *competitive environment* characterising the industry as a whole. Nonetheless, this increase in market concentration does not necessarily increase a dominant bank's incentives to abuse its position, either via a generic abuse of dominance in the loan market, or via the sale of ancillary financial products to depositors. In order for the incentives for anti-competitive conduct to increase (in either market), it was shown that the divergence in equity funding premia between the competing banks muse be sufficiently large. Moreover, the incentives of the dominant bank to exploit consumers via the sale of ancillary financial products is further influenced by the slope of the demand for loans curve: only to the extent that this is sufficiently flat might increases in the capital requirement increase the incentives for harmful conduct. Thus, the central contribution of this chapter was to clarify the conditions under which stability-focused capital regulation conflicts with competition and consumer protection policy in the banking sector.

Appendices

Appendix A

Appendices to Chapter 2

A.1 Collected Proofs

Proof of Lemma 1. The sum of marginal costs (equivalently, cost gaps) is the same, regardless of which firm innovates. Therefore, on the basis of existing results,[1] since the variance of marginal costs is greater when the leader wins, we know that industry profits are also greater in that case: $\Sigma(G+g,0) > \Sigma(G,g)$.

Proof of Lemma 3. Lemma 2 confirms the equality between hazard rates under compulsory licensing, while (2.11) confirms the rankings in the voluntary licensing regime. We can also see that compulsory licensing cannot lead to an increase in the hazard rate chosen by the follower, since, by (2.12),

$$Y^C - Y^V = P^{FRAND} - \pi_F(G+g,g) + \pi_F(G+g,0) \leq 0.$$

The inequality is strict if we have $\phi < 1$.

Proof of Lemma 4. We can write the rate-adjusted hazard rates under compulsory licensing as

$$X^C = \pi_L(G+g,g) - \pi_L(2G+g,G+g) + P^F + P^{FRAND},$$
$$Y^C = \pi_F(2G+g,G+g) - \pi_F(G+g,g) + P^F + P^{FRAND}.$$

The follower will remain the predicted winner of the race if and only if $Y^C > X^C$, which is to say

$$\Sigma(2G+g,G+g) > \Sigma(G+g,g).$$

Given (2.21), (2.26) and (2.27), this is always satisfied.

Proof of Lemma 5. Compulsory licensing reduces the hazard rate of the leader and (weakly) reduces the hazard rate of the follower. By (2.27)

$$X^C - X^V \leq \Sigma(G+g,g) - \Sigma(G+g,0) < 0.$$

[1] Salant and Shaffer (1999)

Also,

$$Y^C - Y^V = (1-\phi)\left[\pi_F(G+g,0) - \pi_F(G+g,g)\right] \leq 0,$$

since $\phi \leq 1$.

A.2 Voluntary Licensing and the 'Regulatory Threat'

We wish to show that, when firms anticipate the possibility of a compulsory licensing remedy in case no voluntary agreement is reached, the licensing conditions (2.5) and (2.8) do not change. As described in Section 2.3.2, let θ^j, $0 \leq \theta^j \leq 1$, be the common probability with which firms anticipate a compulsory licence being imposed on the innovating firm $j = L, F$, if a voluntary deal is refused. Moreover, let $P^{j(FRAND)}$ now denote the FRAND licence price that applies in case firm $j = L, F$ innovates successfully and is forced to license by compulsory licence.

Then, in case the leader innovates and licenses, the cost gaps are $(g_L^{LV}, g_F^{LV}) = (G+g, g)$, while, if the leader innovates and does *not* license, the cost gaps would be $(g_L^{LN}, g_F^{LN}) = (G+g, 0)$ with probability $(1-\theta^L)$, and $(g_L^{LN}, g_F^{LN}) = (G+g, g)$ with probability θ^L. It follows that the minimum price that the leader would be willing to accept for the licence, and the maximum that the follower would be willing to pay, can be written as[2]

$$\underline{P}^L = (1-\theta^L)[\pi_L(G+g,0) - \pi_L(G+g,g)] + \theta^L P^{L(FRAND)}$$

and

$$\overline{P}^L = (1-\theta^L)[\pi_F(G+g,g) - \pi_F(G+g,0)] + \theta^L P^{L(FRAND)},$$

respectively. That is, the reservation prices are now a weighted average of those that apply under voluntary licensing (see (2.3) and (2.4)) and the appropriate FRAND fee. Therefore, the leader will still license if and only if

$$\Sigma(G+g,g) > \Sigma(G+g,0).$$

Similar derivations for the case when the follower innovates shows that the reservation prices in that case can be written as

$$\underline{P}^F = (1-\theta^F)[\pi_F(G,g) - \pi_F(G+g,g)] + \theta^F P^{F(FRAND)}$$

and

$$\overline{P}^F = (1-\theta^F)[\pi_L(G+g,g) - \pi_L(G,g)] + \theta^F P^{F(FRAND)}.$$

Therefore, if the follower innovates, licensing will again take place if and only if

$$\Sigma(G+g,g) > \Sigma(G,g).$$

Since, in our general set-up of Section 2.2.3, it must hold that $\Sigma(G+g,0) > \Sigma(G,g)$,[3] the same intuition concerning the incentives of the leader to refuse to

[2]Note that the expectation of *exogenously-determined* FRAND licence fees does enter into these expressions (unlike the endogenously-determined, voluntary licence fees). While this does not change the conditions under which licensing will occur, it does affect the price level at which the licence would be exchanged.

[3]Salant and Shaffer (1999)

license carry over to this setting. Given (2.10), the leader has no (strict) incentive to license for all $0 \leq \theta^L \leq 1$. It follows that the threat of compulsory licensing alone cannot resolve the refusal to license problem.

Note that, when $\theta^L = 1$, the leader's decision to license has no perceived effect on industry profits, because firms anticipate a compulsory licence with certainty in case no voluntary deal is reached. Therefore, the licensing conditions break down, and firms are indifferent between licensing and not licensing. We may assume that the leader still does not license in that case. Alternatively, note that $\theta^L = 1$ implies that $\underline{P}^L = \overline{P}^L = P^{L(FRAND)}$, so that the *only* voluntary deal that may be reached is the one which exactly replicates the compulsory licence. Therefore, from an analytical point of view, we can still talk of compulsory licensing with no loss in generality.[4]

A.3 Spillovers

We wish to demonstrate that our welfare results are robust to the inclusion of spillovers, a standard method in the context of tournament models of R&D to combat the excess investment problem. Suppose, to that end, that a fraction s, $0 < s < 1$, of the technical progress engendered in any innovation spills over to the non-innovating firm. So, in the absence of licensing, if the leader innovates, the cost gaps would be $(g_L^{LN}, g_F^{LN}) = (G + g, sg)$, while if the follower innovates they would be $(g_L^{FN}, g_F^{FN}) = (G + sg, g)$. Therefore, we will have persistent dominance if and only if

$$\Sigma(G + g, sg) > \Sigma(G + sg, g). \tag{A.1}$$

This always holds (Salant and Shaffer (1999)), so that we still have persistent dominance in our baseline scenario.

Now, given the assumption of fixed fee licensing, it is straightforward to see that, if the leader innovates, licensing will take place if and only if

$$\Sigma(G + g, g) > \Sigma(G + g, sg),$$

[4]This model therefore also nests the voluntary licensing regime of Section 2.3.1 (when $\theta^L = \theta^F = 0$) and the compulsory licensing regime of Section 2.3.3 (when $\theta^L = 1$ and $\theta^F = 0$). Note that, in principle, it is also possible to allow θ^F to increase from zero under a compulsory licensing policy. This would shift the reservation prices, and therefore also the actual price at which the follower licenses towards $P^{F(FRAND)}$. There are then two possibilities. To the extent that $P^{F(FRAND)}$ is low, this would reduce the voluntary licence price P^F, and therefore reinforce the negative incentive effect that is already present in the model. To the extent that $P^{F(FRAND)}$ is very high (that is, close to the total economic benefit $\pi_L(G + g, g) - \pi_L(G, g)$), however, an increase in θ^F could actually increase the voluntary licence fee P^F, and therefore provide an offsetting incentive effect relative to the voluntary licensing scenario. This possibility notwithstanding, since we typically think of compulsory licensing as a tool to combat the refusal by dominant firms to license, rather than one by which follower firms can extract higher prices for their licences, we stick with the model where θ^F remains constant at zero. This is, moreover, consistent with a setting in which compulsory licensing only affects *dominant* firms.

while, if the follower licenses, we will have licensing if and only if

$$\Sigma(G + g, g) > \Sigma(G + sg, g).$$

Given (A.1), it is still true that, if any firm were to refuse to license, it would be the leader, as in Section 2.3.1. Moreover, all of the analysis in the main body of the chapter goes through unchanged, up to and including Section 2.4.1.

What we now require in order for total welfare to be higher under compulsory licensing rather than voluntary licensing (abstracting from cost savings and letting $TW(g_L, g_F)$ denote the total welfare levels associated with cost gaps (g_L, g_F)) is that

$$TW(G + g, g) > TW(G + g, sg).$$

This is equivalent to the requirement that[5]

$$8\epsilon > \frac{(11s + 3)(1 + s)}{1 - s} g + 14G.$$

Therefore, the total welfare effect is still positive when the industry is less competitive (that is, when ϵ is higher) – thus, the nature of Proposition 2 does not change. Nonetheless, the precise threshold *level* of "un-competitiveness" above which the total welfare effect turns positive is clearly increasing in the degree of the spillover s.

[5]Clearly, setting $s = 0$ returns the corresponding expression from the no-spillovers case analysed in the main body of the chapter, see (2.19).

Appendix B

Appendices to Chapter 3

B.1 Proof of Lemma 10

It is sufficient to show that, for each potential counterfactual $j \in \{0, I\}$, there is at least one profitable, potentially illegal action $k \in \{A, I+A\}$. We proceed by proving that (i) $\pi_A(\delta_{c_A}) > \pi_0$ for all $\delta_{c_A} \in D_A$, and (ii) $\pi_{I+A}(\delta_{c_A}, \delta_{c_A}) > \pi_I(\delta_{c_I})$ for all $\delta_{c_A} \in D_A$ and $\delta_{c_I} \in D_I$, which confirms the result.

(i) $\pi_A(\delta_{c_A}) > \pi_0$ for all $\delta_{c_A} \in D_A$. From (3.23), this is trivially true if the counterfactual situation is one of perfect competition, so that $\mu = \sigma = \pi_0 = 0$, or if $\delta_{c_A} \geq \delta_m > 0$, so that the effect of the action is to maintain or lower price and hence either maintain or increase revenue, while, as we have seen, the fraction of revenue going towards profits unambiguously increases. Using (3.23), we see that $\pi_A > \pi_0$ if and only if

$$(\eta - 1)\left(\frac{\delta_m - \delta_{c_A}}{1 + \delta_{c_A}}\right) < \frac{(1-\sigma)\delta_m}{\sigma + \delta_m}.$$

A sufficient condition for this to hold for any value of $\delta_{c_A} \in D_A$ is

$$\eta - 1 < \frac{1-\sigma}{\sigma + \delta_m}, \tag{B.1}$$

which, if we substitute (3.16) into (B.1), is equivalent to

$$\delta_m < \frac{1-\mu}{\mu + \eta - 1},$$

which is guaranteed to hold by (3.17).

(ii) $\pi_{I+A}(\delta_{c_A}, \delta_{c_I}) > \pi_I(\delta_{c_I})$ for all $\delta_{c_A} \in D_A$ and $\delta_{c_I} \in D_I$. The necessary and sufficient condition for $\pi_{I+A} > \pi_I$ is

$$\left(\frac{\sigma + \delta_m}{1 + \delta_m}\right)\left[1 - (\eta - 1)\left(\frac{\delta_m - \delta_{c_{I+A}}}{1 + \delta_{c_{I+A}}}\right)\right] - \sigma\left[1 + (\eta - 1)\left(\frac{\delta_{c_I}}{1 + \delta_{c_I}}\right)\right] > 0.$$

A sufficient condition for this to be positive for any value of $\delta_{c_A} \in D_A$ is

$$\left(\frac{\sigma+\delta_m}{1+\delta_m}\right)\left[1-(\eta-1)\left(\frac{\delta_m-\delta_{c_I}}{1+\delta_{c_I}}\right)\right]-\sigma\left[1+(\eta-1)\left(\frac{\delta_{c_I}}{1+\delta_{c_I}}\right)\right]>0,$$

which is the same as

$$\left(\frac{\sigma+\delta_m}{1+\delta_m}\right)\left[1-(\eta-1)\left(\frac{\delta_m}{1+\delta_{c_I}}\right)\right]-\sigma+\left(\frac{\delta_{c_I}}{1+\delta_{c_I}}\right)\left(\frac{\delta_m}{1+\delta_m}\right)(\eta-1)(1-\sigma)>0.$$

A sufficient condition for this to hold for any value of $\delta_{c_I} \in D_I$ (and therefore also any $\delta_{c_I} > \delta^*_{c_I}$) is

$$\left(\frac{\delta_m}{1+\delta_m}\right)[(1-\sigma)-(\eta-1)(\sigma+\delta_m)]>0,$$

or, equivalently,

$$\eta-1<\frac{1-\sigma}{\sigma+\delta_m},$$

which, by the closing arguments in step (i) of the proof, is always satisfied.

B.2 Proof of Lemma 11

The necessary and sufficient condition for the firm to prefer action $I + A$ over $k = A$ can, on the basis of (3.23) and (3.24), be written as

$$\Delta\pi \equiv \pi_{I+A}-\pi_A = R_0(\eta-1)\left(\frac{\delta_{c_I}}{1+\delta_{c_I}}\right)\left(\frac{\sigma+\delta_m}{1+\delta_{c_A}}\right)-z>0, \tag{B.2}$$

or, equivalently,

$$z<R_0(\eta-1)\left(\frac{\delta_{c_I}}{1+\delta_{c_I}}\right)\left(\frac{\sigma+\delta_m}{1+\delta_{c_A}}\right). \tag{B.3}$$

Therefore, irrespective of the firm's counterfactual action choice, if the realisation of Δ_{c_A} is sufficiently high, the firm will prefer action $k = A$ over $k = I + A$.

To show that there is also a probability that the firm might also choose action $k = I + A$ over $k = A$, irrespective of counterfactual behaviour, consider the marginal non-innovative firm, for which δ_{c_I} is arbitrarily close to $\delta^*_{c_I}$. Inserting the threshold value $\delta^*_{c_I}$ (see (3.22)) into (B.3), we see that, when $\delta_{c_A} = 0$, this firm will prefer action $k = I + A$ to $k = A$ whenever

$$1<\frac{\sigma+\delta_m}{\sigma},$$

which is satisfied for all $\delta_m > 0$. Hence a non-innovative firm may still choose action $k = I + A$, which it will do whenever the realisation of Δ_{c_A} is sufficiently low, and the firm is sufficiently close to the boundary of becoming innovative. Since, for an innovative firm, $\delta_{c_I} > \delta^*_{c_I}$, the same argument implies that the least innovative firm with δ_{c_I} only marginally above $\delta^*_{c_I}$ would still choose action $k = I + A$ when the realisation of Δ_{c_A} is sufficiently low. Hence there is strictly positive probability that a firm will choose either anti-competitive action, irrespective of whether or not it would innovate in the counterfactual.

B.3 Proof of Lemma 12

We wish to show that the conditional probability of the firm being innovative is greater when the potentially illegal action chosen is $k = I + A$ than when it is $k = A$. From (3.21) and (B.2), since both $\pi_I(\delta_{c_I})$ and $\Delta\pi$ are increasing in δ_{c_I}, and given that Δ_{c_A} and Δ_{c_I} are distributed independently (so that higher values of δ_{c_I} are not systematically associated with higher values of δ_{c_A}) the result follows immediately.

To be more precise about the firm's behaviour, we can define the following threshold value for Δ_{c_A} on the basis of (B.2). Let $\delta^*_{c_A}(\delta_{c_I})$ be the threshold value of Δ_{c_A} for a firm with innovation cost savings equal to δ_{c_I}, such that

$$\Delta\pi \begin{cases} \geq 0 & \text{if } \delta_{c_A} < \delta^*_{c_A}(\delta_{c_I}), \\ < 0 & \text{if } \delta_{c_A} \geq \delta^*_{c_A}(\delta_{c_I}). \end{cases} \tag{B.4}$$

Hence the firm will choose action $k = I + A$ over $k = A$ if and only if $\delta_{c_A} < \delta^*_{c_A}$. Applying the implicit function theorem to (B.2) implies that

$$\frac{d\delta^*_{c_A}(\delta_{c_I})}{d\delta_{c_I}} > 0.$$

We can therefore represent the firm's action choices in $(\Delta_{c_I}, \Delta_{c_A})$ space as in Figure B.1 below. For realisations of Δ_{c_I} to the right of the $\delta^*_{c_I}$ line, the firm would innovate in the counterfactual. From this graph, the result concerning conditional probabilities is also immediate.

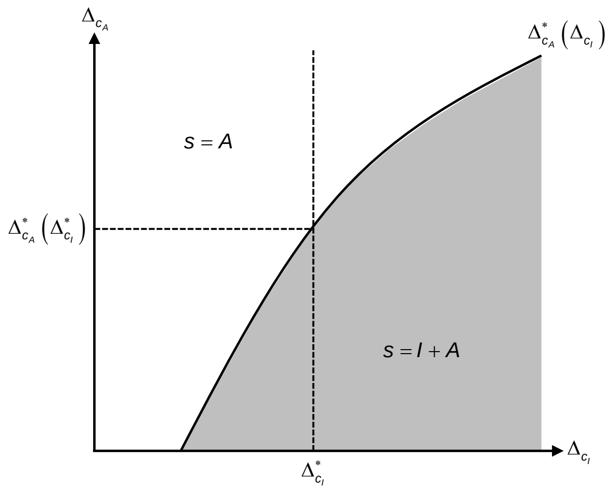

Figure B.1: counterfactual behaviour and action choices in $(\Delta_{c_I}, \Delta_{c_A})$ space

Appendix C

Appendix to Chapter 4

C.1 General Demand in Benchmark Case

We here consider briefly the robustness of the results in Section 4.2 to more general demand specifications. Suppose, therefore, that the inverse demand for loans curve $r^L(L)$ now satisfies the following standard assumptions:

A1. Twice continuously differentiable with $\dfrac{dr^L(L)}{dL} < 0$ whenever $r^L(L) > 0$.

A2. $r^L(0) > r_i > r^L(L)$ for L sufficiently large, $i = I, N$.

A3. Demand is not "too convex" so that $\dfrac{dr^L(L)}{dL} + L\left(\dfrac{d^2 r^L(L)}{dL^2}\right) < 0$.

Denoting the elasticity of the slope of demand by

$$\Theta(L) \equiv \left(\frac{d^2 r^L(L)/dL^2}{dr^L(L)/dL}\right) L,$$

assumption *A3* is equivalent to the requirement that $\Theta(L) > -1$. This specification allows for demand to be convex $(-1 < \Theta < 0)$, concave $(\Theta > 0)$ and linear $(\Theta = 0)$.

C.1.1 Initial Equilibrium

Note that the assumption of a positive equity funding premium ρ_i still implies that banks would choose to hold zero equity voluntarily. Therefore, in any equilibrium,

$$e_i^* = \delta\, l_i^* \quad \text{and} \quad d_i^* = (1-\delta)\, l_i^*$$

for $i = I, N$. Under assumptions *A1*-*A3*, moreover, the existence and uniqueness of a Cournot equilibrium is guaranteed.[1] This equilibrium displays intuitive comparative statics properties. Denoting the equilibrium profits of bank i by π_i^*, we

[1] Novshek (1985)

have[2]

$$\frac{\partial \pi_i^*}{\partial r_i} < 0 \quad \text{and} \quad \frac{\partial \pi_i^*}{\partial r_j} > 0, \;\; j \neq i,$$

so that profits are decreasing in level of the own funding costs, but increasing in the level of the rival bank's funding cost.

C.1.2 Capital Regulation

The marginal effect of raising the capital requirement is still given by (4.5), so that we again seek to represent the increase in the capital requirement via a shock to marginal costs. We follow the approach of Février and Linnemer (2004) (hereafter FL) by representing this cost shock associated with an increase in the capital requirement by the continuous variable $w^\delta \geq 0$. This cost shock w^δ results in funding cost for bank i of $r_i + \gamma_i^\delta w^\delta$, where γ_i^δ represents a sensitivity factor associated with the capital increase. From (4.5), this must satisfy

$$\gamma_i^\delta = \rho_i$$

for $i = I, N$. We may now explore the impact of a marginal increase in the capital requirement by examining the impact of this cost shock on equilibrium outcomes.[3] As a first step, we evaluate the effect on market shares. The market share of bank i as a function of the shock w^δ may be written as[4]

$$s_i^* = \frac{1}{2} + \frac{\overline{r} - r_i + (\overline{\rho} - \rho_i) w^\delta}{2\left[r^L(L^*(w^\delta)) - \overline{r} - \overline{\rho} w\right]}, \tag{C.1}$$

where $\overline{r}$ and $\overline{\rho}$ are the average funding cost and equity funding premium, and $L^*(w^\delta)$ is the function relating the equilibrium total loan volume to the magnitude of the shock w^δ. We first demonstrate that, in this general demand setting, an increase in the capital requirement still increases the market concentration.

Lemma 15. *Marginal increases in the capital requirement δ lead to a more concentrated market equilibrium, in the sense that the Herfindahl index rises.*

Proof. Differentiating (C.1) with respect to w^δ shows that the sign of $\partial s_i^* / \partial w^\delta$ is the same as the sign of

$$(\overline{\rho} - \rho_i)\left[r^L(L^*(w^\delta)) - \overline{r} - \overline{\rho} w^K\right] - \left[\overline{r} - r_i + (\overline{\rho} - \rho_i) w^\delta\right]\left[\frac{dr^L(L^*(w^\delta))}{dL}\frac{\partial L^*}{\partial w^\delta} - \overline{\rho}\right],$$

[2] Amir *et al.* (2013), Linnemer (2003)

[3] That is, we evaluate the effect of increases in δ on the equilibrium value of a given variable z_i via the sign of $\partial z_i^* / \partial w^\delta |_{w^\delta = 0}$. Our main focus in this Appendix will be on the effect of *marginal* changes in the capital requirement, since results for asymmetric cost shocks for general demand do not exist when the cost changes in question are discrete (except in the special case where such shocks leave the average cost unchanged, see Salant and Shaffer (1999)). Where our results do extend to discrete changes, in which case we may drop the $w^\delta = 0$ constraint from the derivative, this will be noted in what follows.

[4] See FL, Lemma 1.

which, evaluated at $w^\delta = 0$ for a marginal change in δ, has the same sign as[5]

$$(\overline{\rho} - \rho_i)\left[-\frac{dr^L(L^*)}{dL}L^*\right] + 2(\overline{r} - r_i)\left[\frac{\overline{\rho}(1+\Theta^*)}{3+\Theta^*}\right]. \tag{C.2}$$

where starred values denote the equilibrium value of a given function when $w^\delta = 0$. Therefore, since for the incumbent $\rho_I < \overline{\rho}$ and $r_I < \overline{r}$, we have

$$\left.\frac{\partial s_I^*}{\partial w^\delta}\right|_{w^\delta=0} > 0,$$

while for the new entrant bank we have $\rho_N > \overline{\rho}$ and $r_N > \overline{r}$, so that

$$\left.\frac{\partial s_N^*}{\partial w^\delta}\right|_{w^\delta=0} < 0.$$

Hence the dominant position of the big bank is strengthened and the Herfindahl index rises. □

Note that this result is independent of whether demand is convex, concave or linear. We also note the following immediate corollary.

Corollary 2. *Lemma 15 also holds for discrete changes in the capital requirement δ.*

Proof. Follows proof of Lemma 15. Without the condition that $w^\delta = 0$, (C.2) becomes

$$(\overline{\rho} - \rho_i)\left\{-\frac{dr^L(L^*(w^\delta))}{dL}L^*(w^\delta)\right\} + 2[\overline{r} - r_i + (\overline{\rho} - \rho_i)w^\delta]\left\{\frac{\overline{\rho}\left[1+\Theta^*(w^\delta)\right]}{3+\Theta^*(w^\delta)}\right\},$$

from which the result is immediate. □

Thus the result that higher capital requirements increase the market concentration is fairly robust.

C.1.3 Anti-competitive Actions – Loan Market

We now consider the profit incentive of a given bank to take the anti-competitive action in the loan market defined in Section 4.2.5. To make the comparative static analysis in this section manageable, we impose one further condition on the form of the inverse loan demand. Specifically, we focus on the family of constant-Θ demand functions, which means that demand takes the form

$$r_L(L) = \max\left\{a - \frac{b}{1+\theta}L^{1+\theta}; 0\right\}, \quad a, b > 0,$$

[5]This step draws on intermediate results from FL.

so that $\Theta(L) = \theta$ for all L, and *A3* now guarantees that $\theta > -1$. Nonetheless, this specification still allows us to distinguish between demand that is convex ($-1 < \theta < 0$), concave ($\theta > 0$) and linear ($\theta = 0$). Indeed, the distinction will turn out to be important for the results we develop in this section.

Following the same definition of the anti-competitive action, we can represent this via another cost shock, associated with the continuous variable w^A, with associated sensitivity parameters $\gamma_j^A > 0$ and $\gamma_i^A = 0$, $j \neq i$, when the bank taking the action is bank i. The profit effect when bank i takes the anti-competitive action is given by[6]

$$\frac{\partial \pi_i^*}{\partial w^A} = l_i^* \left\{ \gamma_j^A + \frac{\gamma_j^A}{3+\theta} \left[\theta (s_i^* - 1) - 1 \right] \right\}, \quad j \neq i \tag{C.3}$$

which is positive for all $\theta > -1$.

By inspection of (C.3), it is clear that the incentives of a given bank to engage in this anti-competitive action are affected by the curvature of the demand curve θ, the equilibrium loan volume l_i^* and (via θ) the market share s_i^*.

Since the latter two of these variables are, in turn, affected by changes in the capital requirement δ, it follows that changes in the capital requirement will alter the incentives of any bank to engage in the anti-competitive action. To investigate when the effect of changes in δ increases the incentives to engage the action, we consider in turn the effects of the cost shock reflected in w^δ, associated with sensitivity parameters $\gamma_i^\delta = \rho_i$, on l_i^* and s_i^*.

From Lemma 15 and Corollary 2, we know that the cost shock associated with the increase in the capital requirement (characterised by sensitivity parameters γ_i^δ) increases the market share of the incumbent at the expense of the new entrant, in other words

$$\frac{\partial s_I^*}{\partial w^\delta} > 0, \qquad \frac{\partial s_N^*}{\partial w^\delta} < 0.$$

Moreover, the incentive effect of increases in δ running via s_i^* depend on the curvature of the demand curve. Increases in the capital requirement δ increase the incentives of the incumbent (respectively, the new entrant) to take the action if and only if demand is concave (respectively, convex).

To analyse the effect of increases in δ (as reflected in w^δ) on the equilibrium loan volume l_i^*, first note that

$$l_i^*(w^\delta) = \frac{L^*(w^\delta)}{2} + \overline{r} - r_i + \frac{(\overline{\rho} - \rho_i) w^\delta}{-[dr^L(L^*(w^\delta))/dL]}.$$

Differentiating this with respect to w^δ, evaluating at $w = 0$ for a marginal change and rewriting, the necessary and sufficient condition for an increase in δ (equivalently, w^δ) to increase the equilibrium loan volume of a given bank is

$$\frac{\rho_i}{\rho_j} < \frac{2+\theta}{4+\theta}, \quad j \neq i.$$

[6]See FL Proposition 2.

Therefore, as before, increases in the capital requirement will always reduce the incentive effect of the new entrant running via l_N^*, and will increase the incentive of the incumbent to take the action if and only if the difference in equity funding premia is sufficiently large. Therefore, we have the following result.

Lemma 16. *A sufficient condition for (marginal) increases in the capital requirement δ to increase the incentives for the incumbent to take the anti-competitive action is*

$$\theta \geq 0 \quad \textit{and} \quad \rho_N > \rho_I \left(\frac{4+\theta}{2+\theta} \right).$$

Clearly, the incentive effect is more likely to be positive, the more concave is demand. This follows because, when demand is concave, the impact of a cost shock that (on average) increases firms' marginal costs is to shift demand from inefficient firms to efficient firms (that is, from small firms to dominant firms).

The results for linear demand presented in the main body of the chapter are therefore a special case of this result when $\theta = 0$, in which case the necessary and sufficient condition becomes

$$\rho_N > 2\rho_I.$$

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