

Technological Convergence and Regulation

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Abstract

This paper discusses some of the links between convergence and regulation in information and communications technologies. The main findings are as follows. First, when industries converge across time and they are subject to extreme regulatory asymmetries, a cross-industry regulatory transmission mechanism emerges. In particular, we found that the unregulated industry is adversely affected by the implementation of welfare-enhancing regulation in the neighbouring industry. Second, the presence of this transmission mechanism creates incentives for regulatory replication by the affected industry. Third, from a cross-industry point of view, the welfare implications of regulatory replication are ambiguous since they depend on the degree of vertical differentiation across platforms, the magnitude of regulatory intervention and, most importantly, of the timing when this replication occurs. We conclude that the implementation of the cross-industry optimal welfare path would require certain degree of regulatory flexibility (switching capacity to move from one regulatory regime to another) and some sort of cross-industry enforcement mechanism that would make the implementation of welfare-enhancing cross-industry policies feasible.

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1. Introduction

During decades the information and communications industry was characterised by a one-to-one correspondence between services and delivery systems. In the 1970's, telephones could only provide analogue voice point-to-point communications whereas cable distribution systems could only provide non-interactive broadcast television programming. In other words, the set of services provided by a particular operator was constrained by the characteristics of its delivery technology. The last years has seen the emergence of a vast number of technological innovations which have ended with this one-to-one correspondence between delivery systems and services. Telephony can now be provided by wired, wireless and satellite technologies, whereas video services can now be provided by cable TV, copper wire pairs –through Digital Subscriber Lines (DSL)– and wireless technologies. The number of services that can be supplied over these delivery systems is still expanding rapidly. The rupture of this one-to-one correspondence between delivery systems and services is usually described as the *convergence* phenomenon.

One of the features of this process of convergence is that the dynamics of the regulatory frameworks governing these industries have historically shown certain degree of *sluggishness* with respect to the competitive dynamics that convergence brings. Regulatory sluggishness occurs, for example, when an incumbent operator is still regulated as a pure monopoly even when its actual behaviour is starting to be constrained by the emergence of new entrants. Regulatory sluggishness also occurs when, as a result of both technological convergence and regulatory inertia, two operators that compete in essentially the same market end up being subject to two distinct regulatory regimes. As pointed out by Tardiff (2000), as technologies develop, markets converge and the historical advantages of incumbency recede, the critical questions become: (a) when do inherited pre-convergence rules favour or handicap the competitive position of a particular platform rather than promoting fair competition in a post-convergence scenario and, (b) to what extent a regulator is able to recognise the point where competition has developed sufficiently so

that regulation can be reduced and, perhaps, ultimately eliminated. Regarding these questions, the OECD has recently pointed out that:

“...the convergence in service offerings between different platforms calls into question the logic of maintaining existing separate regulatory frameworks for telecommunications and broadcasting. The integration of these frameworks is not simple, requiring a review of the legal and policy frameworks covering the formerly distinct sectors and the possible creation of a single policy framework which is coherent across the electronic communications sector. New platforms, in particular broadband Internet, and the services provided on these platforms have already begun to compete with traditional services provided over broadcasting and telecommunications infrastructures. This also provides a challenge to regulation”.¹

This paper discusses some of the challenges that the process of technological convergence impose on the design of an optimal regulatory structure. Our discussion starts from the premise that, as a result of regulatory sluggishness, two increasingly competitive industries end up being subject to distinct regulatory frameworks. We then discuss the extent the harmonization of this asymmetric treatment of industries is welfare-enhancing as the process of technological convergence evolves. It is worth noting that the harmonization of regulatory frameworks across industries as convergence matures is far from being straightforward. Consider as an example the distinct focus that regulation takes when it is implemented over a telecommunications or a broadcasting infrastructure. The focus of regulation over broadcasting facilities has been, historically, more on content than on carriage issues. However, the opposite occurs when a telecommunications facility is at hand. Should, in the interest of fairness, the content regulation of terrestrial, cable and satellite broadcasting be rolled out to Internet broadcasters? Or should the content regulation of terrestrial, cable and satellite broadcasters be

¹ OECD (2005); p. 20.

significantly rolled back since content in the Internet-era can be chosen selectively by consumers without need of watchdog intervention?

To advance in our discussion this paper assumes that the regulatory treatment of platforms operating in different industries can be characterised through a one-dimensional quantitative measure. On this basis, we proceed to discuss three distinct regulatory regimes. The baseline case is one where platforms are symmetrically “regulated” due to the absence of regulation while asymmetric and symmetric regulation of platforms provide the remaining relevant regimes. Our final objective will be to provide a comparative analysis of the relative performance of these three regimes throughout the process of convergence in order to discuss the validity of the assertion that argues that symmetric regulation is the preferred institutional arrangement once convergence between services have started to take place (Crandall, Sidak and Singer, 2002).

The paper is organized as follows. In section 2 we briefly review two recent experiences of asymmetric regulation in the US telecommunications and broadcasting industries. In section 3 we provide a selective literature review of the academic work related to us whereas in section 4 we describe with some detail our analytical framework. The following three sections describe the equilibrium outcomes associated with our three core regulatory regimes: no regulation (section 5); asymmetric regulation (section 6) and symmetric regulation (section 7). Section 8 provides a welfare comparative analysis of these regulatory regimes throughout the process of convergence and, finally, section 9 concludes.

2. Some Empirical Evidence on Regulatory Asymmetry in the US

This section briefly describes two important cases of regulatory asymmetry in the information and communications sector in the US. As it will be obvious from the discussion below, some of the themes surrounding the treatment of regulatory asymmetries are still ongoing discussion.

Cable Modem and DSL Broadband Technologies

In most markets around the world, the provision of broadband services for residential consumers is dominated by two technologies: cable modem and DSL technologies. In most countries these two technologies have been subject to some form of regulation as they are based on infrastructures with natural monopoly features. Historically, the regulatory regime governing each of these underlying technologies was different because the type of core service provided by each of these systems was also different: voice communications for phone infrastructure and TV for cable technology.² The recent process of technological convergence between these two platforms has made possible the provision of broadband services through any of these two technologies. However, the regulatory apparatus governing the provision of services in each of the underlying facilities was automatically extended to the provision of new services as broadband. Not surprisingly, this situation created an environment where the main providers of DSL services (incumbent local exchange carriers) were operating within an entirely different regulatory framework than their cable competitors. As pointed out by Hausman (2002) and Hausman, Sidak and Singer (2001), the providers of broadband services through telephone facilities have not only been required to share their networks with competitive local exchange carriers through *unbundling rules* at prices set by regulation but also their retail broadband rates have been often

² From a legal point of view, the reason why these services were regulated differently is because one is considered a communication service (voice) whereas the other is considered to belong to the realm of information services (TV). Historically, communications services are regulated whereas information services are not.

regulated.³ In contrast, cable modem broadband services are under no legal obligation to open their facilities for the use of competitors and their rates are usually not regulated. A major policy shift occurred in the US broadband market on February 2003 when the Federal Communications Commission stated that will not longer require line-sharing be available as an unbundled element, narrowing in this way the open access requirements governing DSL networks. The phasing-out of “line sharing” eliminated the option to lease only part of the local loop.⁴ Now, Competitive Local Exchange Carriers seeking to use Incumbent Local Exchange Carriers loops to deliver DSL have to pay for the entire circuit as if they were reselling telephone service. This process of partial deregulation sharply raised wholesale prices charged for accessing the incumbent’s network and it represented a significant step towards the regulatory harmonization across technologies providing broadband services.

Cable TV and Satellite Broadcasting Technologies

Another remarkable example of asymmetric regulation in converging technologies is provided by the legal limitations imposed over Direct Broadcast Service (DBS) operators in the transmission of local broadcast station signals during the late nineties. A 1976 copyright law permitted the retransmission of local television signals by local cable franchises through permanent copyright licenses. Under this copyright license scheme, copyright owners are required to license their works to cable systems at government-set prices, terms, and conditions. In practice, cable operators pay minimal or no copyright fees to carry local broadcast signals. A different compulsory copyright license scheme, however, applied to satellite operators. DBS providers were governed by the 1988 Satellite Home Viewer Act, which was

³ Unbundling rules are based in the concept of “unbundled network element” (UNE). UNE is a part of the network that the Incumbent Local Exchange Carrier is required to offer on an unbundled basis to competitors in order to deliver service without laying network infrastructure.

⁴ Until February 2003, US local regulators were free to set DSL local access rental fees based on the cost of using only part of the local loop: the high-frequency portion that is best used for data. Because this bandwidth can be used when the low-frequency portion is simultaneously delivering phone calls, incremental costs were usually set very low.

originally passed at a time when satellite providers did not possess the technology to transmit local broadcast signals. DBS systems were first launched in 1994 but until 1999, the act granted only a limited exception to the exclusive programming copyrights of television networks and their affiliates. This limited exception gave satellite companies license to deliver broadcast network programming only to those customers living in “unserved households.”⁵ Hence, DBS firms had no license to provide broadcast signals to households in urban or suburban areas that generally could receive adequate over-the-air local broadcast signals. Naturally, these legal restrictions on broadcast carriage had become an important competitive disadvantage for satellite providers since while cable subscribers were able to receive their local broadcast stations as part of their programming package, most DBS subscribers could not. This asymmetric regulatory treatment of broadcasting operators concluded when in 1999, in part as recognition that the inability to receive local broadcast signals from DBS operators made subscription to DBS services less attractive, the US Congress enacted the Satellite Home Viewer Improvement Act allowing DBS companies to provide local broadcast signals. In a recent study the US General Accounting Office (2005) has confirmed that the 1999 reforms that eliminated this regulatory asymmetry were successful in promoting higher competition between these two technological platforms.

3. Related Literature

This paper is directly related to the literature of mixed oligopoly where private and public firms engage in mutual competition. In the standard framework, private firms maximize profits whereas public firms maximize welfare. One of the first contributions for the analysis of mixed oligopolies stems from the work of Merrill and Schneider (1966). They show that the entry of a public firm in an oligopolistic industry of homogeneous products with unused capacity can result in an improvement in the short-run market performance: lower prices

⁵ An unserved household is one which cannot adequately receive broadcast signals over the air via traditional rooftop antennas.

and increased output. In a private-firm symmetric equilibrium of homogenous products with positive fixed costs and increasing marginal costs, De Fraja and Delbono (1989) shows that it might be the case that welfare is higher in a pure oligopoly than when the public firm strives to maximize welfare. The reason is that although the behaviour of the public firm increases total output and thus it also increases consumer surplus, the inequality between private- and public-firm production is also significant. Since efficiency requires that total output should be divided across firms as equally as possible, given the shape of the cost functions, the fact that the public firm produces more than the private ones might outweigh the positive effect of the increase in total output. Cremer, Marchand and Thisse (1989) analyse the extent to which public enterprises can be used as a policy instrument to improve welfare in an imperfectly competitive market. In the context of homogeneous products with positive fixed costs of production, they show that total surplus increases only when the number of welfare-maximizing firms is upper bounded. This is because by changing the objective function of a private firm gives rise to an output expansion effect. However, the magnitude of this effect is limited by the break-even constraint stemming from the presence of fixed costs. As more firms are made public, further output expansions are not guaranteed since public firms might be forced to cut output to meet their break-even constraint. When exploring the possibility of entry of a public firm, they conclude that making public an existing private firm is more efficient than entry because of the higher fixed costs involved in the latter case. The previous works assumed that the public firm was a fully welfare-maximizer entity. Matsumura (1998), in contrast, discusses a mixed duopoly with mixed ownership of the public firm: output is determined according to both profit- and welfare maximization principles. Using a model of perfectly substitutable goods, he shows that the optimal ownership structure of the public firm is not associated either to full nationalization or to full privatization when the public firm is as efficient as the private one. On the same spirit of partial ownership of the public firm, Fershtman (1990) considers a mixed duopoly between a private and a partially public firm with homogenous products and identical cost structures. He shows that a partially owned firm serves as a credible commitment to increase output beyond the profit-maximizing level. He also emphasizes that if

firms have unequal production cost such that the partially public firm is less efficient, the creation of a partially public firm may promote inefficiency. Naturally, the overall contribution to welfare of having a partially public firm will depend on the balance between the benefit of greater output and the loss arising from the cost inefficiency. On the other hand, Cremer, Marchand and Thisse (1991) discuss a model of mixed oligopoly with horizontal differentiation. In the context of a Hotelling model with quadratic transportation costs they found that having a public firm maximizing social surplus is not necessarily socially optimal even when the public firm has the same cost structure that its competitors. They also provide the intuition that private firms may benefit from the presence of a public firm in the sense that they earn higher profits than in the private oligopoly case.

The model we discuss in the following pages belongs to the mixed oligopoly tradition since we model regulation as partial public ownership of one or two of the concurring platforms. In particular, we suppose that the higher the degree of partial public ownership the higher the firm's incentives to behave according to welfare-maximization motives. Our discussion differs from previous analysis in the following three dimensions. First, as in Cremer, Marchand and Thisse, we discuss a horizontal differentiation model. However, our model also incorporates the possibility of differentiation along a *vertical attribute*. Second, unlike the above authors, we discuss horizontal differentiation from a dynamic perspective. Finally, our analysis also differs from previous discussions in the fact that we explicitly compare the relative welfare performance of distinct regulatory regimes as horizontal differentiation shrinks and vertical differentiation remains constant.

4. The Model

Consider a differentiated duopoly based in the pioneering work of Bowley (1924). The economy contains two sectors. The first of these has two technological platforms providing differentiated services to consumers

whereas the second is a competitive *numéraire* sector.⁶ There is a continuum of consumers of the same type with a utility function separable and linear in the *numéraire* good. Hence, there are no income effects on the first sector and we can perform partial equilibrium analysis. The standard economic argument to justify this assumption is that consumers spend only a small part of their income on the services associated with this industry. Thus, the representative consumer optimises the programme:

$$\max_{x_1, x_2} U(x_1, x_2) + \left\{ Y - \sum_{k=1}^2 p_k x_k \right\} \quad (3.1)$$

where $U(x_1, x_2)$ represents the utility stemming from the consumption of services x_1 and x_2 . The term inside brackets describes expenditure in outside goods when the price of service k is p_k and consumer's income is Y . By following Sutton (1997) and Symeonidis (2000, 2003), we assume that utility has the functional form:

$$U(x_1, x_2) = \sum_{k=1}^2 \left(x_k - \frac{x_k^2}{(q_k(\gamma))^2} \right) - 2\gamma \prod_{k=1}^2 \left(\frac{x_k}{q_k(\gamma)} \right)$$

where x_k and $q_k(\gamma)$ stand for quantity and quality of service k , respectively. A natural way of interpreting the consumed quantity of a service is simply as the time allocated to its consumption at a given price. We also assume that each platform provides only one variety of the services available in this industry.

The utility function specified above is just a quality-augmented version of the standard quadratic utility function extensively used in the industrial organisation literature (Dixit (1979); Singh and Vives (1984), Shaked and

⁶ By describing a situation where the first sector contains exactly two technological platforms within a framework of no entry or exit we are implicitly assuming that the market structure is exogenous.

Sutton (1990)). This utility function introduces the notion that each service variety is also associated with a vertical attribute (quality), $q_k(\gamma) > 0$. Naturally, higher values along this vertical dimension imply higher demand curves. The parameter γ plays a central role in the analysis and interpretation of the main results of this paper. The standard interpretation of the parameter $0 \leq \gamma \leq 1$ is as a measure of the degree of horizontal differentiation or substitution between the two services. The parameter γ impacts consumer's utility in two different ways. A direct impact on utility stems from the substitutability between platform's services. When $\gamma \rightarrow 0$, the cross-product term in the utility function vanishes and the two services become independent while when $\gamma \rightarrow 1$ they become perfect substitutes if $q_1(\gamma) = q_2(\gamma)$. There is also an *indirect* impact of the parameter γ on consumer's utility through its effect on quality. More on this indirect effect below.

In the context of the present paper, we give to the parameter γ a time-oriented interpretation. In particular, we postulate that one can characterize the '*maturity*' of the process of convergence by a continuous and strictly increasing movement of the parameter γ . When $\gamma \rightarrow 0$, a no convergence regime arises since consumption of the two services require access to two equally distinct platforms. In contrast, when $\gamma \rightarrow 1$, a full convergence regime emerges since, given the perfect substitutability between services at identical qualities, consumption of the available services only require access to one of the two platforms. Hence, monotonous and strictly increasing values in the parameter γ allow us to characterize the evolution of *convergence in substitutes*.⁷ It is worth noting that the validity of the above interpretation of parameter γ strongly relies in the following assumption:

⁷ There is also convergence in complements which occurs when a new technology opens up the possibility of combining existing technologies to provide a new service. In other words, existing technologies are fused together to create new services. A premier example of this type of convergence in technological complements is the emergence of the market for handheld computers in the early 1990s. Partly triggered by new advances in handwriting recognition technology, companies from different industries like telecommunications, computers and consumer electronics combined their technologies to offer the first handheld computers.

ASSUMPTION 1. *The technological platforms operating in both markets are not able to explicitly or implicitly collude.*

Assumption 1 is central to support the validity of the interpretation of γ as an index of convergence. As we will discuss later, the main outcome of the model is a Nash-Cournot level of production for a given level of γ . Because we assume that γ moves continuous and increasingly along time, it follows that, in fact, platforms are playing the same game as many times as γ takes distinct values. The only difference between two successive games is that the game played in the previous period had a lower index of substitutability between services. Naturally, this supergame structure would make a collusive outcome feasible. The surge of a collusive outcome destroys our interpretation of γ as a pure technologically-driven process since in that case observed prices and outputs will be a reflection of both technological changes (γ) and, chiefly, strategic considerations. When we rule out the possibility of having collusive outcomes then prices and outputs are affected purely by the continuous but *exogenous* technological change that γ characterizes. We also make explicit the following assumption:

ASSUMPTION 2. *Quality is driven by the parameter of technological convergence according to the following specification:*

$$q_k(\gamma) = \bar{q}_k(1 + \gamma)$$

for $k = 1, 2$.⁸

Note that, when $\gamma = 0$, the level of quality provided by each platform is fixed at the base level \bar{q}_k . However, when $\gamma \rightarrow 1$, then $q_k(\gamma) \rightarrow 2\bar{q}_k$. Thus, assumption 2 simply describes the fact that the provision of quality throughout

⁸ Observe that a generalization of assumption 2 is $q_k(\gamma) = \bar{q}_k(1 + \alpha\gamma)$, where $\alpha \geq 1$. This generalisation gives the opportunity of considering distinct rates of quality-improvement growth across platforms by doing the parameter α platform-specific. For simplicity, we stick to the case where this parameter is common to both platforms and it is identical to one.

the process of convergence is monotonically increasing. It is straightforward to see that the total impact of technological convergence on utility is given by:

$$\frac{\partial U(x_1, x_2)}{\partial \gamma} = \left(\frac{2}{\bar{q}_1^2 \bar{q}_2^2 (1 + \gamma)^3} \right) (x_1^2 \bar{q}_2^2 + x_2^2 \bar{q}_1^2 - (1 - \gamma) x_1 x_2 \bar{q}_1 \bar{q}_2) > 0$$

The numerical simulations provided in section 8 will show that indeed the sign of the above derivative is strictly positive so that utility is always increasing in γ irrespective of the level of quality differentiation across platforms. What is important to note from the outset is that the total impact of γ on utility involves two opposite effects: a *substitution effect* that decreases utility as γ increases and a *quality-driven demand effect* that increases utility as γ increases. The substitution effect is just a consequence of the fact that, when platforms tend to converge, *ceteris paribus*, consumers derive *lower* utility from the consumption of both platforms due to the increasing substitutability between the functionalities associated with them. The demand effect is the result of continuous quality improvements associated with the set of services that each platform provides to consumers. Since the sign of the above derivative is strictly positive it follows that the demand effect dominates the substitution effect. The following assumption is also central to our analysis:

ASSUMPTION 3. *The degree of quality differentiation across platforms remains constant along the process of convergence and it is bounded as given by the condition:*

$$\frac{2}{3} \leq \frac{q_1(\gamma)}{q_2(\gamma)} \leq \frac{3}{2}$$

Three comments are worth mentioning here. First, assumption 3 is imposed to guarantee that both platforms will produce positive levels of output at equilibrium in any of the three regulatory regimes analysed. Note that if higher levels of quality differentiation are permitted, it would be possible to find an equilibrium configuration where the low quality platform has zero sales and therefore the market is monopolized by the platform providing the highest

quality. In order to rule out this last possibility, we only explore quality differentiation along the range specified above. Second, since convergence affects symmetrically both industries we have that the initial degree of quality differentiation across platforms endures throughout the converging process. In other words, the industry possessing a quality advantage will remain the high-quality industry during the entire process of convergence.⁹ Third, an important implication of assumption 3 is that also ensures that the demand of service x_k , $k = 1, 2$, is strictly increasing in its own quality.

In section 6 we characterize the degree of regulatory intervention in the market by parameter θ , which we assume satisfies:

ASSUMPTION 4. *The magnitude of regulatory intervention in a regulated industry is upper bounded as described by conditions:*

$$(a) \text{ if } q_1(\gamma) = q_2(\gamma) \text{ then } \theta \in [0, 1]$$

$$(b) \text{ if } q_1(\gamma) \neq q_2(\gamma) \text{ then } \theta \in \left(0, \frac{1}{2}\right)$$

Assumption 4 simply guarantees that at any feasible level of quality differentiation both platforms will also produce positive levels of output. To see the importance of this assumption consider the following illustrative example. Suppose that maximal quality differentiation across platforms exists for the case when $q_1(\gamma) > q_2(\gamma)$ and assume that regulatory intervention occurs only in the first industry. To begin with, the first platform is expected to have a higher market share since it provides higher quality. As we will see below, this market share dominance will be reinforced by the implementation of regulation in this industry. In particular, if the set of admissible values associated with θ is not restricted it might be possible that the expansion of output occurring in the regulated industry will fully *crowd out* the output produced by the unregulated industry so that the latter might end up

⁹ The case where the high-quality platform switches to be the low-quality provider can also be explored within the present framework but for simplicity we stick to a situation where such switching does not exist.

producing no output at equilibrium. Assumption 4 simply rules out this possibility.

The solution to the utility maximization programme described in equation (3.1) gives rise to the linear system of inverse demand functions:

$$\begin{aligned} p_1 &= 1 - \left\{ \frac{2x_1}{(q_1(\gamma))^2} \right\} - \left\{ \frac{2\gamma x_2}{q_1(\gamma)q_2(\gamma)} \right\} \\ p_2 &= 1 - \left\{ \frac{2x_2}{(q_2(\gamma))^2} \right\} - \left\{ \frac{2\gamma x_1}{q_1(\gamma)q_2(\gamma)} \right\} \end{aligned}$$

with associated direct demand functions:

$$\begin{aligned} x_1 &= \left\{ \frac{(q_1(\gamma))^2 - \gamma q_1 q_2}{2(1-\gamma)(1+\gamma)} \right\} - \left\{ \frac{(q_1(\gamma))^2}{2(1-\gamma)(1+\gamma)} \right\} p_1 + \left\{ \frac{\gamma q_1(\gamma)q_2(\gamma)}{2(1-\gamma)(1+\gamma)} \right\} p_2 \\ x_2 &= \left\{ \frac{(q_2(\gamma))^2 - \gamma q_1 q_2}{2(1-\gamma)(1+\gamma)} \right\} - \left\{ \frac{(q_2(\gamma))^2}{2(1-\gamma)(1+\gamma)} \right\} p_2 + \left\{ \frac{\gamma q_1(\gamma)q_2(\gamma)}{2(1-\gamma)(1+\gamma)} \right\} p_1 \end{aligned}$$

Note that as $q_k(\gamma) \rightarrow 0$, $k = 1, 2$, demand falls to zero for any $p_k \geq 0$. It can also be seen that x_k , $k = 1, 2$, is strictly decreasing in its own price but strictly increasing in the price of its competing platform for $\gamma > 0$. When $\gamma = 0$, changes in the price of platform 2 do not affect the demand of platform 1 and vice versa.

We also assume that platforms compete in quantities and that all costs are zero. Formally, the non-cooperative game played *at each level of convergence* is described by:

- **PLAYERS.** The two technological platforms providing services in the two industries.

- **STRATEGIES.** The strategy associated with platform k , $k = 1, 2$, is to choose a strictly positive level of service provision or output.
- **PAYOFFS.** An *unregulated platform* has a payoff reflecting purely profit-maximization behaviour:

$$\Pi_k = p(x_k, x_j) x_k \quad \forall \quad j, k = 1, 2 \quad , \quad j \neq k$$

A *regulated platform* has a payoff that reflects a compromise between profit- and welfare-maximization behaviour, as determined by the parameter $0 < \theta \leq 1$:

$$V_k(x_k, x_j) = \theta W_k + (1 - \theta) \Pi_k \quad \forall \quad j, k = 1, 2 \quad , \quad j \neq k$$

where W_k stands for the welfare associated with the industry where the regulated platform operates.

The equilibrium concept used is the non-cooperative Nash equilibrium. Finally, for a given set of qualities, total and consumer surplus are given by $U(x_1, x_2)$ and $U(x_1, x_2) - (\Pi_1 + \Pi_2)$, respectively.

5. No Regulation

Consider first the baseline case where platforms are “regulated” symmetrically due to the absence of regulation in both industries. For a given set of qualities, platform k optimisation programme is described by:

$$\max_{x_k} \Pi_k = \left(1 - \left\{ \frac{2x_k}{(q_k(\gamma))^2} \right\} - \left\{ \frac{2\gamma x_j}{q_j(\gamma)q_k(\gamma)} \right\} \right) x_k \quad \forall \quad j, k = 1, 2 \quad j \neq k$$

By deriving the first order conditions and by solving simultaneously these best-response correspondences we get the equilibrium quantities:

$$x_1^* = \left\{ \frac{(1 + \gamma)^2 (2\bar{q}_1 - \gamma \bar{q}_2) \bar{q}_1}{2(2 - \gamma)(2 + \gamma)} \right\} \quad x_2^* = \left\{ \frac{(1 + \gamma)^2 (2\bar{q}_2 - \gamma \bar{q}_1) \bar{q}_2}{2(2 - \gamma)(2 + \gamma)} \right\}$$

By assumption 3, the above two levels of output are strictly positive at any level of convergence. Observe that the above outputs are differentiated along horizontal and vertical dimensions, γ and $q_k(\gamma)$, respectively. In fact, when $\gamma = 0$, these two outputs belong formally to two distinct markets. Therefore, it is natural to ask to what extent output differentiation along the attributes γ and $q_k(\gamma)$ is high enough to consider these two platforms as operating in distinct output markets. The answer to this question is provided by the following proposition.

PROPOSITION 1. *Define a convergent industry as the set of markets with the properties that: (a) unilateral price increases of magnitude t are not profitable given the presence of close enough substitutes and, (b) the degree of substitutability across services is strictly increasing along time. Hence, when preferences are characterised by $U(x_1, x_2)$ as above, a convergent industry composed by the markets associated with platforms 1 and 2 exists provided $\gamma > 0$.*

PROOF: Consider the case of the platform operating in the first industry and facing a positive amount of substitutability: $\gamma > 0$. The own-price elasticity of demand associated with this platform is given by:

$$|\eta| = \left(\frac{\partial x_1}{\partial p_1} \right) \left(\frac{p_1}{x_1} \right) = \left\{ \frac{\bar{q}_1(1+\gamma)p_1}{\bar{q}_1(1+\gamma)(1-p_1) - \gamma\bar{q}_2(1+\gamma)(1-p_2)} \right\}$$

As we will see in the following pages, equilibrium prices are given by p_1^* and p_2^* , as stated by the set of equations in (3.2) below. By substituting these two equilibrium prices into the above elasticity it simplifies to:

$$\eta|_{(p_1^*, p_2^*)} = \left\{ \frac{1}{(1-\gamma)(1+\gamma)} \right\}$$

Now, a well-know result in antitrust economics is that the critical elasticity of demand for linear demand functions is given by (Church and Ware, 2000):

$$\hat{\eta} = \left\{ \frac{1}{m + 2t} \right\}$$

where m and t stand for the price-cost margin and the small but significant non-transitory price increase, respectively. Now, when $\hat{\eta} - \eta < 0$, the decline in sales arising from the hypothetical monopolist's price increase will be large enough to render it unprofitable. Thus, when the price increase is unprofitable, the hypothetical monopolist lacks of power to raise prices due to the presence of sufficiently close substitutes. From this perspective, condition $\hat{\eta} - \eta < 0$ would define the set of γ values for which the two converging technologies operate, in fact, in the same market. It follows that:

$$\hat{\eta} - \eta < 0 \Leftrightarrow (1 - \gamma)(1 + \gamma) < (m + 2t)$$

To see that the last inequality holds, first observe that $m + 2t > 1$ since $m = 1$ and $t > 0$.¹⁰ By inspection one observes that $(1 - \gamma)(1 + \gamma) \leq 1$ so that $\hat{\eta} - \eta < 0$ holds, implying that the two platforms compete necessarily in the same market ■

Given the fact that the two platforms compete in the same market, it makes sense to analyse their corresponding market shares. The *market share difference* in this convergent industry is given by:

$$x_1^* - x_2^* = \left\{ \frac{(1 + \gamma)^2 (\bar{q}_1 - \bar{q}_2)(\bar{q}_1 + \bar{q}_2)}{(2 - \gamma)(2 + \gamma)} \right\}$$

Hence, unless both platforms provide exactly the same level of quality, market shares in the convergent industry will be distinct. When the quality provided by platforms differs then the market share difference varies along the process of convergence according to the rule:

$$\frac{\partial(x_1^* - x_2^*)}{\partial\gamma} = \begin{cases} > 0 & \text{if } \bar{q}_1 > \bar{q}_2 \\ < 0 & \text{if } \bar{q}_1 < \bar{q}_2 \end{cases}$$

¹⁰ The price-cost margin is identical to one since marginal costs were assumed to be zero.

The intuition is straightforward. Suppose first that $\bar{q}_1 > \bar{q}_2$. The above condition says that the market share associated with the first platform increases as the degree of substitutability between platforms increases, $\gamma \rightarrow 1$. This is because when services tend to be more homogeneous, the first platform looks more attractive to consumers given the fact that it provides higher quality throughout the process of convergence, *ceteris paribus*. Just the opposite occurs when $\bar{q}_1 < \bar{q}_2$. The above outputs imply the following equilibrium prices:

$$p_1^* = \left\{ \frac{2\bar{q}_1 - \gamma\bar{q}_2}{(2-\gamma)(2+\gamma)\bar{q}_1} \right\} \quad p_2^* = \left\{ \frac{2\bar{q}_2 - \gamma\bar{q}_1}{(2-\gamma)(2+\gamma)\bar{q}_2} \right\} \quad (3.2)$$

with a price difference given by:

$$p_1^* - p_2^* = \left\{ \frac{\gamma(\bar{q}_1 - \bar{q}_2)(\bar{q}_1 + \bar{q}_2)}{(2-\gamma)(2+\gamma)\bar{q}_1\bar{q}_2} \right\}$$

Unless platforms provide the same level of quality, prices will differ. In particular, the platform providing higher quality will also charge higher prices.

6. Asymmetric Regulation

We now explore how regulation might influence the evolution of welfare across industries along the process of convergence. In particular, consider a situation where the two concurring technological platforms are regulated asymmetrically. In order to make a clear-cut analysis, we discuss the extreme case where one of the platforms, say platform 1, is subject to some type of regulatory constraint whereas its competitor is not regulated at all. As before, we assume that platforms compete in quantities. Consider first the optimisation programme associated with the regulated industry. Under the

assumption that convergence affects both industries symmetrically, welfare in the regulated industry is given by:

$$W_1 = \int p_1(x_1, x_2) dx_1 + \gamma \left\{ \frac{x_1 x_2}{q_1(\gamma) q_2(\gamma)} \right\} = x_1 - \frac{x_1^2}{(q_1(\gamma))^2} - \gamma \left\{ \frac{x_1 x_2}{q_1(\gamma) q_2(\gamma)} \right\}$$

We model regulatory intervention through the establishment of an explicit link between ownership status and the nature of the decision-making process in the regulated industry. As in Fershtman (1990), we assume that output decisions in the regulated industry stem from a “compromise” between the profit-maximizing output aimed by the regulated operator and the welfare-maximizing output aimed by the regulator. Let the parameter $0 \leq \theta \leq 1$ describe how far the regulator is able to induce the regulated operator to produce its aimed level of output. This coefficient has a dual interpretation: (a) it can be seen as a measure of the degree of regulatory intervention in the regulated market or, (b) it might represent a coefficient of ownership-control of the private platform by the public interest. In any case, the regulated operator now optimises the following programme:

$$\max_{x_1} V(x_1, \bar{x}_2) = \theta W_1 + (1 - \theta) \Pi_1$$

where \bar{x}_2 indicates that the regulated platform takes as fixed the output of its rival when solving its optimisation problem. Also observe that the optimisation programme associated with the unregulated platform remains as in section 5: optimal output still derives from a pure profit maximization exercise. By solving the system of best-response correspondences we obtain the corresponding equilibrium quantities under asymmetric regulation:

$$\hat{x}_1 = \left\{ \frac{(1 + \gamma)^2 [4\bar{q}_1 - \gamma\bar{q}_2(2 - \theta)]\bar{q}_1}{2(2 - \theta)(2 - \gamma)(2 + \gamma)} \right\} \quad \hat{x}_2 = \left\{ \frac{(1 + \gamma)^2 [\bar{q}_2(2 - \theta) - \gamma\bar{q}_1]\bar{q}_2}{(2 - \theta)(2 - \gamma)(2 + \gamma)} \right\}$$

It can be shown that the above two equilibrium outputs are strictly positive.¹¹ The market share difference under asymmetric regulation can be decomposed as follows:

$$\hat{x}_1 - \hat{x}_2 = \underbrace{\left\{ \frac{\theta \bar{q}_2 (1 + \gamma)^2 (2\bar{q}_2 + \gamma \bar{q}_1)}{2(2 - \theta)(2 - \gamma)(2 + \gamma)} \right\}}_{\text{Output Difference due to Asymmetric Regulation}} + \underbrace{\left\{ \frac{(1 + \gamma)^2 2(\bar{q}_1^2 - \bar{q}_2^2)}{(2 - \theta)(2 - \gamma)(2 + \gamma)} \right\}}_{\text{Output Difference due to Quality Differentiation}}$$

Note that when the magnitude of regulatory intervention in the regulated industry tends to zero, $\theta \rightarrow 0$, the first term of the output difference vanishes and output difference across the two industries can only be explained on the basis of their initial quality differentiation as discussed in section 5. However, when asymmetric regulation is implemented, $\theta > 0$, the output gap across industries is affected. Let's denote the output differences due to asymmetric regulation and quality differentiation as $\Delta(r)$ and $\Delta(\bar{q})$, respectively. First, we note that the higher the degree of intervention the higher the output difference in favour of the regulated industry that stems from asymmetric regulation since $\Delta(r) > 0$ for any $\theta > 0$. This output bias in favour of the first platform is just a reflection of the "compromise" between profit- and welfare maximizing interests. Second, we also observe that:

$$\Delta(\bar{q}) \begin{cases} \geq 0 & \Leftrightarrow \bar{q}_1 \geq \bar{q}_2 \\ < 0 & \Leftrightarrow \bar{q}_1 < \bar{q}_2 \end{cases}$$

¹¹ To see that the above two equilibrium outputs are strictly positive first observe that the sign of \hat{x}_1 depends on the sign of the term $4\bar{q}_1 - \gamma\bar{q}_2(2 - \theta)$. The expansion of this term gives $2(2\bar{q}_1 - \gamma\bar{q}_2) + \gamma\theta\bar{q}_2$ which is strictly positive since the term in brackets is positive by assumption 3. Second, the sign of \hat{x}_2 depends on the sign of the term $\bar{q}_2(2 - \theta) - \gamma\bar{q}_1$. This term is non-negative throughout the process of convergence (in other words, by fixing $\gamma = 1$) if and only if $\bar{q}_1 / \bar{q}_2 \leq (2 - \theta)$. This inequality holds trivially for any $\bar{q}_2 \geq \bar{q}_1$. By assumption 4 we know that when $\bar{q}_1 > \bar{q}_2$ then $\max(\theta) = 1/2$ and by assumption 3 that $\max(\bar{q}_1 / \bar{q}_2) = 3/2$ so that $\bar{q}_1 / \bar{q}_2 \leq (2 - \theta)$ holds, implying $\hat{x}_2 \geq 0$.

Hence, the sign of the output difference due to quality differentiation depends, as in section 5, on which platform is providing the highest quality. Also note that the implementation of asymmetric regulation is *not neutral* with respect to this output gap if there is an asymmetry in the provision of quality across platforms. In particular and when quality differentiation across platforms prevails, asymmetric regulation increases *further* the output difference due to quality differentiation in favour of the industry providing the highest quality. In general, when $\bar{q}_1 > \bar{q}_2$, $(\hat{x}_1 - \hat{x}_2) > 0$ since the two relevant output gaps share the same sign: $\Delta(r) > 0$ and $\Delta(\bar{q}) > 0$. When $\bar{q}_1 = \bar{q}_2$, the condition $(\hat{x}_1 - \hat{x}_2) > 0$ still holds since the only surviving output gap is strictly positive, $\Delta(r) > 0$. Finally, when $\bar{q}_1 < \bar{q}_2$, the two output gaps move in opposite directions: $\Delta(r) > 0$ and $\Delta(\bar{q}) < 0$. In this latter case, the evolution of the market share difference $(\hat{x}_1 - \hat{x}_2)$ will depend on which of these two effects prevails. The corresponding equilibrium prices under asymmetric regulation are defined by:

$$\hat{p}_1 = \left\{ \frac{\bar{q}_1[4(1-\theta) + \gamma^2\theta] - \gamma\bar{q}_2(2-\theta)}{(2-\theta)(2-\gamma)(2+\gamma)\bar{q}_1} \right\} \quad \hat{p}_2 = \left\{ \frac{2[\bar{q}_2(2-\theta) - \gamma\bar{q}_1]}{(2-\theta)(2-\gamma)(2+\gamma)\bar{q}_2} \right\}$$

We can also decompose the equilibrium price difference as follows:

$$\hat{p}_1 - \hat{p}_2 = \underbrace{\left\{ \frac{\theta[\gamma\bar{q}_2 - \bar{q}_1(2-\gamma^2)]}{(2-\theta)(2-\gamma)(2+\gamma)\bar{q}_1} \right\}}_{\text{Price Difference due to Asymmetric Regulation}} + \underbrace{\left\{ \frac{2\gamma(\bar{q}_1^2 - \bar{q}_2^2)}{(2-\theta)(2-\gamma)(2+\gamma)\bar{q}_1\bar{q}_2} \right\}}_{\text{Price Difference due to Quality Differentiation}}$$

As before, when $\theta \rightarrow 0$, the price difference across platforms can only be explained on the basis of their initial quality differentiation as discussed in section 5. By denoting the price differences due to asymmetric regulation and quality differentiation as $\nabla(r)$ and $\nabla(\bar{q})$ respectively, consider a scenario where $\theta > 0$. Two observations are in place. First, the platform providing the

highest quality will benefit from a positive price difference due to quality differentiation.¹² Second, the price difference due to asymmetric regulation is sensitive to both the degree of convergence and the magnitude of quality differentiation. In particular, the unregulated industry will face a *negative* price difference due to asymmetric regulation, $\nabla(r) < 0$, throughout the process of convergence when either $\bar{q}_1 \geq \bar{q}_2$ or, if $\bar{q}_2 > \bar{q}_1$, this quality advantage is not particularly high. When the quality advantage in favour of the second platform is relatively high, it will face a negative price difference due to asymmetric regulation only during the first stages of convergence but this price difference will turn out to be positive later on.¹³

Welfare

We proceed now to explore the welfare implications of the implementation of asymmetric regulation in a convergent industry. The following proposition shows the first result of the paper.

¹² Naturally, if qualities are identical across platforms, the price difference due to quality differentiation disappears and no platform benefits from it.

¹³ Formally, the analysis is as follows. The sign of $\nabla(r)$ depends on the term $\gamma\bar{q}_2 - \bar{q}_1(2 - \gamma^2)$. In particular, $\nabla(r) < 0$ occurs when $\bar{q}_2/\bar{q}_1 < (2/\gamma) - \gamma$. Now, if $(2/\gamma) - \gamma \geq 3/2$, any valid quality ratio would satisfy condition $\bar{q}_2/\bar{q}_1 < (2/\gamma) - \gamma$. In order to know if condition $(2/\gamma) - \gamma \geq 3/2$ holds, we simply observe that this condition can be rewritten in its quadratic formulation as $-\gamma^2 - (3/2)\gamma + 2 \geq 0$. Since γ only takes values in the positive unit interval, the relevant range where condition $(2/\gamma) - \gamma \geq 3/2$ holds occurs when $0 \leq \gamma < (-3 + \sqrt{41})/4$. Therefore and irrespective of quality differentiation, $\nabla(r) < 0$ holds when $0 \leq \gamma < (-3 + \sqrt{41})/4$. On the other hand, when $(-3 + \sqrt{41})/4 < \gamma \leq 1$, inequality $-\gamma^2 - (3/2)\gamma + 2 < 0$ holds, which is equivalent to $(2/\gamma) - \gamma < 3/2$. In this case, the valid set of quality ratios is now divided in two: the set of quality ratios lying in the interval $Q_1: 2/3 < \bar{q}_2/\bar{q}_1 \leq (2/\gamma) - \gamma$ and the set of quality ratios lying within $Q_2: (2/\gamma) - \gamma < \bar{q}_2/\bar{q}_1 \leq 3/2$. Note that the sets Q_1 and Q_2 directly imply $\nabla(r) < 0$ and $\nabla(r) > 0$, respectively.

PROPOSITION 2. *When two industries are subject to technological convergence the implementation of asymmetric regulation always increases (decreases) welfare in the regulated (unregulated) industry.*

PROOF: Consider first the regulated industry. Social welfare associated with the no regulation outcome is given by W_1 evaluated at outputs x_1^* and x_2^* . Define this baseline level of welfare as W_1^* . By substituting the equilibrium levels of output under asymmetric regulation, \hat{x}_1 and \hat{x}_2 , into the welfare function W_1 , we get welfare under asymmetric regulation: \hat{W}_1 . Hence, the change in welfare associated to the regulated industry when asymmetric regulation is implemented, $\theta > 0$, is given by:

$$(\hat{W}_1 - W_1^*) = \left\{ \frac{\theta \bar{q}_1 (1 + \gamma)^2 [16 \bar{q}_1 - \gamma^3 \bar{q}_2 (2 - \theta) - 2 \theta \bar{q}_1 (6 - \gamma^2)]}{4(\theta - 2)^2 (\gamma - 2)^2 (2 + \gamma)^2} \right\}$$

Observe that $\hat{W}_1 - W_1^* \geq 0 \Leftrightarrow 16 \bar{q}_1 - \gamma^3 \bar{q}_2 (2 - \theta) - 2 \theta \bar{q}_1 (6 - \gamma^2) \geq 0$. This last inequality can be re-expressed as $\alpha_1 = (2 - \theta) \gamma^3 / (16 - 2 \theta (6 - \gamma^2)) \leq \bar{q}_1 / \bar{q}_2$. Since $\min(\bar{q}_1 / \bar{q}_2) = 2/3$ and, by inspection, $\alpha_1 \leq 1/6 \quad \forall \quad \theta, \gamma \in (0, 1)$, condition $\alpha_1 < \bar{q}_1 / \bar{q}_2$ holds so that $\hat{W}_1 - W_1^* > 0$. Hence, welfare in the regulated industry increases after the implementation of asymmetric regulation. Consider now the unregulated industry. The corresponding welfare function is described by:

$$W_2 = \int p_2(x_1, x_2) dx_2 + \gamma \left\{ \frac{x_1 x_2}{q_1(\gamma) q_2(\gamma)} \right\} = x_2 - \frac{x_2^2}{(q_2(\gamma))^2} - \gamma \left\{ \frac{x_1 x_2}{q_1(\gamma) q_2(\gamma)} \right\}$$

As before, the no regulation welfare in this industry is given by W_2 evaluated at outputs x_1^* and x_2^* . Define this welfare level as W_2^* . Similarly, by plugging \hat{x}_1 and \hat{x}_2 into W_2 we obtain welfare in the unregulated industry under asymmetric regulation: \hat{W}_2 . Hence, the change in welfare associated with the unregulated industry when asymmetric regulation is implemented, $\theta > 0$, is given by:

$$(\hat{W}_2 - W_2^*) = - \left\{ \frac{\gamma \theta \bar{q}_1 (1 + \gamma)^2 [\bar{q}_2 (2 - \theta) (8 - \gamma^2) - \gamma \bar{q}_1 (4 - \theta)]}{4(\theta - 2)^2 (\gamma - 2)^2 (2 + \gamma)^2} \right\}$$

Note that $\hat{W}_2 - W_2^* \leq 0 \Leftrightarrow \bar{q}_2(2-\theta)(8-\gamma^2) - \gamma\bar{q}_1(4-\theta) \geq 0$. This last inequality can be rewritten as $\bar{q}_1/\bar{q}_2 \leq (2-\theta)(8-\gamma^2)/\gamma(4-\theta) = \alpha_2$. Since $\max(\bar{q}_1/\bar{q}_2) = 3/2$ and, by inspection, $7/3 \leq \alpha_2 \quad \forall \theta, \gamma \in (0,1)$, condition $\bar{q}_1/\bar{q}_2 < \alpha_2$ holds so that $\hat{W}_2 - W_2^* < 0$ ■

The result that welfare in the regulated industry unambiguously increases with the implementation of asymmetric regulation is hardly surprising given the redefinition of the objective function as a linear combination of social welfare and profits. A more interesting result arises in the unregulated industry. In particular, we observe the presence of a *transmission mechanism* of regulatory effects across industries that arise from technological convergence. When industries are not converging, $\gamma = 0$, there is no impact from the implementation of asymmetric regulation into the unregulated industry. In other words, the implementation of asymmetric regulation is *welfare neutral* with respect to the unregulated industry. However, when convergence occurs, $\gamma \neq 0$, welfare in the unregulated industry is subject to negative impacts stemming from the regulation implemented in the neighbouring industry. From a theoretical point of view, this transmission mechanism derives from the *strategic substitutability* between the outputs of the two industries (Bulow, Geanakoplos, Klemperer, 1985). When regulation induces the production of higher levels of output in the first industry, the unregulated industry optimally reacts by reducing its own supply. The magnitude of this output contraction will depend on how far the process of convergence has gone: the higher the degree of convergence the higher the optimal output contraction associated with the unregulated industry.

Proposition 2 also leads to the following question. Does aggregate welfare *across* industries increases as a result of the implementation of asymmetric regulation? The relevance of this question lies in the fact that a social planner would be indifferent to any reallocation of welfare across industries that stems from asymmetric regulation as long as its implementation increases total

aggregate welfare.¹⁴ In other words, asymmetric regulation would not be a policy issue as long as the increase in welfare associated with the regulated industry is, at least, as big as the decrease in welfare occurring in the unregulated industry. Naturally, situations where the welfare decrease in the unregulated industry is not compensated by a corresponding welfare increase in the neighbouring industry will certainly represent the basis for a case against asymmetric regulation. The following proposition addresses directly the above question.

PROPOSITION 3. *Social welfare across industries increases after the implementation of asymmetric regulation only when $\chi_1 \leq \bar{q}_1 / \bar{q}_2$. This unambiguously occurs when either $\bar{q}_1 \geq \bar{q}_2$ or, if $\bar{q}_1 < \bar{q}_2$, then the quality advantage of the unregulated industry is not particularly high: $\bar{q}_1 / \bar{q}_2 \in (\max(\chi_1(\gamma, \bar{\theta}), 1), 1)$, where $\bar{\theta}$ represents the set of θ values as restricted by part (b) of assumption 4 and*

$$\chi_1 = \left\{ \frac{8\gamma(2-\theta)}{\gamma^2(4+\theta) + 4(4-3\theta)} \right\}$$

PROOF: Aggregate welfare levels in the regulated and unregulated industries are obtained by directly substituting (x_1^*, x_2^*) and (\hat{x}_1, \hat{x}_2) into the welfare function, respectively. Hence, the aggregate welfare change due to the implementation of asymmetric regulation is given by:

$$\hat{W} - W^* = \left\{ \frac{\theta \bar{q}_1 (1+\gamma)^2 [\bar{q}_1 (\gamma^2(4+\theta) + 4(4-3\theta)) - 8\gamma \bar{q}_2 (2-\theta)]}{4(\theta-2)^2 (\gamma-2)^2 (2+\gamma)^2} \right\}$$

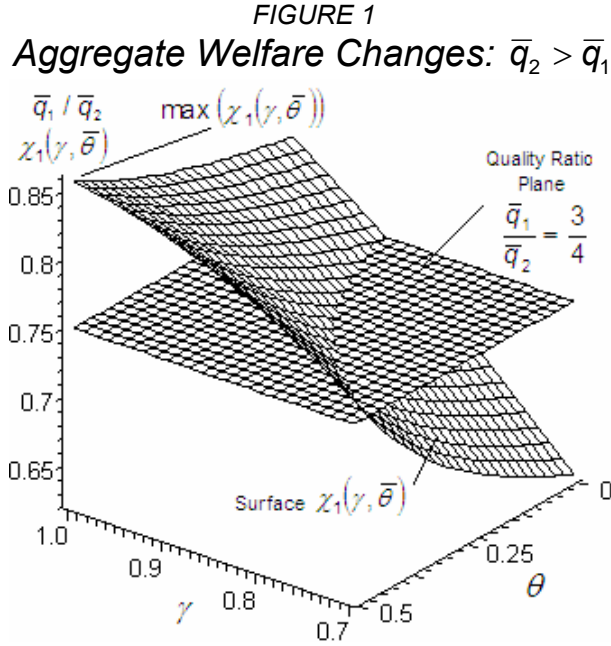
Note that $\hat{W} - W^* \geq 0 \Leftrightarrow \bar{q}_1 (\gamma^2(4+\theta) + 4(4-3\theta)) - 8\gamma \bar{q}_2 (2-\theta) \geq 0$. This last condition can be rewritten as $\chi_1 = 8\gamma(2-\theta) / (\gamma^2(4+\theta) + 4(4-3\theta)) \leq \bar{q}_1 / \bar{q}_2$. By direct inspection, one can easily show that $\max(\chi_1)$ occurs when $(\theta, \gamma) = (1, 2\sqrt{5}/5)$ or, $\max(\chi_1) \approx 0.894$. Suppose first that $\bar{q}_1 = \bar{q}_2$. Hence, the inequality $\chi_1 \leq \bar{q}_1 / \bar{q}_2 = 1$ holds trivially $\forall \theta, \gamma \in (0, 1)$. Suppose now that $\bar{q}_1 > \bar{q}_2$. It follows immediately that $\bar{q}_1 / \bar{q}_2 > 1$ so that condition $\chi_1 \leq \bar{q}_1 / \bar{q}_2$ also holds

¹⁴ In the following analysis, we assume that the social planner assigns the same weight to the welfare associated with each industry.

$\forall \theta, \gamma \in (0, 1)$. Thus, $\chi_1 \leq \bar{q}_1 / \bar{q}_2$ holds whenever $\bar{q}_1 \geq \bar{q}_2$. This proves the first part of the proposition. Suppose now that $\bar{q}_2 \geq \bar{q}_1$. By part (b) of assumption 4 the valid range of regulatory intervention is given by $\theta | (\bar{q}_2 > \bar{q}_1) \in [0, 1/2]$. We denote this valid set of levels of regulatory intervention as $\bar{\theta}$ below. Now, the strict inequality $\chi_1 < \bar{q}_1 / \bar{q}_2$ still holds for any $\gamma \in (0, 1)$ and any θ belonging to the set $\bar{\theta}$ provided $\bar{q}_1 / \bar{q}_2 \in (\max(\chi_1(\gamma, \bar{\theta}), 1), 1)$. To see this, note that when $\bar{q}_1 / \bar{q}_2 = \max(\chi_1(\gamma, \bar{\theta}), 1)$, the associated plane described by the quality ratio in the restricted space (θ, γ) is tangent to the surface $\chi_1(\gamma, \bar{\theta})$. Therefore, when $\bar{q}_1 / \bar{q}_2 \in (\max(\chi_1(\gamma, \bar{\theta}), 1), 1)$ any quality-ratio plane in the space $(\gamma, \bar{\theta})$ will lie above or will be tangent to the surface $\chi_1(\gamma, \bar{\theta})$, thus satisfying condition $\chi_1(\gamma, \bar{\theta}) \leq \bar{q}_1 / \bar{q}_2$, as described by the second part of the proposition. Conversely, when the quality ratio lies outside the interval $\bar{q}_1 / \bar{q}_2 \in (\max(\chi_1(\gamma, \bar{\theta}), 1), 1)$, any the quality-ratio plane in the space $(\gamma, \bar{\theta})$ and the surface $\chi_1(\gamma, \bar{\theta})$ will intersect implying that the sign of the change in welfare is ambiguous ■

As described by proposition 3, $\chi_1(\gamma, \theta) \leq \bar{q}_1 / \bar{q}_2$ gives the condition that guarantees non-negative aggregate welfare changes across industries when asymmetric regulation is implemented. Condition $\chi_1(\gamma, \theta) \leq \bar{q}_1 / \bar{q}_2$ holds trivially when the level of quality provided by the regulated industry is equal or higher than the one provided by the unregulated industry. In other words, aggregate welfare across industries always increases when the regulatory intervention occurs in the most quality-advantaged industry. The driving force behind this result is again the strategic substitutability between the outputs of the two industries. When regulation is implemented in the first industry and thus higher levels of output are supplied, the industry providing the lowest quality responds by contracting its own output. Since the final outcome is characterised by the most advantaged industry (in a vertical dimension sense) supplying higher output throughout the process of convergence, aggregate welfare increases. The above proposition also argues that the implementation of asymmetric regulation still increases aggregate welfare across industries when $\bar{q}_2 > \bar{q}_1$, provided this quality advantage is not particularly high: $\max(\chi_1(\gamma, \bar{\theta})) < \bar{q}_1 / \bar{q}_2 < 1$. Geometrically speaking, this occurs when the plane depicted by the quality ratio in the three-dimensional space (χ_1, γ, θ) lies strictly above the surface $\chi_1(\gamma, \bar{\theta})$ so that their surfaces do not intersect.

When the quality ratio plane and the surface $\chi_1(\gamma, \bar{\theta})$ intersect, $2/3 < \bar{q}_1 / \bar{q}_2 < \max(\chi_1(\gamma, \bar{\theta}))$, there will always be a convergence time span where aggregate welfare across industries decreases. Figure 1 below provides a graphical representation of this situation.



In the above figure, the surface $\chi_1(\gamma, \bar{\theta})$ is depicted for the domain $(\gamma, \theta) = ((0.7, 1), (0, 0.5))$ exclusively. The γ domain is restricted only for expositional purposes whereas the θ domain is restricted as prescribed by part (b) of assumption 4 since $\bar{q}_2 > \bar{q}_1$. For illustrative purposes we also assume that $\bar{q}_1 / \bar{q}_2 = 3/4$. Observe that this level of quality ratio is represented in the above space simply as a plane. If we assume that the degree of regulatory intervention is closer to its upper bound: $\theta \approx 0.5$, the above figure shows that, roughly, during the last 30% of the convergence process aggregate welfare across industries will decrease since the relevant condition for non-negative welfare changes is clearly violated. In general, the higher the quality advantage of the unregulated platform the smaller the set of parameter values (γ, θ) for which strictly positive welfare changes occurs as the quality ratio plane moves downward. The economic intuition behind this

result is simple. When the implementation of asymmetric regulation forces the less advantaged industry (in a vertical dimension sense) to supply higher output at expense of the supply provided by the most advantaged (the unregulated one), aggregate welfare across industries decreases.

7. Symmetric Regulation

Consider now the situation where the two concurring technological platforms are regulated symmetrically in the sense that the parameter θ is common to both industries. The optimisation programmes associated with these two industries are now given by:

$$\begin{aligned} \max_{x_1} V_1(x_1, x_2) &= \theta W_1 + (1 - \theta) \Pi_1 \\ \max_{x_2} V_2(x_1, x_2) &= \theta W_2 + (1 - \theta) \Pi_2 \end{aligned}$$

We derive the optimal levels of output associated with this regime along the lines discussed in the previous sections. We get:

$$\bar{x}_1 = \left\{ \frac{(1 + \gamma)^2 (2\bar{q}_1 - \gamma\bar{q}_2)\bar{q}_1}{(2 - \theta)(2 - \gamma)(2 + \gamma)} \right\} \quad \bar{x}_2 = \left\{ \frac{(1 + \gamma)^2 (2\bar{q}_2 - \gamma\bar{q}_1)\bar{q}_2}{(2 - \theta)(2 - \gamma)(2 + \gamma)} \right\}$$

with associated output difference given by:

$$\bar{x}_1 - \bar{x}_2 = \left\{ \frac{2(1 + \gamma)^2 (\bar{q}_1 - \bar{q}_2)(\bar{q}_1 + \bar{q}_2)}{(2 - \theta)(2 - \gamma)(2 + \gamma)} \right\}$$

We do not stop any longer in the description of the above two levels of output since their interpretation is straightforward. We move directly to the welfare implications associated with this outcome. The next proposition summarizes the main result of this section.

PROPOSITION 4. *The implementation of symmetric regulation in industries no previously regulated always increases industry-specific welfare.*

PROOF: Consider the second industry first. Denote as W_2^* the level of welfare associated with this industry when no regulation is in place. By substituting the equilibrium levels of output associated with symmetric regulation, \tilde{x}_1 and \tilde{x}_2 , into the welfare function W_2 , we get welfare under symmetric regulation. Denote this welfare as \tilde{W}_2 . The welfare change in the second industry when symmetric regulation is implemented with respect to the no regulation outcome, for $\theta > 0$, is then given by:

$$\tilde{W}_2 - W_2^* = \left\{ \frac{\theta(1+\gamma)^2(2\bar{q}_2 - \gamma\bar{q}_1)[\gamma\bar{q}_1(\theta - 4) - \bar{q}_2(6\theta - \theta\gamma^2 - 8)]}{4(\theta - 2)^2(\gamma - 2)^2(2 + \gamma)^2} \right\}$$

Since by assumption we know that $2\bar{q}_2 - \gamma\bar{q}_1 > 0$ then $\tilde{W}_2 - W_2^* > 0$ if and only if $\gamma\bar{q}_1(\theta - 4) - \bar{q}_2(6\theta - \theta\gamma^2 - 8) > 0$ or, equivalently, if $\bar{q}_1 / \bar{q}_2 < (8 + \theta\gamma^2 - 6\theta) / \gamma(4 - \theta) = \alpha_3$. It easy to see by inspection that $\min(\alpha_3) = 1 \forall (\gamma, \theta) \in (0, 1)$. Therefore, condition $\bar{q}_1 / \bar{q}_2 \leq \alpha_3$ holds trivially when $\bar{q}_2 \geq \bar{q}_1$. Now, when $\bar{q}_1 > \bar{q}_2$, condition $\bar{q}_1 / \bar{q}_2 < \alpha_3$ holds along the entire process of convergence only when the set of intervention is restricted. In particular, condition $\bar{q}_1 / \bar{q}_2 < \alpha_3$ holds at any level of quality differentiation when the θ set is restricted so that $3/2 < \alpha_3$ holds. By solving this last inequality for θ we get $\theta < (12\gamma - 16) / (2\gamma^2 - 12 + 3\gamma)$. Since this condition must hold for the entire process of convergence, $\gamma \rightarrow 1$, is should be the case that $\theta < 4/7$, which holds by part (b) of assumption 4. Hence, since when $\bar{q}_1 > \bar{q}_2$ part (b) of assumption 4 applies, we have that condition $\bar{q}_1 / \bar{q}_2 < \alpha_3$ holds so that $\tilde{W}_2 - W_2^* > 0$ at any level of quality differentiation. Consider now the first industry. As before, W_1^* and \tilde{W}_1 denote the welfare levels in this industry under no and symmetric regulation, respectively. The welfare change associated with the transition from no to symmetric regulation in the first industry is given by:

$$\tilde{W}_1 - W_1^* = \left\{ \frac{\theta(1+\gamma)^2(2\bar{q}_1 - \gamma\bar{q}_2)[\bar{q}_1(8 + \theta\gamma^2 - 6\theta) + \bar{q}_2(\theta\gamma - 4\gamma)]}{4(\theta - 2)^2(\gamma - 2)^2(2 + \gamma)^2} \right\}$$

As before, we also know by assumption that $2\bar{q}_1 - \gamma\bar{q}_2 > 0$ so that $\tilde{W}_1 - W_1^* > 0$ if and only if $\bar{q}_1(8 + \theta\gamma^2 - 6\theta) + \bar{q}_2(\theta\gamma - 4\gamma) > 0$ or, equivalently, if $\alpha_4 = \gamma(4 - \theta) / (8 - \theta(6 - \gamma^2)) < \bar{q}_1 / \bar{q}_2$. By inspection, one observes that $\max(\alpha_4) = 1$. Thus, condition $\alpha_4 \leq \bar{q}_1 / \bar{q}_2$ holds trivially when

$\bar{q}_1 \geq \bar{q}_2$ implying $\tilde{W}_1 - W_1^* \geq 0$. Now when $\bar{q}_2 > \bar{q}_1$, condition $\alpha_4 < \bar{q}_1 / \bar{q}_2$ holds along the entire process of convergence only when the set of intervention is restricted. In particular, condition $\alpha_4 < \bar{q}_1 / \bar{q}_2$ holds at any level of quality differentiation when the θ set is restricted so that $\alpha_4 < 2/3$ holds. By solving this last inequality for θ we get as before $\theta < (12\gamma - 16)/(2\gamma^2 - 12 + 3\gamma)$. Since this condition must hold for the entire process of convergence, $\gamma \rightarrow 1$, it should be the case that $\theta < 4/7$, which again holds by part (b) of assumption 4. Hence, since when $\bar{q}_2 > \bar{q}_1$ part (b) of assumption 4 applies, we have that condition $\alpha_4 < \bar{q}_1 / \bar{q}_2$ holds so that $\tilde{W}_1 - W_1^* > 0$ at any level of quality differentiation ■

A careful joint reading of propositions 2 and 4 give the interesting implication that the presence of a regulatory transmission mechanism across industries creates incentives for regulatory replication. More specifically, the presence of a regulatory transmission mechanism will make for the unregulated industry particularly attractive to replicate the regulatory framework governing the neighbouring industry. The attractiveness of this regulatory replication stems from proposition 4 since the implementation of symmetric regulation always improves welfare in the second industry. This result contrasts with the case where the second industry is not regulated but it is adversely affected by the regulation implemented in the neighbouring industry (proposition 2). In a nutshell, by replicating the regulation governing the neighbouring industry, the unregulated industry is able to outweigh the adverse welfare effects stemming from the initial implementation of asymmetric regulation.

Finally, a corollary of proposition 4 is that, since industry-specific welfare per industry unambiguously increases then, it must be true that aggregate welfare in the whole sector also increases.

8. Comparative Statics of Regulatory Regimes

In this section we provide the comparative statics of the three regulatory regimes discussed so far. The analysis is presented according to the magnitude of vertical differentiation prevailing across platforms.

No Quality Differentiation

When no quality differentiation prevails across platforms then $\bar{q}_1 = \bar{q}_2$. In order to keep our analysis as simple as possible, we assume that this common level of quality is identical to one. With this simplification, aggregate welfare deriving from the outcome with no regulation is only a function of the degree of convergence. Denote this welfare level as $W_{\min}(\gamma)$: welfare under *minimum* regulation (or no regulation).

In turn, welfare under asymmetric and symmetric regulation is a function of both the magnitude of regulatory intervention and the degree of convergence. The numerical simulations provided in this section will assume that, when regulatory intervention occurs, this intervention is moderate or extreme exclusively. This means that, under no quality differentiation, the parameter of intervention is given by $\bar{\theta}_1 = 1/2 < 1 = \bar{\theta}_2$ depending on the type of intervention that takes place (moderate and extreme in the first and second case, respectively).¹⁵ Hence, with no quality differentiation and when the degree of intervention is $\bar{\theta}_1$ or $\bar{\theta}_2$, welfare under asymmetric and symmetric regulation is also a function of the magnitude of convergence only.

Denote as $W_{asy}(\gamma, \bar{\theta}_1)$ and $W_{asy}(\gamma, \bar{\theta}_2)$ welfare under asymmetric regulation when intervention is moderate and extreme, respectively. Similarly, denote as $W_{max}(\gamma, \bar{\theta}_1)$ and $W_{max}(\gamma, \bar{\theta}_2)$ welfare under symmetric regulation when intervention is also moderate and extreme, respectively. The following proposition follows.

¹⁵ Formally, θ_1 and θ_2 represent, respectively, the middle and the highest point within the range of feasible degrees of regulatory intervention under no quality differentiation, as described by part (a) of assumption 4.

PROPOSITION 5. *Consider the case of no quality differentiation across platforms. When the degrees of regulatory intervention are $\bar{\theta}_1$ and $\bar{\theta}_2$, then:*

(a) *when $\bar{\theta}_1: W_{\max}(\gamma, \bar{\theta}_1) > W_{asy}(\gamma, \bar{\theta}_1) > W_{\min}(\gamma)$. This ordering holds throughout the process of convergence.*

(b) *when $\bar{\theta}_2: W_{\max}(\gamma, \bar{\theta}_2) > W_{asy}(\gamma, \bar{\theta}_2) \quad \forall \gamma \in (0, \gamma^*)$ but $W_{\max}(\gamma, \bar{\theta}_2) < W_{asy}(\gamma, \bar{\theta}_2) \quad \forall \gamma \in (\gamma^*, 1)$, where:*

$$\gamma^* = \frac{5}{6} + \frac{23}{6\sqrt[3]{19+12\sqrt{87}}} - \frac{\sqrt[3]{19+12\sqrt{87}}}{6}$$

No regulation is always welfare-dominated by any of the two alternative regimes.

PROOF: *It follows immediately from direct substitution of the relevant set of values into the corresponding welfare functions ■*

Regarding proposition 5, two comments are worth mentioning. First, the no regulation outcome is always welfare-dominated by any of the two alternative regulatory regimes throughout the process of convergence and this occurs irrespective of the degree of intervention. Second, the welfare dominance of symmetric regulation over asymmetric regulation along the entire process of convergence is unambiguous only when intervention is moderate (figure 2). When the degree of intervention is extreme, symmetric regulation outperforms asymmetric regulation during, roughly, the initial 75% of the process of convergence (figure 3). At higher levels of convergence, a social planner would find optimal to switch from symmetric to asymmetric regulation. The welfare implications of proposition 5 are illustrated in the following two graphs.

FIGURE 2
Aggregate Welfare across Regimes
Low Regulatory Intervention
 $\theta = \bar{\theta}_1$; $\bar{q}_1 = \bar{q}_2$

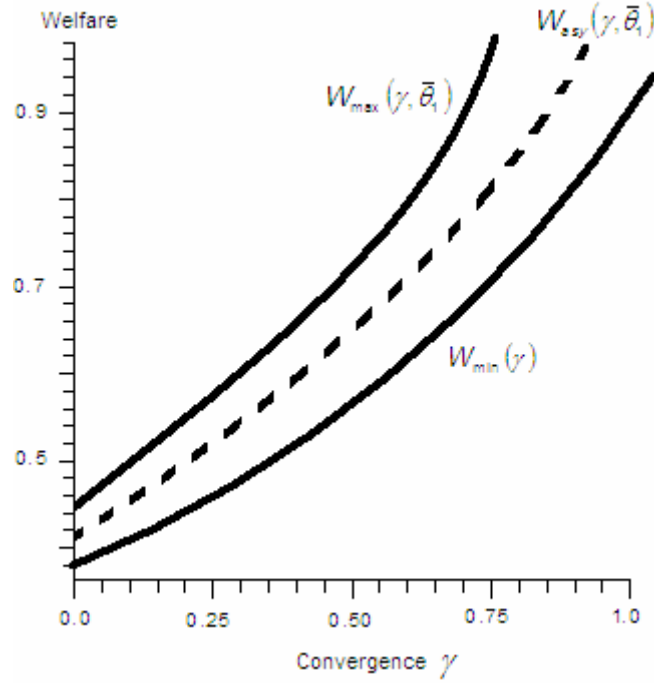
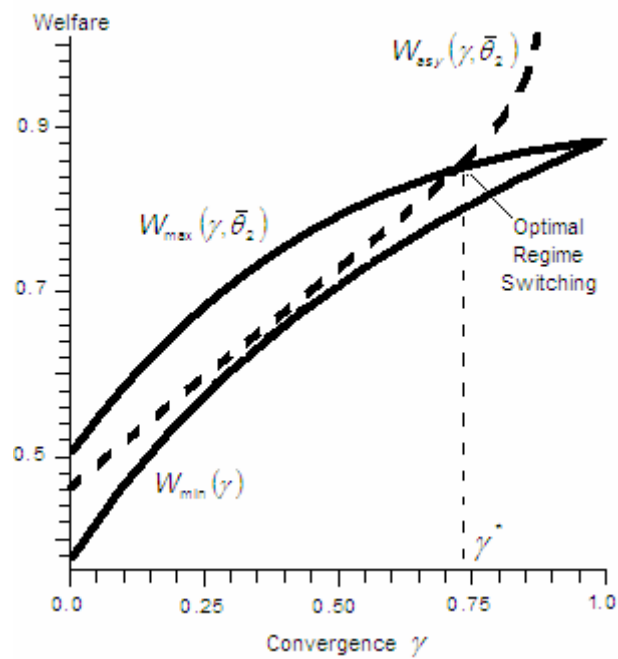


FIGURE 3
Aggregate Welfare across Regimes
High Regulatory Intervention
 $\theta = \bar{\theta}_2$; $\bar{q}_1 = \bar{q}_2$



Maximum Quality Differentiation: $\bar{q}_1 > \bar{q}_2$

Suppose now that $\bar{q}_1 > \bar{q}_2$. Moreover, assume that this quality differentiation is given to its maximal level: $\bar{q}_1 / \bar{q}_2 = 3/2$.¹⁶ As before, $W_{\min}(\gamma)$ denotes welfare under the no regulation outcome. Consider now the following levels of regulatory intervention: $\tilde{\theta}_1 = 1/4$ and $\tilde{\theta}_2 = 1/2$. These two values represent now a moderate and an extreme degree of intervention when maximal quality differentiation is biased in favour of the first platform.¹⁷ Denote as $W_{asy}(\gamma, \tilde{\theta}_1)$ and $W_{asy}(\gamma, \tilde{\theta}_2)$ welfare under asymmetric regulation when intervention is moderate and extreme, respectively. Similarly, denote as $W_{\max}(\gamma, \tilde{\theta}_1)$ and $W_{\max}(\gamma, \tilde{\theta}_2)$ welfare under symmetric regulation when intervention is also moderate and extreme, respectively. The following proposition provides some results of this numerical simulation.

PROPOSITION 6. *When maximal quality differentiation is biased in favour of the first platform, $\bar{q}_1 / \bar{q}_2 = 3/2$, and the degrees of regulatory intervention are $\tilde{\theta}_1$ and $\tilde{\theta}_2$, then:*

(a) when $\tilde{\theta}_1$: $W_{\max}(\gamma, \tilde{\theta}_1) > W_{asy}(\gamma, \tilde{\theta}_1) \quad \forall \gamma \in (0, \tilde{\gamma}_1)$ but

$$W_{\max}(\gamma, \tilde{\theta}_1) < W_{asy}(\gamma, \tilde{\theta}_1) \quad \forall \gamma \in (\tilde{\gamma}_1, 1).$$

(b) when $\tilde{\theta}_2$: $W_{\max}(\gamma, \tilde{\theta}_2) > W_{asy}(\gamma, \tilde{\theta}_2) \quad \forall \gamma \in (0, \tilde{\gamma}_2)$ but

$$W_{\max}(\gamma, \tilde{\theta}_2) < W_{asy}(\gamma, \tilde{\theta}_2) \quad \forall \gamma \in (\tilde{\gamma}_2, 1), \text{ where:}$$

$$0 < \tilde{\gamma}_2 < \tilde{\gamma}_1 < 1$$

(c) No regulation is always welfare-dominated by any of the two alternative regimes.

¹⁶ As before, this section will normalize the value of \bar{q}_2 to one for simulation purposes.

¹⁷ Note that $\tilde{\theta}_2$ is, in fact, the upper bound of the set of admissible degrees of intervention when $\bar{q}_1 > \bar{q}_2$, as described by part (b) of assumption 4.

PROOF: It follows immediately from direct substitution of the relevant set of values into the corresponding welfare functions ■

Proposition 6 shows that a social planner will never find optimal to stick to one regulatory regime throughout the process of convergence. In particular, it shows that symmetric regulation will never outperform asymmetric regulation during the last stages of convergence and this occurs regardless of the magnitude of regulatory intervention. The interesting aspect of the above proposition is that it provides support for the optimality of implementing asymmetric regulation during, at least, some part of the convergence process.

The following two figures illustrate the welfare evolution of aggregate welfare along the entire process of convergence according to the assumptions stated in proposition 6.

FIGURE 4
Aggregate Welfare across Regimes
Low Regulatory Intervention
 $\theta = \tilde{\theta}_1$; $\bar{q}_1 > \bar{q}_2$

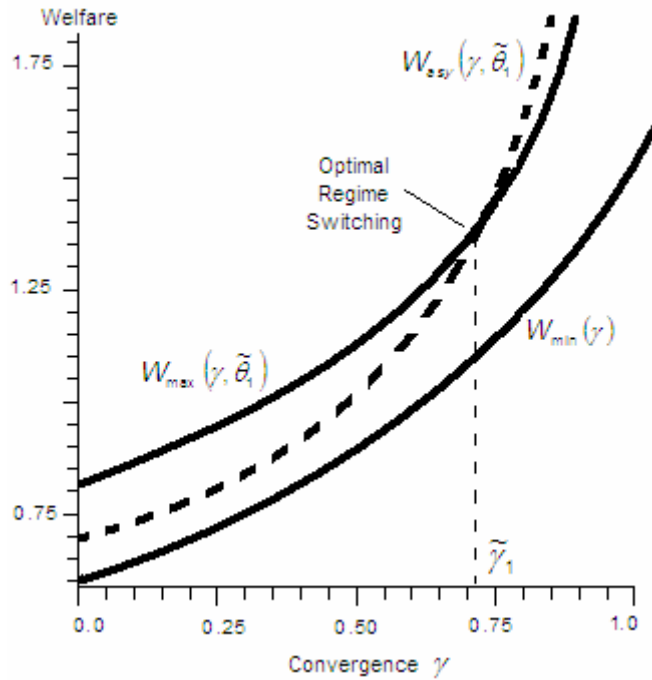
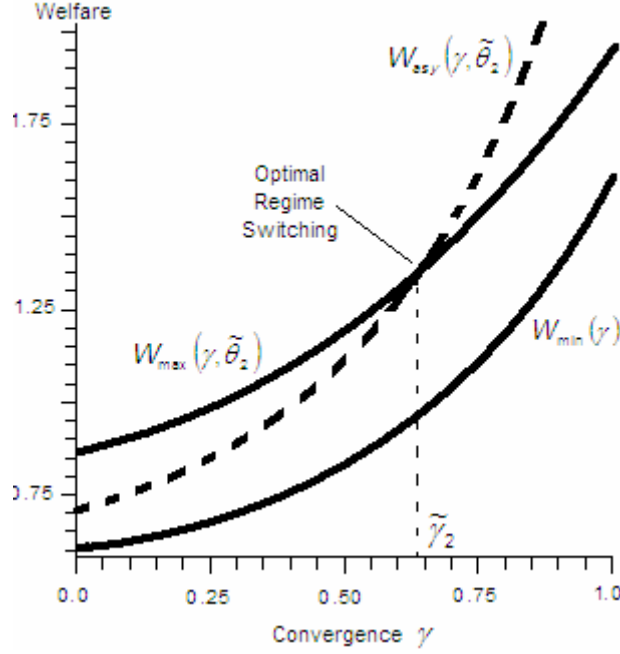


FIGURE 5
Aggregate Welfare across Regimes
 High Regulatory Intervention
 $\theta = \tilde{\theta}_2$; $\bar{q}_1 > \bar{q}_2$



Maximum Quality Differentiation: $\bar{q}_2 > \bar{q}_1$

Finally, suppose that $\bar{q}_2 > \bar{q}_1$ holds at its maximal level: $\bar{q}_1/\bar{q}_2 = 2/3$.¹⁸ As before, $W_{\min}(\gamma)$ denotes welfare under no regulation. As in previous sections, we consider the cases where the degrees of intervention are given by $\hat{\theta}_1 = 1/4$ and $\hat{\theta}_2 = 1/2$ (these values represent a moderate and an extreme degree of intervention when maximal quality differentiation occurs in favour of the second platform). Denote as $W_{asy}(\gamma, \hat{\theta}_1)$ and $W_{asy}(\gamma, \hat{\theta}_2)$ asymmetric regulation welfare when moderate and extreme degrees of intervention occur, respectively. Similarly, denote as $W_{\max}(\gamma, \hat{\theta}_1)$ and $W_{\max}(\gamma, \hat{\theta}_2)$ symmetric regulation welfare when the degrees of intervention are $\hat{\theta}_1$ and $\hat{\theta}_2$, respectively. The following proposition follows:

¹⁸ The subsequent numerical simulations normalise the value of \bar{q}_2 to one.

PROPOSITION 7. *When maximal quality differentiation is biased in favour of the second platform, $\bar{q}_1/\bar{q}_2 = 2/3$, and the degrees of regulatory intervention are $\hat{\theta}_1$ and $\hat{\theta}_2$, then:*

(a)

$$W_{\max}(\gamma, \hat{\theta}_j) > \begin{cases} W_{\min}(\gamma) \\ W_{asy}(\gamma, \tilde{\theta}_j) \end{cases}$$

$$\forall \hat{\theta}_j, \quad j = 1, 2.$$

(b) *if symmetric regulation is not feasible then,*

$$(b.1) \quad \text{when } \hat{\theta}_1: W_{asy}(\gamma, \hat{\theta}_1) > W_{\min}(\gamma) \quad \forall \gamma \in (0, \hat{\gamma}_1) \quad \text{but}$$

$$W_{asy}(\gamma, \hat{\theta}_1) < W_{\min}(\gamma) \quad \forall \gamma \in (\hat{\gamma}_1, 1).$$

$$(b.1) \quad \text{when } \hat{\theta}_2: W_{asy}(\gamma, \hat{\theta}_2) > W_{\min}(\gamma) \quad \forall \gamma \in (0, \hat{\gamma}_2) \quad \text{but}$$

$$W_{asy}(\gamma, \hat{\theta}_2) < W_{\min}(\gamma) \quad \forall \gamma \in (\hat{\gamma}_2, 1), \text{ where:}$$

$$0 < \left\{ \frac{2}{3} \right\} = \hat{\gamma}_2 < \hat{\gamma}_1 = \left\{ \frac{42 - 4\sqrt{55}}{17} \right\} < 1$$

PROOF: *It follows immediately from direct substitution of the relevant set of values into the corresponding welfare functions ■*

Two comments derive from proposition 7. First, symmetric regulation will always outperform any of the two alternative regulatory regimes throughout the process of convergence. Second, when the implementation of symmetric regulation is not feasible, the *second-best* regulatory regime is not unique. Figures 6 and 7 below show that no regulation will outperform asymmetric regulation only during the last stages of convergence but that just the opposite will occur at the beginning of this technological process.

FIGURE 6
Aggregate Welfare across Regimes
 Low Regulatory Intervention
 $\theta = \hat{\theta}_1 ; \bar{q}_2 > \bar{q}_1$

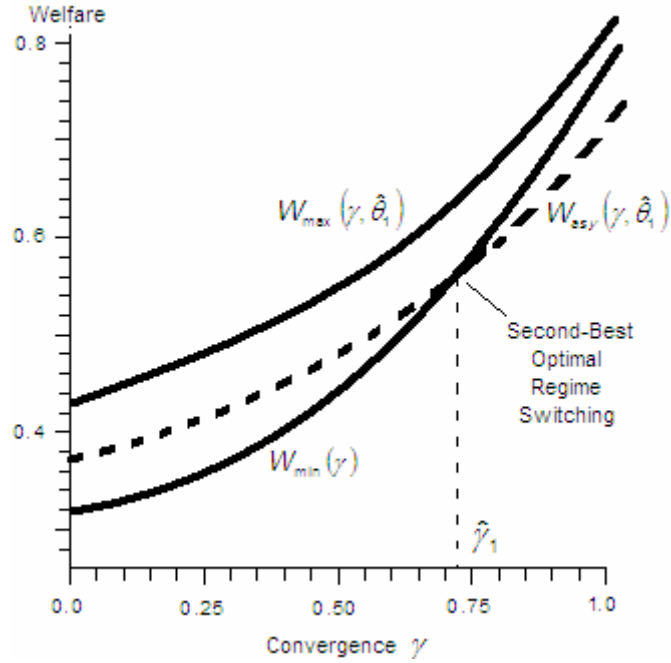
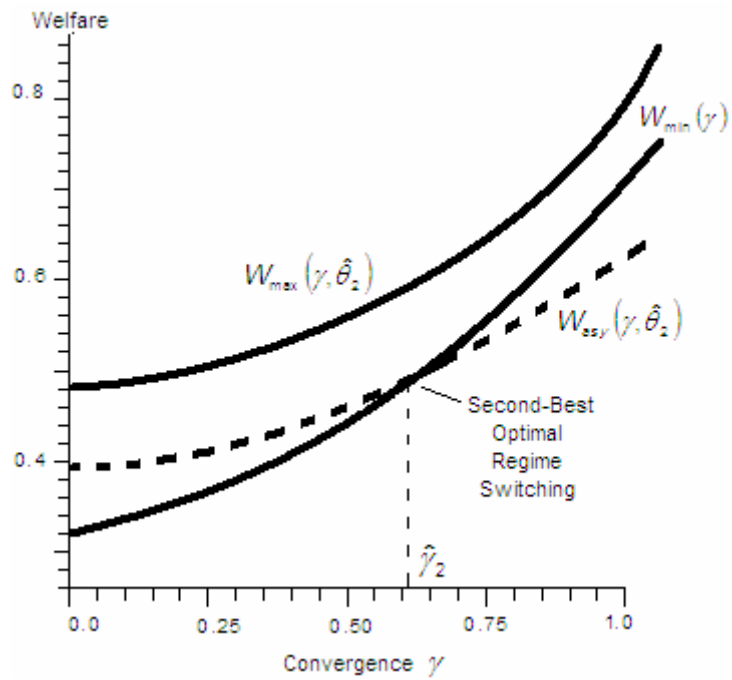


FIGURE 7
Aggregate Welfare across Regimes
 High Regulatory Intervention
 $\theta = \hat{\theta}_2 ; \bar{q}_2 > \bar{q}_1$



9. Discussion

This paper represents a first formal attempt to discuss some of the links between technological convergence and regulation. Our discussion was based in the characterisation of: (a) convergence as an *exogenous* process of technological change that makes the degree of horizontal differentiation between two initially distinct services to disappear over time and (b) regulation as the extent to which welfare-maximization motives are incorporated into the firm's behaviour.

The main contributions of this paper are as follows. First, we found that when industries converge through time and they are subject to extreme regulatory asymmetries, a *regulatory transmission mechanism* emerges. In particular, we found that the unregulated industry is adversely affected by the implementation of welfare-enhancing regulation in the neighbouring industry. Second, the existence of this transmission mechanism creates incentives for regulatory replication as discussed in section 7. Third, from a cross-industry point of view, the welfare implications of regulatory replication are ambiguous since they depend on the degree of *vertical differentiation* across platforms, the magnitude of regulatory intervention and, most importantly, of the timing when this replication occurs. To illustrate this idea, suppose that regulatory replication occurs at time $0 < \underline{\gamma} < 1$. In other words, assume that we move from asymmetric to symmetric regulation at point $\underline{\gamma}$. Proposition 5 shows that, when there is no quality differentiation across platforms and intervention is moderate, regulatory replication is always welfare-enhancing. However, the same proposition shows that, when intervention is extreme, regulatory replication is not longer optimal throughout the process of convergence. Consider as an example the evolution of welfare as illustrated by figure 3 and assume that regulatory replication occurs before point γ^* . In this case, regulatory replication is welfare-enhancing within the interval $\underline{\gamma} \leq \gamma < \gamma^*$ but once γ^* has been reached, sticking to symmetric regulation is not longer optimal: asymmetric outperforms symmetric regulation for $\gamma > \gamma^*$.

This implies that the cross-industry optimal welfare trajectory would be to switch from symmetric to asymmetric regulation once γ^* has been reached. In other words, the implementation of the cross-industry optimal welfare path requires certain degree of regulatory flexibility. Moreover, the implementation of the cross-industry optimal welfare path raises a sort of *policy trap*. This is because, from a cross-industry social point of view, deregulation of one of the industries would be optimal for $\gamma > \gamma^*$. However, no industry-specific regulator will be willing to unilaterally deregulate its own industry because of the adverse welfare effects stemming from such an action (proposition 2). In a nutshell, the implementation of the cross-industry optimal welfare path also requires some sort of *cross-industry enforcement mechanism* that would make industry-specific deregulation compulsory when it is optimal to do so. The set of issues discussed before –for the case where no quality differentiation exists and extreme intervention is implemented– are also present when the initially regulated industry has a quality advantage: $\bar{q}_1 > \bar{q}_2$. Because of this analytical similarity, we do not discuss this case further.

A contrasting vision emerges when $\bar{q}_2 > \bar{q}_1$. In this case and, irrespective of the magnitude of intervention, regulatory replication is always welfare-enhancing. The important feature of this scenario arises when the feasibility of regulatory replication is restricted: when the only way to eliminate the regulatory asymmetry is by scaling-down the regulation prevailing in the regulated industry. Upward regulatory replication might be difficult to implement, for example, because of sector-specific “*institutional*” constraints. Consider the case depicted in figure 7 as an example. Since upward regulatory replication is not feasible, the prevailing asymmetric regulatory regime ensures a second-best cross-industry optimal welfare path for $\gamma \leq \hat{\gamma}_2$. However, when $\gamma > \hat{\gamma}_2$, the implementation of the second-best cross-industry optimal welfare path would require scaling-down the prevailing (asymmetric) regulatory apparatus. This last situation makes room, once again, for the emergence of a policy trap. This is because the regulator operating in the

regulated industry has no incentives to scale-down its own regulation (own-industry's welfare increases in θ) when it would be optimal to do so from a cross-industry welfare perspective. Hence, unless a cross-industry enforcement mechanism is available, asymmetric regulation would persist through the remaining process of convergence making the second-best cross-industry optimal policy unfeasible for $\gamma > \hat{\gamma}_2$. An interesting point implied also by figure 7 when the first-best regime is unfeasible is that, throughout the process of convergence, it would be in the best interest of the unregulated industry to lobby for the deregulation of the neighbouring industry in order to eliminate the adverse welfare effects stemming from the transmission mechanism. The aggregate welfare implications of successful lobbying efforts will critically depend on timing. Deregulation will always be welfare-increasing only when $\gamma > \hat{\gamma}_2$ but welfare-decreasing otherwise: selecting the right policy is as important as implementing it at the right time.

In our framework, regulatory replication is institutionally equivalent to regulatory harmonization through the creation of a *supraregulator* with powers across industrial boundaries. Hence, when regulatory harmonization is called for, the existence of a supraregulator might make automatic the implementation of the symmetric outcome.¹⁹ However, a closer and better coordination between regulators operating in different industries would also be enough to make regulatory harmonization feasible. The problem with this last approach is that such cross-industry regulatory coordination might be costly and difficult to implement, in which case the possibility of having a supraregulator would make regulatory harmonization easier to implement.

Our discussion also shows that implementing the concept of technological neutrality in converging technologies is far from being straightforward. As an example, consider the case where no quality differentiation across platforms

¹⁹ The recently created UK's Office of Communications, *Ofcom*, has its origins, in the voice of some of its top officials, in the need of improving regulation across industries as convergence evolves. The Federal Communications Commission in the US and the CRTC in Canada are also example of regulatory entities with duties that cross industry boundaries.

exists as illustrated by figures 3 and 4. Since technological neutrality refers to the idea of equal treatment of similar services, consider the situation where the degree of horizontal differentiation between services is not particularly high, say $\bar{\gamma}$, where $\bar{\gamma} < \gamma^*$ but assume these two values do not differ significantly. A first observation is that, as figure 3 shows, when the magnitude of regulatory intervention is moderate, the implementation of the principle of technological neutrality (symmetric regulation) is always welfare-increasing with respect to either the asymmetric or the no regulation regimes. This provides a case for supporting the implementation of technologically neutral policies. However, figure 4 shows that, when the degree of regulatory intervention is extreme, sticking to the principle of technological neutrality (for $\gamma > \gamma^*$) might be a strictly welfare-decreasing policy. The bottom line of the above analysis is simple but important: the welfare effects of implementing technological neutrality are also sensitive to the *nature of the regulatory intervention*. In other words, if the aim of implementing technological neutrality is to maximise cross-industry welfare, regulators should be aware that the gains of implementing such policy might be undermined by the way this is executed.

Finally, it is important to observe that the discussion in this paper was based in the assumption that differentiation across platforms along the *vertical attribute* remained constant throughout the process of convergence. In other words, we assumed that platform's quality dominance was preserved throughout the process of technological change. However, it would be also worthy to explore the case where the magnitude of differentiation along the vertical dimension also varies through convergence. One should expect more complex interactions between welfare and convergence from this type of analysis and certainly it offers an interesting agenda for future research.

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