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DOES MUTUAL RECOGNITION OF NATIONAL MINIMUM QUALITY STANDARDS SUPPORT REGIONAL CONVERGENCE?

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ABSTRACT

Does Mutual Recognition of National Minimum Quality Standards Support Regional Convergence?*

In a model of vertical product differentiation, duopolistic firms face quality-dependent costs and compete on quality and price in two segmented markets. Minimum quality standards, set according to the principle of Mutual Recognition, can be used to increase welfare. The results of the one-shot game suggest that standards achieve initial convergence in terms of qualities produced and national welfares. Therefore, the static game is repeated in multiple periods and firms' qualities in the previous period determine their costs. In an N-period game, quality standards will, in fact, lead to convergence in terms of qualities and national welfares.

JEL Classification: F12, F13, L13
Keywords: product differentiation, oligopoly, trade, quality standards, regional convergence

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NON-TECHNICAL SUMMARY

Changes in international regulation affecting several economically interlinked countries lead to questions about their long-term impacts. These issues are the matter of debates currently taking place in the European Union. A specific question that arises is whether regulation, such as minimum standards for product quality, contributes to regional economic convergence or, rather, supports further divergence? There is currently no general agreement on the impact of such regulation on the process of European economic integration. The differences in opinion are often due to different assessments of the medium- and long-term effects of such standards. Currently, the country-of-origin principle (i.e. mutual recognition of national minimum quality standards) is prevalent within the EU as the main alternative to national (destination-oriented) treatment of product standards. This gives rise to questions about the dynamic effects of such a standards arrangement. In particular, will an initial quality difference in the presence of adjustment costs lead to divergence of regional welfares in future periods? Given these dynamic effects, how will quality standards affect future outcomes?

This paper analyses these questions using a two-country model of imperfect competition. The analysis captures some of the most important aspects of European markets. National industries bear quality-dependent product development costs, choose different quality levels, and compete by setting prices in two segmented national markets. Trade takes place, since both industries are present in both markets. Since increased differentiation in terms of quality reduces competition between rival products, higher-quality products will coexist with lower quality products, even if all firms are identical. In the presence of technological differences, however, high-quality products will normally be provided by national industries with low product development costs. Without regulation, equilibrium qualities and prices will not be optimal due to imperfect competition.

The static one-period analysis without regulation and with quality standards demonstrates that standards achieve initial convergence in terms of product qualities produced and national welfares. It is of interest to know whether convergence continues during future periods, however, when firms must bear the costs of adjusting quality beyond the past level of quality offered. If one national industry offers better quality than its international competition from the beginning, will this industry not increase its lead in each period? Extending the one-period analysis to multiple periods, where firms' product qualities in the previous period determine their costs, essentially confirms the convergence results.

The analysis presented here suggests that minimum quality standards applied according to the country-of-origin principle may speed up regional convergence by supporting those industries that provided products of lower quality in the past. In addition, such standards might speed up technological development in all industries. Both effects would lead to welfare gains in all countries. In the long run, the lagging industries could even be better off in terms of profits than without regulation. For an intermediate period of time, however, standards would imply very high additional costs for those industries.

Does Mutual Recognition of National Minimum Quality Standards Support Regional Convergence?

I. Introduction

At this time, there is no general agreement on the best way to achieve European economic integration. In particular, support for the harmonization of standards, especially minimum standards concerning product quality, safety, or environmental protection, varies considerably within the EU. The differences in opinion are often due to different assessments of the medium- and long-term effects of such standards. Currently, the Country-of-Origin principle (*i.e.*, mutual recognition of national minimum quality standards) is prevalent within the EU as the main alternative to national (destination-oriented) treatment of product standards.[1] This gives rise to questions about the dynamic effects of such a standard arrangement. In particular, will an initial quality difference in the presence of adjustment costs lead to divergence of regional welfares in future periods? Given these dynamic effects, how will quality standards affect future outcomes? In this paper, we will analyze these questions within a framework of vertical product differentiation

To analyze the questions raised above, I employ a two-country version of a model of vertical product differentiation that includes simultaneous standard-setting by governments when two-way trade occurs. The model describes a static three-stage game in standards, qualities and prices. Dynamics are introduced by repeating the one-shot game and assuming that firms have to bear adjustment costs that are increasing with the quality change but independent of quality in the previous period.

In both the fields of industrial organization and of international trade, there are fairly large bodies of literature focusing on models of vertical product differentiation. The basic features of these models have been well known for some time. Gabszewicz and Thisse (1979) developed a framework for quality preferences where consumers with identical tastes but different income levels demand different quality levels. They analyzed the Cournot-duopoly equilibrium and showed its dependence on the income distribution and quality parameters.

Shaked and Sutton (1982) showed that in the case of duopolists that first choose quality and then compete in price, the equilibrium will include both firms entering with distinct quality levels enjoying positive profits, *i.e.*, they demonstrated how quality differences relax price competition. Ronnen (1991) uses Shaked and Sutton's framework to demonstrate cases where quality standards improve welfare. He concludes that there exists a binding minimum quality standard such that all consumers are weakly better off, both firms have positive profits, and total welfare is increased. As a result of such a standard, profits of the high-quality provider must fall, whereas profits of the low-quality provider may even rise if the standard is set close to the equilibrium level of low quality without regulation.[2] But since there is only one market, the analysis of the case of Mutual Recognition is not possible and there is no scope for a welfare analysis in the presence of more than one regulating government. Motta and Thisse (1993) analyze uniform minimum quality standards in a single market using a model formally similar to Ronnen and explicitly derive equilibrium qualities. They reinterpret quality as "environmental quality" and derive results comparable to Ronnen's. Crampes and Hollander (1995) present a study where quality improvements fall on variable costs. They present results where all consumers lose through the imposition of a standard, contrary to Ronnen or Motta and Thisse. However, this literature is still limited to the analysis of uniform standards in a single market. Similarly, the earlier literature lacks the elements of two-way trade and strategic interaction of governments.[3] Only recently has the existing analysis been extended to include these features. Boom (1993) introduces National Treatment of standards into a two-country model. Contrary to Ronnen or Motta and Thisse, a relatively high standard imposed in one country can lead to market exit and a reduction of product variety in one country reducing consumers' welfare. But to our knowledge, none of this literature covers Mutual Recognition.[4]

The static one-shot game presented in this paper represents a two-country extension of the framework of Shaked/Sutton and Ronnen, *i.e.*, it is a partial-equilibrium model of vertical product differentiation and trade in which duopolistic firms face quality-dependent fixed costs and compete in quality and price in two segmented markets. We present a comparison between market outcomes in the absence of regulation and under Mutual Recognition abstracting from differences in technology, regional demand and market size. This allows for a clearer exposition of the effects of standards.[5]

As in Ronnen, the effects of quality standards on industry competition are primarily driven by their influence on price competition and the qualities produced. Due to the duopoly situation and the nature of price and quality competition, an unregulated equilibrium results in qualities being too low, prices being too high and quality differentiation being too low when compared to a welfare-maximizing solution. When qualities produced become more similar, price competition intensifies. In response to quality standards, qualities rise, quality differentiation is reduced, and prices adjusted for quality fall. In the case of a single standard, only the low-quality provider is constrained. High quality rises also because qualities are strategic complements due to the effect of quality differentiation on price competition. Reduced quality differentiation results because increasing quality is increasingly costly. Under Mutual Recognition, each government maximizes regional welfare subject to its own standard. Now both firms face binding standards and are forced to increase quality. This leads to a higher degree of product differentiation than with a single standard. However, since costs are convex in quality, the government regulating the low-quality provider prefers to increase its industry's quality more than the other government. Therefore, quality differentiation is lower than without regulation. In addition, each region benefits from an increase in quality of the other region's product. The results of the static one-shot game without regulation and with quality standards suggest that standards achieve initial convergence in terms of qualities produced and national welfares. Introducing quality standards will increase both qualities, reduce the ratio of qualities, reduce both national industries' profits, increase national welfare in both regions, and reduce the ratio of national welfares.

However, it is of interest to know whether convergence continues during future periods when firms have to bear costs of adjusting quality beyond the past level of quality offered. Considering that one firm offers a higher quality than its competitor from the beginning, will this firm not increase its lead with each passing period? In other words, will an initial quality difference in the presence of adjustment costs lead to divergence of regional welfares in future periods? Furthermore, given these dynamic effects, how will quality standards affect future outcomes?

As mentioned earlier, effects of standards under Mutual Recognition have not been analyzed in the literature, even for the one-shot game. But the question whether an initial quality advantage will persist over time has been treated in the context of two-period models of vertical product differentiation. Motta, Thisse and Cabrales (1995) investigate whether the opening of trade will lead to persistence of an initial quality leadership caused by national differences in demand. Countries operate under autarchy in the first period, whereas trade occurs in the second. They conclude that persistence of leadership is most likely to result. This is the only possible outcome if differences in national demand are very large. In all other cases, *i.e.* when multiple equilibria exist, using the risk dominance criterion leads to the selection of the persistence-of-leadership outcome. Similarly, other studies using two-period models focus on the effects of trade liberalization or market integration occurring at a specific date. The effects of regulation occurring over several periods is typically not analyzed.[6]

Extending the one-shot game to multiple periods, where the static game is repeated each period and firms' qualities in the previous period determine their costs, basically confirms the convergence results. In an N-period game, quality standards will lead to convergence in terms of qualities and national welfares. Without standards, national welfares will diverge over time even though quality differentiation stays constant. It is noteworthy that the ratio of national welfares first rises for a few periods before further convergence is achieved. This indicates that there is a nontrivial difference between two-period and N-period extensions of this game.

The remainder of the paper is organized as follows. Section 2 presents the model, market equilibria without minimum quality standards, and market equilibria with minimum quality standards. Dynamic behavior in the presence of adjustment costs is analyzed in Section 3. Main conclusions are presented in Section 4.

2. The Model in the Absence of Standards

2.1. Basics

In this section we present a two-market, partial-equilibrium model of vertical product differentiation. The model describes a two-stage game with firms interacting simultaneously in both stages. To derive solutions, I will use the concept of subgame-perfect equilibrium, computing the solutions for each stage in reverse order. There are two separate regions, the "domestic region" (D) and the "foreign region" (F). Markets (and demands) in both regions are segmented but identical. There are two firms, the "domestic firm" (d) is located in the domestic region and the "foreign firm" (f) is located in the foreign region. The two firms produce distinct goods, sold at prices p_d and p_f, respectively. The two products carry a single quality attribute denoted by s_d and s_f, respectively. Either firm faces costs of quality development. There are no unit costs of production. Quality development costs are identical for both firms and take the form of increasing, convex (quadratic) functions of quality, the exact level of which depending on quality chosen and a quality cost parameter b. Total costs of firm i are then:

$$c_i = b\, s_i^2 \tag{1}$$

In each market, there is a continuum of consumers distributed uniformly over the interval [0, t] with unit density, where $t \geq 1$. Each consumer purchases at most one unit of either firm d's product or firm f's product. The higher consumer i's income parameter t_i, the higher is her (his) reservation price. Consumer i's utility is given by equation (2) if good j is purchased. Consumers who do not purchase receive zero utility.[7]

$$u_{t_i} = s_j\, t_i - p_j \tag{2}$$

Firms d and f play a two-stage game. In the first stage, firms determine qualities to be produced and incur costs c_i ($i = d, f$). In the second stage, firms choose prices simultaneously. Note that both firms choose their respective product quality from the same interval $[0, \infty)$. This also means that both firms' choice whether to be the low-quality or the high-quality provider is now endogenous. The resulting market equilibria will include some consumers in the lower segment of the interval [0, t] not valuing quality enough to even buy from the low-quality provider.[8] Because the markets are segmented and demands are identical across regions, each firm's profits are identical across regions. It follows also that consumer surplus is the same across regions. This greatly simplifies the following analysis and allows for dropping regional indices when deriving the main model components.

2.2. Price Competition

To solve the game, consider first the demand faced by the high-quality and low-quality provider in each market, respectively. Let h and o stand for high and low quality, respectively. These demands are then given by:

$$q_h = -\left(\frac{p_h - p_o}{s_h - s_o}\right) + t \tag{3a}$$

$$q_o = \frac{p_h - p_o}{s_h - s_o} - \frac{p_o}{s_o} \tag{3b}$$

Let $t_h = (p_h - p_o)/(s_h - s_o)$ and $t_o = p_o/s_o$. Consumers with $t_i = p_o/s_o$ will be indifferent between buying the low-quality product and not buying at all. Consumers with $t_i = (p_h - p_o)/(s_h - s_o)$ will be indifferent between buying either the high-quality or low-quality the product. Consumers with $t \geq t_i > t_h$ will buy high quality, consumers with $t_h > t_i > t_o$ will buy low quality, and consumers with $t_i < p_o/s_o$ will not buy at all.

Let $i = h, o$; let $j \neq i$. The profit function for firm i is given by $p_i q_i(p_i, p_j, s_i, s_j) - c_i(s_i)$. Taken both qualities as given, the price reaction functions in each market are given as the solutions to the first order conditions. Solving the resulting equations for both prices, equilibrium prices are then given as:

$$p_h = \frac{2ts_h(s_h - s_o)}{4s_h - s_o}, \quad p_o = \frac{t(s_h - s_o)s_o}{4s_h - s_o} \tag{4}$$

Note that for all $s_h > s_o$, $t > t_h > t_o > 0$ will hold, *i.e.*, equation (4) is in fact an unconstrained price equilibrium.

Given the price equilibrium depicted above, demands and thus profits can be expressed in terms of qualities. For positive qualities s_i ($i = h, o$), these profit functions are:

$$PI_h = 2\frac{4t^2 s_h{}^2 (s_h \quad s_0)}{(4s_h - s_0)^2} - bs_h{}^2 \tag{5a}$$

$$PI_o = 2\frac{t^2 s_h (s_h \quad s_o) s_o}{(4s_h - s_o)^2} - bs_o{}^2 \tag{5b}$$

2.3. Market Equilibria Without Quality Standards

To derive the firms' quality best responses, we investigate each firm's profit function, given the other firm's quality choice, and taking into account the behavior in the price-setting subgame. Since the choice of high or low quality as compared to the competitor is endogenous, a firm's profit function will be a composite function, consisting of a segment where low quality is chosen and another segment where high quality is chosen. Firm i's profit as a function of own quality, s_i, is then given by:

$$\begin{aligned} PI_i = {} & 2\frac{4t^2 s_i^2 (s_i - s_j)}{(4s_i - s_j)^2} - bs_i{}^2 \text{ for } s_i \geq s_j; \\ & 2\frac{t^2 s_i s_j (-s_i + s_j)}{(-s_i + 4s_j)^2} - bs_i{}^2 \text{ for } 0 < s_i \leq s_j; \\ & 0 \text{ for } s_i = 0; \\ & \text{where } i = d, f;\ j \neq i. \end{aligned} \tag{6}$$

The properties of the regional revenue functions used to derive results are presented in the appendix. The economic content of these properties lies in the effects that quality choice has on price competition and marginal costs. These properties are used to establish the shape of the profit function which, in turn, allows for the derivation of firm i's quality best response. For any strictly positive quality chosen by the competitor, a firm can choose either a higher or a lower level of quality. The closer the two qualities are, however, the more are profits curtailed by price competition. If both qualities are identical, price equals marginal cost and profit is negative. This implies that an increase in the competitor's quality increases maximum profit in the low-quality segment while decreasing maximum profit in the high-quality segment. Redefine PI_h and PI_o as the expressions in the first and second line of the right hand side (RHS) of equation (6), respectively. Lemma 1 describes the shape of firm i's profit function taking the competitor's quality as given. It also describes the change in local profit maxima when the competitor's quality changes.[9]

Lemma 1. Firm i's profit as a function of own quality s_i consists of two strictly concave segments, the low-quality segment PI_o and the high-quality segment PI_h, connected at $s_i = s_j$ (where s_j is the competitor's quality). Each of these segments has a unique local maximum, say PI_o^{max} and PI_h^{max} for the low and the high-quality segment, respectively. As s_j approaches zero, $PI_h^{max} - PI_o^{max}$ approaches a positive limit. For any s_j, an increase in s_j will decrease $PI_h^{max} - PI_o^{max}$. There exists a unique switchpoint $s_j{*} = (s_j \mid PI_h^{max} - PI_o^{max} = 0)$. At $s_j{*}$, both local profit maxima are positive.

Lemma 1 implies that firm i will earn higher profits as the high-quality provider for s_j between zero and the switchpoint s_j^*, while earning higher profits as the low-quality provider for $s_j > s_j^*$. Hence, firm i's switchpoint is that level of firm j's quality where firm i is indifferent between being the high-quality and the low-quality provider. Profits along firm i's quality best response are decreasing in s_j for $s_j < s_j^*$, increasing in s_j for $s_j > s_j^*$, and attain a minimum at the switchpoint. In the absence of fixed costs , profits along firm i's quality best response are strictly positive for any $s_j > 0$. If s_j was to change from $s_j^* - \varepsilon$ to $s_j^* + \varepsilon$, firm i would switch from being the high-quality provider to being the low-quality provider. Hence, we can derive the shape of firm i's quality best response. This is done in Lemma 2.

Lemma 2. a) Firm i's quality best response consists of two segments satisfying the following conditions. For $0 \leq s_j < s_j^*$, firm i provides high quality. For $s_j > s_j^*$, firm i provides low quality. At $s_1 = s_j^*$, firm i is indifferent between providing high or low quality. Profits along firm i's quality best response are decreasing in s_j for $s_j < s_j^*$, increasing in s_j for $s_j > s_j^*$, and attain a minimum at the switchpoint.

b) Firm i's quality best response is strictly increasing in s_j for all $s_j \neq s_j^*$.

c) Firm i's quality best response is strictly decreasing in b.

The market equilibria in pure strategies without government intervention are simply given by the intersections of the quality best responses. Generally, there will be two pure-strategy equilibria as long as firms are identical or not too different with respect to cost of providing quality.[10] This is illustrated in Figure 1. The ratio of high quality to low quality, s_h/s_o, is constant with respect to market size t and cost parameter b.[11]

Insert FIGURE 1 about here

Consumer surplus for each equilibrium can be expressed in the following way:

$$CS_D = CS_F = \frac{s_h^2(4s_h + 5s_o)}{2(-4s_h + s_o)^2} \quad (7)$$

Region I's welfare, W_I, is just the sum of regional consumer surplus and the profit of the firm located in that region. Total welfare, W, is then the sum of the welfare in both regions. Although welfare can only be calculated after determining which firm provides high quality and which provides low quality, some welfare results can be obtained that hold in either quality equilibrium. The qualities chosen in an unregulated equilibrium will generally not be optimal from the point of view of either government, since each government prefers higher quality levels than those chosen in a market equilibrium. The properties of consumer surplus in either region necessary to derive these results are shown in the appendix. In both regions, an increase of either quality will lead to increases of consumer surplus at increasing rates. This leads to the result in Lemma 3.

Lemma 3. a) Given an unregulated quality equilibrium, regional welfare of both regions can be increased by increasing either or both qualities.

b) There exists a single standard that, if imposed in both regions, would increase welfare of both regions.

In the following section we extend the model introduced above to include the interaction of governments that use minimum quality standards as optimizing policy instruments. The two-stage industry game is preceded by a government stage where standards are set that will be constraints for the subsequent industry game.

2.4. Market Equilibria With Quality Standards

Under the standard-setting procedure of Mutual Recognition, governments noncooperatively set producer standards for their respective firms and recognize the adequacy of each other's standard.[12] The two-stage industry game is now preceded by a stage where governments set their respective standards simultaneously. Each government maximizes regional welfare with respect to a minimum quality standard, taking the other government's standard as given. Both firms will face binding standards. This means that each government maximizes regional welfare with respect to its own firm's quality subject to nonnegative profits to derive the regional standard best response.[13] Differentiating region I's objective function with respect to s_i yields equation (8).

$$\frac{dW_I}{ds_i} = (MR_i - MC_i) + \frac{\partial}{\partial s_i} CS^I \tag{8}$$

At the unregulated equilibrium, the RHS of equation (8) is positive for both regions since marginal consumer surplus is positive.[14] However, as s_i is increased this change diminishes and eventually becomes negative. In fact, it can be shown that, under our assumptions, each region's objective function either has a single maximum at which it is locally strictly concave or has a maximum where profits of the local firm just equal zero.[15] It follows, that both regional governments have an incentive to set a binding minimum quality for their respective firm. In effect, either firm's quality is now set by its government. This means also, that the governments' standard best responses (to each other's standards) are of the same general shape as firms' quality best responses (illustrated in Figure 1).[16]

We are now in the position to compare results. The results of the static one-shot game without regulation and with quality standards are shown in the first rows (Period 0) of Tables 1 and 2, respectively. Introducing quality standards will increase both qualities and national welfare in both regions. Since low quality is increased overproportionally, the ratio of qualities falls from about 5.2 to about 3.2 and the ratio of national welfares falls from about 2 to about 1.4. Welfare in the region hosting the low-quality provider increases by about 50%, whereas welfare in the other region increases only marginally. Both national industries' profits decrease. It is noteworthy that the low-quality provider's profits are driven to zero. This means that regulation in that region is constrained by its industry's lower profit opportunities. In summary, initial convergence in terms of qualities produced and national welfares is achieved. The next section extends the analysis to multiple periods and introduces adjustment costs into the model.

3. Dynamic Behavior with Adjustment Costs

As we have seen in the previous section, static analysis suggests that quality standards lead to convergence. This result can be applied straightforwardly to a multiple-period setting with finite time horizon, no discounting, and no knowledge spillovers where firms have to incur costs of quality each period new. In this case, the subgame-perfect equilibrium of the static game forms the solution for each period in the dynamic game. But since both firms start from the same initial positions each period, the pair of chosen qualities will be identical for all periods, *i.e.* neither divergence nor convergence will occur over time.[17] It is more realistic to assume that firms face adjustment costs of changing product quality relative to last period's quality. In this case, providing a given level of quality this period will be cheaper for the firm that provided higher quality in the previous period.[18] This gives a cost advantage to the firm with the higher quality last period. We assume adjustment costs to contribute to divergence, ceteris paribus, since cumulative cost advantages of the high-quality provider are carried over from period to period. Knowledge spillovers would tend to reduce this cost advantage. The following focuses on the dynamic effects of these adjustment costs abstracting from knowledge spillovers.

In the N-period repeated game, quality development costs are now quadratic functions of the difference of qualities in the current period τ and the previous period τ-1. Total costs of firm i are then:

$$c_i = b\,(s_{i,\tau} - s_{i,\tau-1})^2 \tag{9}$$

Costs are independent of initial quality. This implies that there is no a priori bias in favor of the high- or low-quality provider. Firms, consumers, and governments are assumed to have rational expectations and to discount future periods completely.

The results for ten periods are reported in Figures 2 and 3 and Tables 1 and 2. Without quality standards, qualities, profits and consumer surplus steadily increase from period to period. The ratio of qualities stays constant since adjustment costs are independent of initial quality. However, national welfares tend to diverge since profits of the high-quality provider increase much faster than those of the low-quality provider. The high-quality provider profits more from a high degree of product differentiation than the low-quality provider.

Insert TABLES 1 & 2 (together!) and FIGURES 2 & 3 (together!) about here

A comparison of the results in Tables 1 and 2 shows that minimum quality standards accelerate the growth of qualities and national welfares. With quality standards, the ratio of qualities steadily decreases over time. The ratio of national welfares decreases steadily after two periods of increases. The initial divergence of national welfares is due to the low-quality provider's nonnegative-profit constraint being binding in these periods. This leads to the setting of lower standards for this firm, implying relatively low quality levels and a relatively high degree of quality differentiation. It also means that the low-quality provider initially bears a very high cost of being regulated. Regulation reduces profits of the low-quality provider in the first three periods, but increases profits thereafter. The high-quality provider faces reduced profits due to regulation for all periods. This long-run effect on profits is reminiscent of Ronnen's result with respect to a single standard, where profits of the low-quality provider might be increased whereas profits of the high-quality provider are reduced by an appropriately chosen standard. The underlying intuition carries over to our results and lies in regulation giving the low-quality provider a means of committing to higher quality.

4. Conclusions

Changes in international regulation affecting several economically interlinked countries lead to questions about their long-term impacts. These issues are the matter of debates currently taking place in the European Union. A specific question that arises is whether regulation, such as quality standards, contributes to regional economic convergence or rather supports further divergence. Our analysis suggests that minimum quality standards applied according to the Country-of-Origin principle may speed up regional convergence by supporting those industries that provided products of lower quality in the past. In addition, standards might speed up technological development in all industries. Both effects would lead to welfare gains in all countries. In the long run, the lagging industries could even be better off in terms of profits than without regulation. However, for an intermediate period of time, standards would imply very high additional costs for those industries.

While this is only a very specific attempt to analyze dynamic issues by extending a static model of vertical product differentiation to include multiple periods, it is nevertheless a step towards closing the gap between static and dynamic analysis in this field. Due to the simplicity of the model, the effects of standards could be clearly demonstrated. The cost specification leads to a natural benchmark where without regulation the ratio of qualities produced stays constant over time. The results demonstrate that while the choice of multiple periods rather than just two is nontrivial, the precise number of periods does not change the qualitative results of the analysis. Furthermore, the qualitative results are maintained for cases where firms have different cost functions.

On the other hand, the simplicity of the model implies that this analysis is yet incomplete. It is of interest to investigate the effects of asymmetries in national demand. A priori, we assume a larger national market or a higher willingness to pay by consumers to lead to higher standards imposed on the industry residing in this country. Since it is likely that the country with the greater demand for quality will host the high-quality provider, this will certainly weaken the case for convergence. Furthermore, an extension of the analysis to the case of several firms in each country would be desirable.

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Appendix

Properties of the Revenue Functions

Let R_t and MR_t denote firm i's regional revenue and marginal revenue functions, respectively, where t = h, o specifies whether firm i is the provides high or low quality. The other firm's quality is denoted by s_j.

$$\frac{\partial R_h}{\partial s_i} = \frac{4t^2 s_i\ (4s_i^2 - 3s_i s_j + 2s_j^2)}{(4s_i - s_j)^3} \geq 0 \qquad \text{(A.1a)}$$

$$\frac{\partial R_0}{\partial s_i} = \frac{t^2\ (7s_i - 4s_j)\ s_j^2}{(s_i - 4s_j)^3} \geq 0 \text{ for } s_i \leq \frac{4s_j}{7} \qquad \text{(A1.b)}$$

$$\frac{\partial R_h}{\partial s_j} = \frac{4t^2 s_i^2\ (2s_i + s_j)}{(-4s_i + s_j)^3} < 0 \text{ (A.1c)}; \qquad \frac{\partial R_o}{\partial s_j} = \frac{t^2 s_i^2\ (s_i + 2s_j)}{(-s_i + 4s_j)^3} > 0 \qquad \text{(A.1d)}$$

$$\frac{\partial MR_h}{\partial s_i} = \frac{-8t^2 s_j^2 (5s_i + s_j)}{(-4s_i + s_j)^4} \leq 0 \text{(A.2a)}; \qquad \frac{\partial MR_o}{\partial s_i} = \frac{-2t^2 s_j^2\ (7s_i + 8s_j)}{(s_i - 4s_j)^4} \leq 0 \qquad \text{(A.2b)}$$

$$\frac{\partial MR_h}{\partial s_j} = \frac{8t^2 s_i s_j\ (5s_i + s_j)}{(-4s_i + s_j)^4} > 0 \text{(A.2c)}; \qquad \frac{\partial MR_o}{\partial s_j} = \frac{2t^2 s_i s_j\ (7s_i + 8s_j)}{(-s_i + 4s_j)^4} > 0 \qquad \text{(A.2d)}$$

First-Order Conditions and Slopes of Firms' Quality Best Responses

The first order conditions for the high and low quality branches of firms' quality best responses are given as:

$$\begin{aligned}&(2s_i(16t^2s_i^2 - 64b_is_i^3 - 12t^2s_is_j + 48b_is_i^2s_j + 8t^2s_j^2 - \\ &2b_is_is_j^2 + b_is_j^3))/(4s_i - s_j)^3 = 0\end{aligned} \tag{A.3a}$$

$$\begin{aligned}&(2(b_is_i^4 - 12b_is_i^3s_j - 7t^2s_is_j^2 + 48b_is_i^2s_j^2 + 4t^2s_j^3 - 64b_is_is_j^3))/ \\ &(4s_j - s_i)^3 = 0\end{aligned} \tag{A.3b}$$

The slopes of the high and low quality branches of firms' quality best responses are given as:

$$\begin{aligned}&\frac{ds_i}{ds_j}\Big|_h = (8t^2s_is_j(5s_i + s_j))/(256b_is_i^4 - 256b_is_i^3s_j + \\ &40t^2s_is_j^2 + 96b_is_i^2s_j^2 + 8t^2s_j^3 - 16b_is_is_j^3 + b_is_j^4) > 0\end{aligned} \tag{A.4a}$$

$$\begin{aligned}&\frac{ds_i}{ds_j}\Big|_o = (2t^2s_is_j(7s_i + 8s_j))/(b_is_i^4 - 16b_is_i^3s_j + 14t^2s_is_j^2 + \\ &96b_is_i^2s_j^2 + 16t^2s_j^3 - 256b_is_is_j^3 + 256b_is_j^4) > 0\end{aligned} \tag{A.4b}$$

Both slopes are positive, but less than one.

Proof of Lemma 1

The concavity properties of the profit function in equation (6) follow from concavity of revenues, since costs are convex. Revenues are concave by equations (A.1a), (A.1b), (A.2a) and (A.2b). The first-order conditions for local maxima are shown in equations (A.3a) and (A.3b). As s_j approaches zero, PI_o^{max} approaches profits at $s_i = s_j = 0$ equaling 0, whereas PI_h^{max} approaches the monopoly profits. By equations (A.1c) and (A.1d), PI_h^{max} decreases and PI_o^{max} increases as s_j increases. QED

Proof of Lemma 2

a) By Lemma 1, for firm i, $(PI_h^{max} - PI_o^{max}) > 0$ for $s_j < s_j^*$, $(PI_o^{max} - PI_h^{max}) > 0$ for $s_j > s_j^*$, and $PI_h^{max} - PI_o^{max} = 0$ for $s_j = s_j^*$. By inequalities (A.1c) and (A.1d), PI_h^{max} decreases and PI_o^{max} increases as s_j increases.

b) At firm i's quality best response, marginal revenue (of quality s_i) equals marginal cost. An increase in s_j increases marginal revenue while leaving marginal cost unchanged. Increasing s_i will decrease marginal revenue while increasing marginal cost until marginal revenue equals marginal cost again. See equation (1) and inequalities (A.2a) through (A.2d). The first order conditions for the quality best responses and the resulting slope expressions are shown in equations (A.3) and (A.4).

c) Starting at firm i's quality best response, an increase in b_i increases marginal cost while leaving marginal revenue unchanged. Decreasing s_i will increase marginal revenue while decreasing marginal cost until marginal revenue equals marginal cost again. QED

Proof of Lemma 3

a) For any pair of qualities chosen in a market equilibrium, marginal profits of both firms are zero, whereas marginal consumer surplus in both regions with respect to both qualities is positive. In addition, an increase in high quality will increase low-quality profit and an increase in low quality will decrease high-quality profit less than consumer surplus increases, *i.e.* $\partial CS_I/\partial s_o + \partial PI_h/\partial s_o > 0$. See equations (A.1c), (A.1d), (A.5a) through (A.5e) and note that by equation (A.1b), $s_o < 4s_h/7$ is a necessary condition for low-quality marginal profits to be equal to zero.

b) If a standard were set slightly above low quality in the unregulated equilibrium, it would be binding for the low-quality provider, but not for the high-quality provider. Since by equation (A.3a), the high-quality provider's quality best response is increasing in low quality, both qualities will increase. The welfare result follows then from part a). QED

Properties of the Consumer Surplus Functions

Let CS_I (I = D, F) denote region I's consumer surplus function. Firms' qualities are denoted by s_h and s_o for high and low quality, respectively.

$$\frac{\partial CS_I}{\partial s_h} = \frac{t^2 s_h\left(-8s_h^2 + 6s_h s_o + 5s_o^2\right)}{\left(-4s_h + s_o\right)^3} > 0 \text{ for } s_o < \frac{4s_h}{5} \quad \text{(A.5a)}$$

$$\frac{\partial CS_I}{\partial s_o} = \frac{ts_h^2\left(28s_h + 5s_o\right)}{2\left(4s_h - s_o\right)^3} > 0 \quad \text{(A.5b)}$$

$$\frac{\partial^2 CS_I}{\partial s_h^2} = \frac{t^2 s_o^2 (52s_h + 5s_o)}{(-4s_h + s_o)^4} > 0 \quad \text{(A.5c)}; \qquad \frac{\partial^2 CS_I}{\partial s_o^2} = \frac{t^2 s_h^2 (52s_h + 5s_o)}{(-4s_h + s_o)^4} > 0 \quad \text{(A.5d)}$$

$$\frac{\partial^2 CS_I}{\partial s_o \partial s_h} = -\frac{t^2 s_h s_o (52s_h + 5s_o)}{(-4s_h + s_o)^4} < 0 \quad \text{(A.5e)}$$

Notes

[1] Full Harmonization, the main goal until the late 1970s, will be constrained to essential safety and health requirements. In all other cases, as a rule Mutual Recognition of national standards applies. As an exception, National Treatment (NT) can be applied in certain cases governed by the EEC Treaty Articles 100 and 36. The differences between the three arrangements are best illustrated using an example. Suppose a French and a German manufacturer of household appliances are selling their products in both national markets. Under FH, one standard set by the EU Council of Ministers applies in both countries. Under MR, German products are governed by German standards even if they are sold in France and French products need only meet French standards even if they are sold in Germany (the country-of-origin principle). Under NT, German standards must be met by all products sold in Germany including the French products while French standards must be met by all products sold in France including the German products.

[2] Ronnen starts from the assumption that the chosen order of qualities is already determined, *i.e.* it is a priori clear which of the firms offers the higher quality. Consequently, Ronnen analyzed firms quality best responses only in the vicinity of one existing equilibrium. However, with completely endogenous choice of quality, there exist up to two equilibria and each firm's quality best response is discontinuous and contains a high- and a low-quality branch, respectively. In our paper, we demonstrate the derivation of complete quality best responses and the resulting equilibria. These equilibria are in pure strategies. If there are two pure-strategy equilibria, there also exists at least one mixed-strategy equilibrium. However, the analysis of mixed-strategy equilibria is beyond the scope of this work. The emergence of multiple equilibria has also been acknowledged by, *e.g.*, Boom (1993) or Crampes/ Hollander (1995). The question of selection between two asymmetric equilibria was recently addressed by Motta/Thisse/Cabrales (1995) who demonstrate how the risk dominance criterion can be utilized for this purpose in models of the type employed here.

[3] See, *e.g.*, Leland (1979), Shapiro (1983), Besanko/Donnenfeld/White (1988) and Das/Donnenfeld (1989).

[4] In addition, these studies have generally neglected the possibility that a standard may give firms providing high quality the ability to deter entry by potential suppliers of lower qualities.

[5] Assuming identical technologies and markets leads to multiple equilibria in our model, so that we cannot identify which country will initially host the high-quality producer and have the higher welfare. However, the emergence of quality leadership arising from national differences in demand or technology has been demonstrated elsewhere. See, *e.g.*, Motta/Thisse/Cabrales (1995).

[6] See , *e.g.*, Barros/Martinez-Giralt (1994) and Motta (1992).

[7] For the derivation of utility and demand see, *e.g.*, Tirole (1988, pp. 96, 97).

[8] This guarantees an interior solution of the price game. If the distribution of consumers would not cover the entire interval [0, t], but were instead of the form covering the interval [t-1, t], then this would not necessarily be true. If t were large, the firms would cover the whole market. However, including this case would not change the qualitative results to be obtained.

[7] Proofs of the results presented in Lemma 1 through Lemma 3 are shown in the appendix.

[10] The existence of a unique quality equilibrium due to cost differences can be illustrated using Lemma 2(c) and Figure 1. In Figure 1, an increase in b_i would lead to a downward shift in qbr_i. If b_i/b_j gets sufficiently large, the intersection of qbr_i and qbr_j in the northwest corner of Figure 3 vanishes. Only one equilibrium with firm j providing high quality remains.

[11] Equilibrium qualities can be calculated as multiples of t^2/b. If firms 'cost parameters are different, then equilibrium qualities can be calculated as multiples of t^2/b_h for any given ratio b_o/b_h. In this case, s_h/s_o increases monotonically in b_o/b_h.

[12] Recall that each firm's product quality is governed by the regulation of the country of origin, regardless of destination.

[13] It also implies that the high-quality provider has no possibility to preempt entry by the low-quality provider.

[14] Note also that the RHS of equation (8) is positive at $s_i = 0$. This means that a solution involving only one firm in the market cannot be optimal.

[15] For an illustration of this procedure, see equations (A.12a) through (A.12c) in Lutz (1993, Appendix A).

[16] If costs are identical or not too different, there exist two equilibria. Under large cost differences, only one equilibrium with the low-cost firm providing high quality remains. Derivation is analogous to that of unregulated equilibria. See Section 2.3 and Footnote 8.

[17] In this case, the identity of the high-quality provider cannot be predertimed and may change from period to period, *i.e.* leapfrogging of competitors is possible.

[18] Given the form of the cost function, this implies that the same incremental quality increase each period can be achieved with identical cost, but there are diminishing returns to increasing the speed of quality improvement over time.

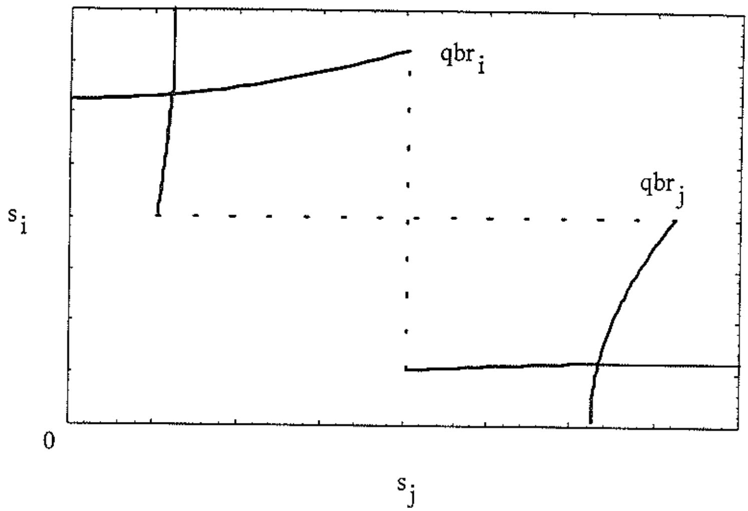

Figure 1. Quality Equilibria - Identical Firms

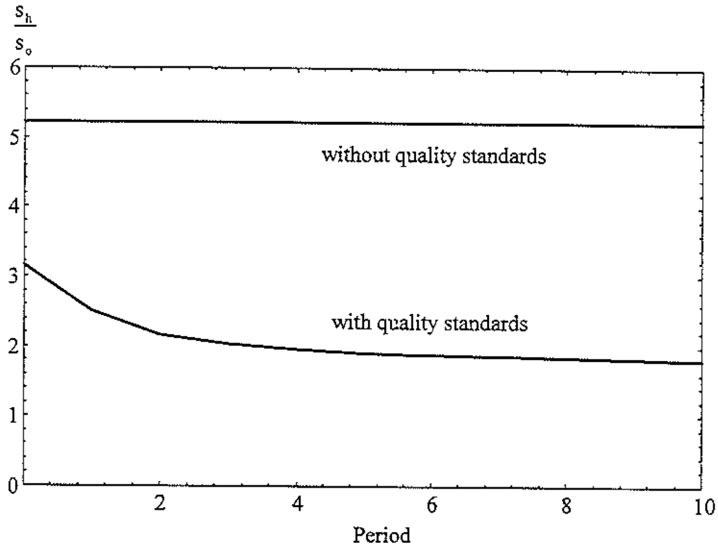

Figure 2. Quality Ratios

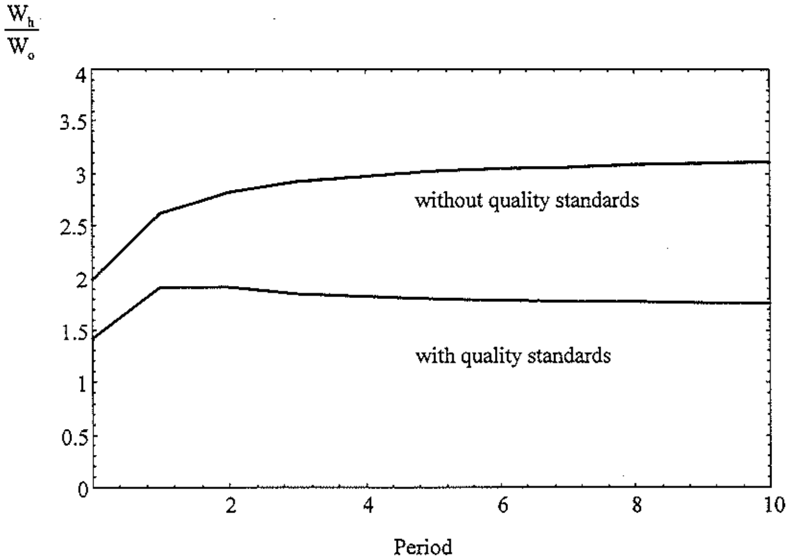

Figure 3. Welfare Ratios

Table 1. Results without Regulation

Period	s_h*)	s_o*)	PI_h**)	PI_o**)	W_h**)	W_o**)	W**)
0	0.253311	0.048238	0.048877	0.003055	0.092095	0.046273	0.138368
1	0.506622	0.096477	0.161921	0.008437	0.248357	0.094873	0.343230
2	0.759932	0.144715	0.274964	0.013818	0.404619	0.143473	0.548029
3	1.013243	0.192953	0.388008	0.019200	0.560881	0.192073	0.752954
4	1.266554	0.241192	0.501051	0.024582	0.717142	0.240673	0.957815
5	1.519865	0.289430	0.614095	0.029964	0.873404	0.289273	1.162677
6	1.773176	0.337668	0.727138	0.035345	1.029670	0.337873	1.367543
7	2.026490	0.385907	0.840182	0.040073	1.185930	0.386473	1.572403
8	2.279797	0.434145	0.953226	0.046109	1.342190	0.435073	1.777263
9	2.533110	0.482383	1.066270	0.051491	1.498450	0.483673	1.982123
10	2.786419	0.530622	1.179310	0.056872	1.654710	0.532273	2.186983

*) Multiply values with t^2/b

**) Multiply values with t^4/b

Table 2. Results with Quality Standards

Period	s_h*)	s_o*)	PI_h**)	PI_o**)	W_h**)	W_o**)	W**)
0	0.316249	0.100601	0.027247	0	0.092456	0.065210	0.157666
1	0.635173	0.253962	0.133581	0	0.280577	0.146996	0.427573
2	0.956819	0.442369	0.225395	0.002512	0.466669	0.243786	0.710455
3	1.280080	0.631688	0.317368	0.016204	0.654020	0.352856	1.006876
4	1.602410	0.821548	0.409774	0.029792	0.842186	0.462204	1.304390
5	1.927470	1.011740	0.500965	0.043432	1.029630	0.572097	1.601727
6	2.253070	1.202170	0.593642	0.057066	1.218770	0.682190	1.900960
7	2.579070	1.392770	0.686478	0.070699	1.408200	0.792426	2.200626
8	2.905410	1.583510	0.779431	0.084333	1.597870	0.902770	2.500640
9	3.232000	1.774340	0.872499	0.097969	1.787730	1.013200	2.800930
10	3.558800	1.965260	0.965646	0.111608	1.977730	1.123690	3.101420

*) Multiply values with t^2/b

**) Multiply values with t^4/b