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VERTICAL PRODUCT DIFFERENTIATION, QUALITY STANDARDS, AND INTERNATIONAL TRADE POLICY

Stefan Lutz

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Centre for Economic Policy Research
25–28 Old Burlington Street
London W1X 1LB
Tel: (44 171) 878 2900
Email: cepr@cepr.org

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ABSTRACT

Vertical Product Differentiation, Quality Standards, and International Trade Policy*

This paper studies the influence of minimum quality standards in a partial-equilibrium model of vertical product differentiation and trade in which duopolistic firms face quality-dependent costs and compete on quality and price in two segmented markets. Three alternative standard setting arrangements are Full Harmonization, National Treatment and Mutual Recognition. Under these alternatives, standards can be found that increase welfare in both regions. The analysis integrates the governments' choice of a particular standard setting alternative into the model. Mutual Recognition emerges as one regulatory alternative that always improves welfare in both regions when compared to the case without regulation. Under certain cost conditions, both regions will prefer Mutual Recognition over the alternatives.

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

Stefan Lutz
Institute for Post Graduate Studies
University of Mannheim
D–68131 Mannheim
GERMANY
Tel: (49 621) 292 5421
Email: lutz@pool.uni-mannheim.de

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NON-TECHNICAL SUMMARY

International coordination of national regulations is of particular importance to the European Common Market. Currently, three alternative product standard arrangements are prevalent within the EU. Full Harmonization, where uniform standards are set for all member countries, is the goal of the directives on harmonization of standards contained in the Commission's white paper (1985). In all other cases, as a rule, the Country-of-Origin principle (or principle of Mutual Recognition) applies. This means that governments set standards for their national industries only, while recognizing the adequacy of foreign standards on imported products. National (destination-oriented) treatment of product standards is permitted under certain circumstances as an exception to this rule.

Support for the harmonization of standards, such as minimum standards concerning product quality, safety, or environmental protection, varies considerably within the EU, however. In part, this is based on the common belief that these standards, when binding for less advanced national industries but not for more advanced national industries, lead to increased market shares for the latter. Therefore, some of the economically weaker members of the EU fear economic disadvantage from harmonized standards. A similar reasoning applies to destination-oriented standards, despite the fact that they allow for national differences in the degree of regulation. Here, national standards might be used to prevent market entry by less advanced foreign industries. In contrast to these standard arrangements, the Country-of-Origin principle allows national regulation only for domestically manufactured products. But in this case, the more advanced national industries might be afraid that higher standards imposed on them by their own governments will put them at a disadvantage. On the other hand, all consumers may benefit from increased product qualities caused by standards.

This paper presents a comparison of the effects of the three alternative standard-setting arrangements on national welfare, industry profits and consumers' welfare using a two-country model of imperfect competition. The model includes restricting assumptions to capture stylized facts about the EU. 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 decreases competition between rival products, higher quality products will

coexist with lower quality products, even if all firms were 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. In response to quality standards, qualities rise, quality differentiation is reduced, and prices are adjusted for reductions in quality. This tends to increase welfare while reducing industry profits.

Under either standard-setting alternative, standards can always be found that increase welfare in both regions. The analysis above is therefore extended to integrate the governments' choice of a particular standard setting alternative and the subsequent setting of standards into the model. Mutual Recognition emerges as one regulatory alternative that always improves welfare in both regions when compared to the case without regulation. Since the economically disadvantaged region always prefers Mutual Recognition over all available alternatives and this is the default in the first stage of the game, this is also the only possible equilibrium outcome of the game. Reported results with respect to the other standard arrangements change with changes in relative costs, i.e. technological country differences.

These results suggest that the Country-of-Origin Principle is the most preferable alternative. There are two main reasons for this: first, it is the only standard arrangement that unambiguously increases welfare in both regions irrespective of technological country differences; and second, it never leads to the exit of industries from national markets.

VERTICAL PRODUCT DIFFERENTIATION, QUALITY STANDARDS, AND INTERNATIONAL TRADE POLICY[1]

1. Introduction

Questions about economic integration in the presence of market imperfections have gained new importance with the advent of the European Common Market. This is exemplified by the ongoing efforts to implement the directives on harmonization of standards put forth in the EC Commission's (1985) White paper. However, support for the harmonization of standards, especially minimum standards concerning product quality, safety, or environmental protection, varies considerably within the EC. On one hand, the Association of German Chambers of Industry and Commerce [DIHT (1988)] stresses the importance of harmonized standards for several areas of industrial policy and recommends transitionary adjustment measures.[2] Not surprisingly, the German industry has traditionally favored uniform standards, whereas other EC countries have opposed them. This is based on the common belief that these standards, when binding for less advanced national industries but not for more advanced national industries, lead to increased market share for the latter. On the other hand, some of the economically weaker members in the EC would only agree to the Common Market program in exchange for massive subsidy promises.[3] In fact, the EC currently utilizes three alternative ways of handling standards. These arrangements are: Full Harmonization, where uniform standards are set for all member countries; Mutual Recognition, where governments set standards for their own industries and recognize the adequacy of each others' standards; and National Treatment, where governments apply national standards to any product sold within their country.[4] This gives rise to questions about the relative effects of different standard setting procedures and in particular about the possibility to regulate standards in such a way that the economically weaker regions do not take welfare losses. This paper will address some of these questions.

The model to be developed below will represent some stylized facts about economic asymmetries within the EC. More precisely, the EC will be divided into two regions, labeled core and periphery, respectively. The core will be characterized by a larger market, higher per-capita income, lower cost of producing or developing products of a certain level of quality, and the ability to generally produce products of higher quality than the periphery. Industry structure will be duopolistic. Regional governments, as members of an interregional council, either unanimously choose one of three alternative standard setting procedures or a default procedure takes effect.

Following, for example, Smith and Venables (1988) or Venables (1990), we can identify France, Germany, Italy and Great Britain as the core, and the rest of the EC as periphery. Using this categorization, the following can be said about core and periphery, respectively. Within the EC, the core accounts for about 60% of total area, 70% of total population, and 80% of total Gross Domestic Product. Per-capita income is on average approximately 60% higher in the core than in peripheral countries.[5] Core countries

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[1] This paper is based on Chapter One of Lutz (1993).

[2] Some of these are food and drug laws, harmonization of technical standards, environmental protection standards, consumer protection, product liability, reciprocal recognition of university degrees, general vocational training policies, and harmonization of regulation of services such as insurance or telecommunication. DIHT identifies all these areas as contributing to the potentially costly segmentation of the European regional market.

[3] See, for example, Franzmeyer (1989), p. 313.

[4] Full Harmonization, the main goal until the late 1970s, will be constrained to essential safety and health requirements. In all other cases, Mutual Recognition of national standards applies. This approach was substantially furthered by recent decisions of the European Court. It has also been embraced in the Commission's White Paper. However, the Single European Act provided a caveat to Mutual Recognition in Article 100A(4), which allows single governments to apply National Treatment "... on grounds of major needs referred to in Article 36 ..." These major needs include, among others, public morality and the protection of commercial property.

[5] These and the following stylized facts can be verified using readily available data sources such as Basic Statistics of the Community (EC-Commission), International Financial Statistics (IMF) and Statistics of Foreign Trade (OECD).

account for over 75% of the EC's total R&D expenditure, patents, and high-technology exports.[6] Manufacturing accounts for approximately 70% of intra-EC trade and intra-EC trade accounts for about 60% of total EC trade. Industries providing products with medium to high technology content and requiring high R&D efforts or investments within the EC are, for example, medical devices and specialties, telecommunications, automated machines for data processing, office equipment, computers, and automobiles. These industries largely exhibit oligopolistic structures, often, as in the case of automobiles, operate in segmented national markets and, in some cases such as automobiles and computers, engage in intensive price competition.[7] Furthermore, they are also targeted by the legislative directives on harmonization of standards introduced in the EC Commission's (1985) White Paper.[8]

According to Nevin (1990, p. 32), the Council of Ministers of the European Communities is the "... sole effective centre of power in the [EC's administrative] system."[9] The Council of Ministers consists of representatives of the governments of the member states. Each government normally sends one of its ministers, according to the subject to be discussed. The Council ensures the coordination of the Community's general economic policies and makes decisions necessary for carrying out the treaties. It also makes the final decisions on all important issues. Its main instruments used are regulations and directives. Regulations become immediately effective in all affected member states whereas directives bind affected member governments to adopt national legislation. Qualified majority voting is permitted in certain policy areas, while unanimity is required in others. The voting allocations in the Council are such that the core has 40 votes and the periphery has 36 votes. A qualified majority consists of 54 votes. In addition, at least 8 countries must vote in favor of proposals not emanating from the Commission of the European Communities.[10] The legislative directives on harmonization of standards introduced in the EC Commission's (1985) White Paper will eventually all be submitted to the Council for final decision. If we assume that core countries and peripheral countries respectively represent homogenous interests, unanimous decision making in the Council can be taken as a stylized fact describing decisions about standard setting on the Community level. Based on Articles 100A and 30 of the EEC-Treaty and current rulings of the European Court, Mutual Recognition of standards can be seen as the default ruling in the EC. The facts presented above build the basis for the stylistic features of the model developed below.

In both the fields of industrial organization and of international trade, there are fairly large bodies of literature focusing on product quality. Some of this literature investigates the effects of minimum quality standards [e.g., Leland (1979), Shapiro (1983), Besanko/Donnenfeld/White (1988), Das/Donnenfeld (1989), Ronnen (1991), Copeland (1992)]. But to my knowledge, the existing literature does not yet cover the analytical treatment of simultaneous standard-setting by governments when two-way trade occurs. However, this is a prerequisite to discussing the problems raised above. The basic features of models of quality differentiation with monopolistic competition 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,

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[6]This is reported in Papagni (1992).

[7]See, for example, Clement (1989) and Cecchini (1988).

[8]COM (85), 310 final. If the White Paper describes the planned changes in Community regulation, then the resulting gains, from the view of the Commission, are most comprehensively described in the Cecchini (1988) Report.

[9]Nevin takes this citation from the Vedel Report of 1972 and elaborates that "... this remains an accurate summary of the realities of the situation."

[10]See, for example, Sbragia (1992, p. 293) and Nevin (1990, p. 34).

and total welfare is increased. However, since there is only one market, there is no scope for strategic government interaction in this model. Similarly, other literature lacks either the element of strategic government interaction or the element of two-way trade. For example, Das and Donnenfeld (1989) study the influence of minimum quality standards and quotas in a model in which a foreign firm and a domestic firm compete in qualities and quantities in the domestic market. The home government unilaterally chooses a trade policy. A quota will lead to positive protection, whereas a minimum quality standard will result in negative protection and a decrease of national welfare. Existing comparisons between different standard setting procedures, such as in Copeland (1992), are subject to similar restrictions. Copeland studies the influence of minimum quality standards under three different standard setting arrangements in a model in which a foreign and a domestic firm compete in quality and quantity in the home market while the foreign firm is the sole supplier in the foreign market. Hence, the home country is only importing and the foreign country is only exporting. Each country imposes a quality standard to control an externality generated by the products. Both countries have an incentive to use standards as a protective measure. The intervention results obtained depend on the particular standard-setting arrangement chosen.

The model employed extends the framework of Shaked/Sutton and Ronnen for the two-country case, *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. First, I model a two-stage industry game in pure strategies. In the first stage, firms simultaneously determine quality to be produced. In the second stage, firms compete in prices, given their quality choice. There exist at most two unregulated equilibria[11]. In either equilibrium, one firm sells high quality whereas the other sells low quality. The resulting market equilibrium will generally not be optimal from the point of view of either regional government, since governments will prefer higher quality levels than those chosen in equilibrium. However, the nature of governments' choices will depend on the standard setting procedure agreed upon. Under Full Harmonization of standards, there always exists some minimum quality standard that will increase welfare in both regions. If such a standard is set, all consumers will be (weakly) better off and producers' profits will generally decrease. If a minimum quality standard is set close to low quality, however, the low-quality producer's profits will increase. Two other alternatives to Full Harmonization are National Treatment and Mutual Recognition. Under either alternative, standards can always be found that increase welfare in both regions. The analysis above is therefore extended to integrate the unanimous choice of a particular standard setting alternative by governments and the subsequent setting of standards into the model. This allows a comparison of the effects of alternative standard setting procedures.

I extend the basic model to be a four-stage game in pure strategies. In the first stage, both governments, as members of an interregional council, announce one choice out of three alternative standard setting procedures. These alternatives are: (1) National Treatment, (2) Full Harmonization, and (3) Mutual Recognition (the default procedure). If the two announcements coincide the particular procedure will be applied, otherwise the default procedure takes effect. The governments' role in the second stage depends on the first-stage outcome: under alternative (1) governments maximize regional social welfare by noncooperatively setting regional standards; under alternative (2) the council maximizes the sum of regional welfares by setting one uniform standard[12]; and under alternative (3) governments maximize regional social welfare by noncooperatively setting producer standards. The industry game described earlier builds the third and fourth stages of this game.

I also employ a number of restricting assumptions designed to capture stylized facts about the EC as well as to simplify further analysis. In the two-region model, one (the "domestic") region is assumed have a larger demand (market size) than the other ("foreign") region. The producer in this region is

[11]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.
[12]Maximizing the sum of regional welfares can be seen as the outcome of Nash-Bargaining between both governments in the Council.

assumed to have a cost advantage guaranteeing a single pure-strategy industry-equilibrium in the last two stages of the game in which it provides a higher quality than its competitor. The effects of relaxing these assumptions are discussed later on. Under National Treatment, it is possible that one region sets a regional standard that deters entry by the foreign producer leaving this producer to sell only in its home market. This case is included in the analysis, but a similar scenario under Full Harmonization is excluded by assumption.[13] I obtain results under Full Harmonization assuming that firms do not exit even if profits are negative. If a firm were to earn negative profits in equilibrium, its government is assumed to provide a lump-sum subsidy making profits at the Full-Harmonization solution exactly equal to zero. While the true Full-Harmonization solution would incorporate a nonnegativity constraint for profits, the obtained solution provides bounds on domestic and foreign welfare and thus permits welfare comparisons.[14]

Even with these assumptions, the results obtained do not permit a full characterization of all possible outcomes. Nevertheless, Mutual Recognition emerges as one regulatory alternative that always improves welfare in both regions when compared to the case without regulation. Since the foreign region always prefers Mutual Recognition over all other available alternatives and this is the default in the first stage of the game, this is also the only possible equilibrium outcome of the game.[15] If the domestic firm has a sufficiently large cost advantage, then the domestic region will also prefer Mutual Recognition over all available alternatives.

The structure of this paper is as follows. Section 2 presents the two-stage industry game. Section 3 discusses the potential effects of standards. The complete model is presented in Section 4. Full Harmonization and Mutual Recognition are compared in Section 5. Section 6 introduces the case of National Treatment. Section 7 presents and illustrates the choice of a standard setting procedure. A summary and main conclusions are presented in Section 8.

2. The Model in the Absence of Standards

2.1. Basics

In this section we develop a two-country (or, two-region), partial-equilibrium model of vertical product differentiation. The model describes a two-stage game with firms interacting simultaneously in both stages.[16] 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).[17] 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. Each firm produces a single variety of a quality-differentiated product. Products are differentiated on the basis of a single attribute, "quality" (s). When the qualities provided differ, we refer to them as "high" (h) quality and "low" (o) quality, respectively. Both firms have constant marginal cost (equal to zero) in quantity produced. However, they have to incur a "cost of providing quality" (k) before entering into production. Costs are increasing, convex (quadratic) functions of quality provided. The exact level of cost depends on quality chosen and a "quality cost parameter" (b). The domestic firm has a technological advantage in developing quality, *i.e.*, it has a lower quality cost parameter than the foreign firm. Total costs of firm i are then given by:

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[13] In the context of the EC, deterred entry would mean that the particular industry would not even sell in its own country. Since the standard set by the Council is viewed as the outcome of Nash-Bargaining between both governments, excluding this case seems plausible.

[14] Given the current state of the EC debate, explicitly allowing this kind of subsidy in the model could also be defended as a realistic feature.

[15] Note that there at least three and at most seven Nash equilibria depending on relative costs.

[16] In what follows, terms within quotation marks will denote names to be used in the analysis. The corresponding symbols to be used for short-hand notation will be added in parentheses. As a convention, I will use subscripts to denote regions, firms and high/low (in quality). E. g., p_{Fd} is the price of the domestic firm in the foreign market and s_h is high quality offered.

[17] The regions D and F can be interpreted as core and periphery, respectively.

(1) $$k_i = b_i s_i^2$$

The domestic market is larger than the foreign market and shows a preference for higher quality. The two product markets are regionally segmented. The product qualities are known to all consumers. Each consumer may purchase at most one unit of a product of either high or low quality. We assume consumers have identical ordinal preferences across regions and differ only in their incomes. The population is equal to one in the foreign region and greater than one (equal to two) in the domestic region. Populations can be ordered according to an "income parameter" (t), where t is uniformly distributed over the intervals [0, 2] and [0, 1] in the domestic and foreign regions, respectively.[18] Under our assumption, the income parameter t represents the inverse of consumers' marginal rate of substitution between income and quality - wealthier consumers have a lower marginal utility of income (which means a higher t), they prefer higher quality products. Hence, we can use t when referring to single consumers or segments of consumers. Expenditure on the product, *i.e.*, price (p), is small relative to income. Hence, consumer i's preference can be represented by:[19]

(2) $$U = \begin{cases} t_i s_i - p_i & \text{if one unit of quality } s_i \text{ at price } p_i \text{ is purchased} \\ 0 & \text{otherwise} \end{cases}$$

In the first stage, firms determine quality to be produced. In the second stage, firms compete in prices, taking their quality choice as given.

2.2. Price Competition

Let h and o stand for high and low quality, respectively. Let t_{Ik} be the income parameter of consumer k in region I; I = D, F. Recall that income parameters are uniformly distributed over the intervals $[0, u_I]$; I = D, F. Define $t_{Ih} = (p_{Ih} - p_{Io})/(s_h - s_o)$ and $t_{Io} = p_{Io}/s_o$. Consumers with $t_{Ik} = p_{Io}/s_o$ will be indifferent between buying the low-quality product and not buying at all. Consumers with $t_{Ik} = (p_{Ih} - p_{Io})/(s_h - s_o)$ will be indifferent between buying either the low-quality or the high-quality product. Consumers with $u_I \geq t_{Ik} > t_{Ih}$ will buy the high-quality product, consumers with $t_{Ih} > t_{Ik} > t_{Io}$ will buy the low-quality product, and consumers with $t_{Ik} < p_{Io}/s_o$ will not buy at all. The demand functions for region I are then given by $q_{Io} = t_{Ih} - t_{Io}$ and $q_{Ih} = u_I - t_{Ih}$. Assuming $u_D=2$ and $u_F=1$, demands are:

(3a) $$q_{Do} = \frac{p_{Dh} - p_{Do}}{s_h - s_o} - \frac{p_{Do}}{s_o};$$ (3b) $$q_{Dh} = 2 - \frac{p_{Dh} - p_{Do}}{s_h - s_o}$$

(3c) $$q_{Fo} = \frac{p_{Fh} - p_{Fo}}{s_h - s_o} - \frac{p_{Fo}}{s_o};$$ (3d) $$q_{Fh} = 1 - \frac{p_{Fh} - p_{Fo}}{s_h - s_o}$$

Regional consumer surplus, CS_I, is obtained by building the integrals of individual consumer surplus functions over the segments $[t_{Ih} - t_{Io}]$ and $[u_I - t_{Ih}]$ and adding up:

(4a) $$CS_D = \int_{t_{Dh}}^{1} ts_h - p_{Dh}\,dt + \int_{t_{Do}}^{t_{Dh}} ts_o - p_{Do}\,dt$$ (4b) $$CS_F = \int_{t_{Fh}}^{1} ts_h - p_{Fh}\,dt + \int_{t_{Fo}}^{t_{Fh}} ts_o - p_{Fo}\,dt$$

The profit of a particular firm is given by its revenues in both markets minus cost of providing the chosen quality level. Note that we assume $b_f > b_d$, *i.e.*, the domestic firm can provide quality at lower cost. However, we do not yet know which firm will provide the higher quality. Therefore, I refer generically to a high-quality and a low-quality firm until the firms' quality choices are determined. Let i=h, o. Then the profit function of the firm producing high quality is given by PI_h, whereas the profit function of the firm producing low quality is given by PI_o:

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[18]This also implies that the domestic region has higher per capita income than the foreign region.
[19]For the derivation of utility and demand see, for example, Tirole (1988, pp. 96, 97).

(5a) $$PI_h = p_{Dh}q_{Dh}(p_{Dh}, p_{Do}, s_h, s_o) + p_{Fh}q_{Fh}(p_{Fh}, p_{Fo}, s_h, s_o) - k_h(s_h)$$

(5b) $$PI_o = p_{Do}q_{Do}(p_{Dh}, p_{Do}, s_h, s_o) + p_{Fo}q_{Fo}(p_{Fh}, p_{Fo}, s_h, s_o) - k_o(s_o)$$

Each firm will have two first order conditions for price choice, obtained by setting the partial derivatives of profit with respect to own prices in either market equal to zero, since markets are segmented. Solving these two equations simultaneously for the firm's own prices yields the price reaction function for each firm. Again, h and o denote high-quality and low-quality firm, respectively.

(6a) $$p_{Dh} = \frac{p_{Do} + 2s_h - 2s_o}{2};$$ (6b) $$p_{Fh} = \frac{p_{Fo} + s_h - s_o}{2}$$

(6c) $$p_{Do} = \frac{p_{Dh}s_o}{2s_h};$$ (6d) $$p_{Fo} = \frac{p_{Fh}s_o}{2s_h}$$

Because the markets are segmented, each firm's reaction function in either market is increasing in the other firm's price in that market, but is independent of the price in the other market. The high-quality firm sets positive prices when the other firm's quality is zero, *i.e.* when there is a monopoly. An increase (decrease) in quality offered by one firm lets both firms' reaction functions shift up (down). However, in the case of the high-quality firm these will be parallel shifts, whereas the low-quality firm's reaction function rotates around the origin. Deriving equilibrium prices as functions of both firms' qualities will allow for immediate checking of the nonnegativity conditions on quantities. These conditions are derived in equations (9b) and (9d) below. Prices have to lie in the area spanned by these two functions for demands to be positive. For zero-cost, this condition coincides with the positive-profit condition. An explicit derivation of nonnegative-profit conditions will be introduced when discussing the firms' quality best responses. It will be shown that when firms choose profit-maximizing qualities their profits are always nonnegative in the neighborhood of the price equilibrium. Note that nonnegative-profit conditions generally depend on conduct in both markets if prices are not set at their equilibrium values.

Solving all four reaction functions simultaneously yields the following equilibrium prices:

(7) $$p_{Dh} = \frac{4s_h(-s_h + s_o)}{-4s_h + s_o} \quad p_{Do} = \frac{2(s_h - s_o)s_o}{4s_h - s_o}$$
$$p_{Fh} = \frac{2s_h(-s_h + s_o)}{-4s_h + s_o} \quad p_{Fo} = \frac{(s_h - s_o)s_o}{4s_h - s_o}$$

The second order conditions for price choice for the high-quality and the low-quality firm are given in equations (8a) and (8b), respectively. They are (locally) satisfied.

(8a) $$\{H_{11}, |H|\} = \left\{\frac{-2}{s_h - s_o}, \frac{4}{(s_h - s_o)}\right\}$$ (8b) $$\{H_{11}, |H|\} = \left\{\frac{2s_h}{-(s_h s_o) + s_o^2}, \frac{4s_h^2}{(-(s_h s_o) + s_o^2)^2}\right\}$$

Consumers' positive-demand conditions are then given by:

(9a) $$2(s_h - s_h) - (p_{Dh} - p_{Do}) = \frac{4(s_h^2 - s_h s_o)}{4s_h - s_o} > 0$$

(9b) $$(s_h - s_o) - (p_{Fh} - p_{Fo}) = \frac{2(s_h^2 - s_h s_o)}{4s_h - s_o} > 0$$

(9c) $$\left(\frac{p_{Dh}}{s_h}\right) - \left(\frac{p_{Do}}{s_o}\right) = \frac{2(s_h - s_o)}{4s_h - s_o} > 0$$ (9d) $$\left(\frac{p_{Fh}}{s_h}\right) - \left(\frac{p_{Fo}}{s_o}\right) = \frac{s_h - s_o}{4s_h - s_o} > 0$$

With both firms providing positive finite qualities and $s_h > s_o$, conditions (9a) through (9d) are always satisfied at the price equilibrium.

Increases in high quality lead to increases in quality differentiation. This gives the low-quality provider the opportunity to increase price, even at unchanged quality offered. The high-quality provider increases price because quality offered was increased. Increases in low quality lead to decreases in quality differentiation. Therefore, the high-quality provider has to decrease price. For the low-quality provider the positive demand effect from increasing quality dominates the negative differentiation effect initially which allows price increases in the beginning. But as quality differentiation becomes smaller price will eventually have to be reduced again.

2.3. Quality Best Responses

To derive the firms' quality best responses, we need to investigate each firm's profit function, given the other firm's quality choice, and taking into account that both firms choose equilibrium prices. This profit function will be a composite function, consisting of a segment where the firm is the low-quality producer and another segment where the firm is the high-quality producer. Firm i's profit as a function of own quality, s_i, is then given by:

$$PI_i = -(b_i s_i^2) + \frac{5 s_i s_j (-s_i + s_j)}{(s_i - 4 s_j)^2} \quad \text{for all } s_i \le s_j;$$

(10)
$$-(b_i s_i^2) + \frac{20 s_i^2 (s_i - s_j)}{(-4 s_i + s_j)^2} \quad \text{for all } s_i \ge s_j;$$

$$i = d, f;\ j \ne i.$$

From either branch of equation (10), we can derive that profit will be equal to minus the cost of providing quality when both qualities are equal. But it is not entirely obvious that either branch of equation (10) is concave in quality and has a local maximum. To get this result, we need only to demonstrate that revenues are concave. Concavity of the profit function follows, since cost of providing quality is convex. Let R_{Tt} be firm i's revenue in market T offering quality t, where T=D, F and t=h, l. These revenues are:

(11a) $R_{Dh} = \dfrac{16 s_i^2 (s_o - s_j)}{(-4 s_o + s_j)^2} = 4 R_{Fh}$; (11b) $R_{Do} = \dfrac{4 s_i s_j (-s_i + s_j)}{(-s_i + 4 s_j)^2} = 4 R_{Fo}$.

Note that (11a) reduces to the monoply revenues at $s_j = 0$, *i.e.*, when the low-quality firm does not enter the market.

Since $R_{Dj} = 4\ R_{Fj}$ (j = h, o), we can look at the properties of combined revenues in both markets without much loss of generality. Marginal revenues of firm i in both markets combined are shown in equations (12). They are denoted by $M_{Rt} = \partial R_i / \partial s_i$, where the subscripts indicate again whether firm i is the high or the low quality provider:

(12a) $MR_h = \dfrac{20 s_i (4 s_i^2 - 3 s_i s_j + 2 s_j^{2)}}{(4 s_i - s_j)^3} \ge 0$ (12b) $MR_o = \dfrac{5(7 s_i - 4 s_j) s_j^2}{(s_i - 4 s_j)^3} \ge 0$ for $s_i \le \dfrac{4 s_j}{7}$

Equations (13) show the second derivatives of revenues with respect to own quality. They are denoted by $MR2_t$, where $MR2_t = \partial^2 R_i / \partial s_i^2$:

(13a) $MR2_h = \dfrac{-40 s_j^2 (5 s_i + s_j)}{(-4 s_i + s_j)^4} \le 0$ (13b) $MR2_o = \dfrac{-10 s_j^2 (7 s_i + 8 s_j)}{(s_i - 4 s_j)^4} \le 0$

Equations (12) and (13) establish that the two segments of the profit function are indeed concave in quality. The following are some additional properties of firm i's revenue function, which I will use extensively later on:

(14a) $\frac{\partial R_h}{\partial s_j} = \frac{20 s_i^2 (2s_i + s_j)}{(-4s_i + s_j)^3} < 0$ (14b) $\frac{\partial R_o}{\partial s_j} = \frac{5 s_i^2 (s_i + 2s_j)}{(-s_i + 4s_j)^3} > 0$

(14c) $\frac{\partial MR_h}{\partial s_j} = \frac{40 s_i s_j (5s_i + s_j)}{(-4s_i + s_j)^4}$ (14d) $\frac{\partial MR_o}{\partial s_j} = \frac{10 s_i s_j (7s_i + 8s_j)}{(-s_i + 4s_j)^4} > 0$

Equations (14a) through (14d) describe properties of the total revenue function for both markets. These properties hold also if revenues in both markets are examined separately. Figure 1 shows firm i's profit as a function of its own quality offered, given its cost of providing quality, b_i (here equal to 0.5), and firm j's quality. The profit functions PI_i^1 and PI_i^2 are evaluated at $s_j = 0.2$ and $s_j = 0.8$, respectively. Note that the profit functions have two local maxima - one in the low-quality and one in the high-quality branch - and that they are kinked at $s_i = s_j$. As firm j's quality increases, firm i's low-quality maximum profit increases whereas its high-quality maximum profit decreases. From equations (14a) and (14b) it immediately follows that an increase in firm j's quality will lead to an increase in firm i's low-branch profit and a decrease in firm i's high-branch profit at any level of firm i's quality. Hence, the maximal profit attainable in each branch will increase for the low branch and decrease for the high branch. Furthermore, it is easy to show that as firm j's quality approaches zero, low-branch profits will approach zero whereas high-branch profits will approach the monopoly profits.

It follows that firm i will choose high quality for s_j between 0 and some s_j^* (the "switchpoint"), will choose low quality for s_j greater than s_j^*, and will switch from high quality to low quality at $s_j = s_j^*$. The switchpoint s_j^* solves equation (15).

(15) $$\max_{s_i} PI_h = \max_{s_i} PI_o$$

We are now able to determine the general shape of firm i's quality best response. First, it is obvious that the high-quality branch starts with the monopoly choice of quality at $s_j = 0$. This choice is shown in equation (16):

(16) $$s_i = \frac{5}{8b_i}$$

Firm i's monopoly quality was calculated by solving its first-order conditions for quality choice for the high-quality branch after setting $s_j = 0$. (Doing the same for the low- quality branch leads to a hypothetical value of $s_i = 0$.) These first-order conditions are given by equations (17a) and (17b) for the high-quality and the low-quality branch, respectively:

(17a) $$\frac{2s_i(40s_i^2 - 64b_i s_i^3 - 30 s_i s_j + 48 b_i s_i^2 s_j + 20 s_j^2 - 12 b_i s_i s_j^2 + b_i s_j^3)}{(4s_i - s_j)^3} = 0$$

(17b) $$\frac{2b_i s_i^4 - 24 b_i s_i^3 s_j - 35 s_i s_j^2 + 96 b_i s_i^2 s_j^2 + 20 s_j^3 - 128 b_i s_i s_j^3}{(-s_i + 4s_j)^3} = 0$$

Applying the implicit function theorem to the first-order conditions for quality choice for both branches, we can derive the slopes of both branches of the reaction function. This slope is given by $ds_i/ds_j|_t = -(\partial(\partial PI_t/\partial s_i)/\partial s_j)/(\partial(\partial PI_t/\partial s_i)/\partial s_i)$, where $\partial PI_t/\partial s_i$ (t=h, l) are the left-hand sides of equations (17a) and (17b), respectively:

(18a) $0 < \frac{ds_i}{ds_j}\Big|_h < 1$; (18b) $0 < \frac{ds_i}{ds_j}\Big|_o < 1$

Inequalities (18a) and (18b) are shown in the appendix.

Another application of the implicit function theorem to the first-order conditions in equations (17) lets us derive the effects of a change in cost of quality, represented by a change in b_i, on the locations of both branches of the quality best response. These effects are given by $ds_i/db_i|_t = -(\partial(\partial PI_t/\partial s_i)/\partial b_i)/(\partial(\partial PI_t/\partial s_i)/\partial s_i)$:

(19a) $$\frac{ds_i}{db_i}\Big|_h < 0;$$ (19b) $$\frac{ds_i}{db_i}\Big|_o < 0$$

Inequalities (19a) and (19b) are shown in the appendix. They describe the reaction of the two branches of the quality best response as b_i (quality cost parameter) changes.

Hence, the quality best response shifts downward as b_i (or, the cost of providing quality) increases. Furthermore, it is easy to show that the switchpoint s_j^*, *i.e.* that level of s_j that solves equation (15), is decreasing in b_i. Recall that $\partial PIt/\partial bi = - 2\, b_i\, s_i$, where $s_i \leq s_j$ for t=l and $s_i \geq s_j$ for t=h. However, we can ignore the case of $s_i = s_j$ since it clearly cannot be a maximizing choice for either branch as long as positive profits are attainable. Hence, $|\partial PI_h/\partial b_i| > |\partial PI_o/\partial b_i|$ holds for all relevant values of s_i, especially for those values that locally maximize the two respective branches. Now suppose that s_j^1 was a switchpoint at b_i^1, solving equation (15). Let the quality cost parameter increase to a level $b_i2 > b_i^1$. This will decrease the high-quality branch of profits more than the low-quality branch. Consequently, firm i will now prefer to be the low-quality provider at s_j^1, *i.e.* it must have a new switch point $s_j^2 < s_j^1$.

Finally, we have to determine that firm i's profits are nonnegative at each point on its quality best response. I will show that this is generally the case, *i.e.* along the quality best response firm i's profit is positive for all positive finite values of b_i and s_j. The following are some properties necessary to derive this result:

a) Firm i's profits decrease monotonically along the high-quality branch of the quality best response as s_j is increased. This follows directly from equations (14a), (14c), inequality (18a) and the discussion above.

b) Firm i's profits at the low-quality branch, given any positive s_j, are always positive at some s_i close to zero. This follows from a comparison of marginal revenue given in equation (12b) with marginal cost of providing quality. The limit of marginal revenue minus marginal cost as $s_i \to 0$ is a positive constant for all positive sj.

c) Firm i's profits increase monotonically along the low-quality branch of the reaction function as s_j is increased. This follows from equations (14b), (14d), inequality (18b) and the discussion above.

d) If firm i's monopoly profits are positive, its profits at the switchpoint will be positive also. This follows directly from property b), equations (14a) and (14b), and the discussion above.

Properties a) and c) establish that profits as a function of optimal response quality attain a global minimum at the switchpoint. Properties b) and d) establish that this global minimum will be positive if monopoly profits are positive. Hence, a sufficient condition for generally positive profits along firm i's reaction function is that its monopoly profits are positive, which is generally true for finite b_i. Figure 2 shows firm i's best quality response together with its isoprofit curves at cost of providing quality $b_i = 0.4$. Firm i's profit decreases when moving from the origin along the 45-degree line. From any point on the 45-degree line, profits increase when moving to the left or right.

2.4. Market Equilibria in Quality

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 not too different with respect to cost of providing quality.[20] This is illustrated in Figure 3 below.

Figure 3 shows the quality best responses of two different firms i and j, RQ_i1 and RQ_i2, evaluated at $\{b_i, b_j\} = \{0.4, 0.6\}$. The intersections e_1 and e_2 are two pure-strategy equilibria.

For the purpose of this study, I want to concentrate on asymmetric pure-strategy equilibria where the low-cost firm provides high quality, *i.e.* cases described by e_1 in Figure 3. With respect to the basic

[20]Note that in this case, there generally exists at least one non degenerate mixed-strategy equilibrium also. However, the following analysis covers only pure-strategy equilibria.

model, this means that the domestic firm provides high quality, whereas the foreign firm provides low quality. This case arises naturally if firms' costs of providing quality are sufficiently different. Starting from the situation depicted in Figure 3, firm j's quality best response RQ_j will shift to the left as its cost parameter b_j was increased. If b_j is high relative to b_i, the the high-quality branch of firm j's quality best response is too low to intersect with the low-quality branch of firm i's quality best response. Since s_j is everywhere lower than firm i's switchpoint, the only remaining pure-strategy equilibrium would be given by e_1. However, it may not be very realistic to assume large cost differences among firms. Another way to ensure a unique equilibrium is to make the somewhat plausible assumption that firm f faces a technological constraint of the form $s_f \le s_f^{max}$ (in other words, $k_f(s_f)$ is infinite for all sf > s_f^{max}), where s_f^{max} is smaller than firm d's switchpoint. This condition is given by equation (20).

(20) $$s_f^{max} \le s_f^*$$

Again, the only remaining (pure-strategy) equilibrium would be given by e_1. In addition, the high-quality branch of firm j's quality best response would be horizontal at s_j^{max} and firm j's switchpoint would be smaller than without this constraint. Recall that, without a constraint, firms increase their own quality to partly offset decreases in profits as they move along their reaction function's high-quality branch. Since firm j faces a technological constraint, it can not increase its quality as firm i's quality increases. Hence its profit will decrease faster and it will reach the switchpoint earlier. However, it is not necessary for e_1 to exist that firm j makes positive profits at s_j^{max} at all. If the condition in equation (21) below is not satisfied, firm j's quality best response will consist of a low-quality branch only.

(21) $$s_j^{max} > \frac{5}{4b_h}$$

3. Minimum Quality Standards

The previous section has shown that there are generally two equilibria in quality. Profit and consumer surplus for each equilibrium can be expressed in the following way:

(21a) $$PI_h = \frac{20s_h^2(s_h - s_o)}{(-4s_h + s_o)^2} - b_h s_h^2$$ (21b) $$PI_o = \frac{5s_h s_o(s_h - s_o)}{(4s_h - s_o)^2} - b_o s_o^2$$

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

Regional welfare is just the sum of regional consumer surplus and the profit of the firm located in that region. Total welfare 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. Moreover, it can be shown that both governments prefer higher quality levels than those chosen in a market equilibrium. The following properties of consumer surplus in either region will be used to show this.

(23a) $$\frac{\partial CS_D}{\partial s_h} = 4\frac{\partial CS_F}{\partial s_h} = 4\frac{s_h(-8s_h^2 + 6s_h s_o + 5s_o^2)}{(-4s_h + s_o)^3}$$

(23b) $$\frac{\partial CS_D}{\partial s_o} = 4\frac{\partial CS_F}{\partial s_o} = \frac{2s_h^2(28s_h + 5s_o)}{(4s_h - s_o)^3} > 0$$

(24a) $$\frac{\partial^2}{\partial s_h^2}CS_D = 4\frac{\partial^2}{\partial s_h^2}CS_F = \frac{4s_o^2(52s_h + 5s_o)}{(-4s_h + s_o)^4} > 0$$

(24b) $$\frac{\partial^2}{\partial s_o \partial s_h}CS_D = 4\frac{\partial^2}{\partial s_o \partial s_h}CS_F = -\frac{4s_h s_o(52s_h + 5s_o)}{(-4s_h + s_o)^4} < 0$$

The expressions in equations (24a) are strictly positive for any pair of qualities chosen in a market equilibrium. This is so, since a market equilibrium requires the low-quality firm's marginal revenue to be positive, which is only the case if $s_o < 4s_h/7$. 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 1.

Lemma 1. 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.

Proof. 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. See equations (23a) through (24b) and note that by equation (12b), $s_o < 4s_h/7$ is a necessary condition for marginal profits of the low-quality firm 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 inequality (18a), 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

4. The Complete Model

4.1. The Four-Stage Game

In this section we extend the model introduced above to include standard-setting governments. The extended model describes a four-stage game with regional governments (or their representatives in a multinational council) interacting in the first two stages and firms interacting in the third and fourth stages. To derive solutions, I will again use the concept of subgame-perfect equilibrium. Each of the two separate regions, the "domestic region" (D) and the "foreign region" (F), has an independent central government. Both governments are members in the joint "Council." Decisions by the Council are either made unanimously, *i.e.* both governments have to agree on the choice made, or a previously chosen default rule applies. Firms and consumers are as previously introduced.

In the first stage, both governments, announce one choice out of three alternative standard setting procedures. These alternatives are: (1) National Treatment (NT), which lets governments simultaneously set minimum quality standards for their respective consumers; (2) Full Harmonization (FH), which has the Council equalize standards across countries; and (3) Mutual Recognition (MR), which lets governments simultaneously set minimum quality standards for their respective producers (the default procedure). If the two announcements coincide the particular procedure will be applied, otherwise the default procedure takes effect. The governments' role in the second stage depends on the first-stage outcome: under alternative (1) governments maximize regional social welfare by noncooperatively setting regional (consumer) standards; under alternative (2) the Council maximizes the sum of regional welfares by setting one uniform standard; and under alternative (3) governments maximize regional social welfare by noncooperatively setting producer (firm) standards. Under National Treatment, it is possible that one region sets a regional standard that deters entry by the foreign producer leaving this producer to sell only in its home market. This case is included in the analysis, but a similar scenario under Full Harmonization is excluded by assumption. I obtain results under Full Harmonization assuming that the Council calculates its standard best response conditional on both firms remaining in the market. If a firm were to earn negative profits at the so calculated Full-Harmonization solution, its government will pay a lump-sum subsidy equal to minus profits if that firm stays in the market.[21] The effects of removing this assumption are discussed below together with the analysis of the Full-Harmonization case. In the third stage, firms simultaneously determine quality to be produced subject to minimum quality constraints on either their productions or market access. The domestic producer is assumed to have a cost advantage guaranteeing a single pure-strategy industry-equilibrium such that it provides a higher quality than its competitor. In the last stage, firms compete in prices, given their quality choice and possible market access constraints.

Figure 4 shows the complete game tree and Figure 5 shows the first-stage game in table format. Several implications about the game can be deduced directly from Figure 5. The default rule introduces the possibility of at least three (cells 3, 6, 9 or cells 7, 8, 9) and at most seven (cells 2, 3, 4, 6, 7, 8, 9) outcome-equivalent equilibria where Mutual Recognition takes effect. Both governments announcing Mutual Recognition (cell 9) is always a Nash equilibrium. A sufficient condition for Mutual Recognition to be the only equilibrium outcome is that at least one region strictly prefers it to the other two alternatives. Necessary condition for National Treatment to be an equilibrium (cell 1) is that both regions weakly prefer National Treatment to Mutual Recognition. An analogous condition applies for Full Harmonization (cell 5).

5. Full Harmonization vs. Mutual Recognition

5.1. Full Harmonization

Under the standard setting procedure of Full Harmonization, governments agree to set a single minimum quality standard for both regions. In this case, the council maximizes the sum of regional welfares with respect to a minimum quality standard. Since firm d is the high-quality producer, this standard will be binding for the foreign firm but not for the domestic firm, since the foreign firm stays in the market (by assumption). This means that the council's problem can be reduced to maximizing total welfare with respect to firm f's quality subject to the constraints that firm f's profits must be nonnegative and that firm d operates on its quality reaction function. Since firm d moves along its quality best response as firm f is forced to increase its quality, firm d's profit will be positive, but decreased. Firm f's profit, however, may increase if the minimum quality standard is sufficiently close to the unregulated market solution and decrease below zero if the standard is high. For tractability, the results below will be obtained assuming that the council calculates its standard best response conditional on both firms remaining in the market. If a firm were to earn negative profits at the so calculated Full-Harmonization solution, its government will pay a lump-sum subsidy equal to minus profits if that firm stays in the market. (Regional welfare is measured as the sum of consumer surplus and profits net of the subsidy.) Results obtained in this way overstate both qualities, total welfare and domestic welfare while understating foreign welfare. The analysis of National Treatment (with accomodated entry) will provide an upper bound on foreign welfare and the lower bounds on qualities, total welfare and domestic welfare. Using the true Full-Harmonization solution, *i.e.* removing the subsidy assumption will relax the conditions under which the domestic region will prefer Mutual Recognition over Full Harmonization. All other welfare comparisons presented below will be essentially unchanged.

Let ds_d/ds_f denote the slope of firm d's quality reaction function according to inequality (18a). Note that firm d provides high quality whereas firm f provides low quality. Equation (25) describes then the change in firm f's profits as s_f is forced upward by a minimum quality standard.

$$\frac{d}{ds_f}(R_f - b_f s_f^2) = (MR_f - MC_f) + \frac{\partial R_f}{\partial s_d}\frac{ds_d}{ds_f} \tag{25}$$

[21] Regional welfare is measured as the sum of consumer surplus and profits net of the subsidy.

At equilibrium qualities, this change is positive since marginal revenue minus marginal cost of quality is zero and the remaining terms on the RHS of equation (25) are both positive. However, as firm f's quality is forced up higher this change diminishes and eventually becomes negative. In other words, foreign profits along the domestic firm's quality best response are concave. Differentiating the RHS of equation (25) with respect to s_f yields the following negative expression.

$$(26)\qquad \frac{d^2}{ds_f^2}(R_f - b_f s_f^2) = (\frac{\partial MR_f}{\partial s_f} - 2b_f) + \frac{ds_d}{ds_f}\frac{\partial MR_f}{\partial s_d} + \frac{\partial R_f}{\partial s_d}\frac{\partial}{\partial s_f}(\frac{ds_d}{ds_f}) < 0$$

The sign in equation (26) is verified in the appendix. There exists a uniform standard that will make all consumers in both regions weakly better off and some consumers strictly better off. Let i = D, F, u_D=2, and u_F=1. Recall that in region ;, consumers with incomes in the segment $[u_i, t_{id}]$ will purchase high quality, consumers with incomes in the segment $[t_{id}, t_{if}]$ will purchase low quality, all other consumers will not purchase, and $t_{if} = p_{if}/s_f$.

$$(27a)\qquad -\frac{\partial t_{Dd}}{\partial s_f} > \frac{\partial t_{Dd}}{\partial s_d} > 0;\quad -\frac{\partial t_{Fd}}{\partial s_f} > \frac{\partial t_{Fd}}{\partial s_d} > 0$$

$$(27b)\qquad -\frac{\partial t_{Df}}{\partial s_f} > \frac{\partial t_{Df}}{\partial s_d} > 0;\quad -\frac{\partial t_{Ff}}{\partial s_f} > \frac{\partial t_{Ff}}{\partial s_d} > 0$$

$$(27c)\qquad -\frac{\partial}{\partial s_f}\frac{P_{Dd}}{s_d} > \frac{\partial}{\partial s_d}\frac{P_{Dd}}{s_d} > 0;\quad -\frac{\partial}{\partial s_f}\frac{P_{Fd}}{s_d} > \frac{\partial}{\partial s_d}\frac{P_{Fd}}{s_d} > 0$$

Together with inequality (18a), inequalities (27a) through (27c) can be used to show that market participation in both regions will increase, the segment of consumers buying high quality will increase in both markets, and utility per unit bought will increase in both regions for both qualities. This is done in the appendix.

Under our assumptions, the Council's maximization problem has a unique solution even though the objective function may not be stricly concave in s_f. Let firm d's marginal quality best response be denoted by ds_d/ds_f. Differentiating the objective function with respect to s_f yields equation (28).

$$(28)\qquad \frac{d}{ds_f}W = (MR_f - MC_f) + \frac{\partial CS_F}{\partial s_f} + \frac{ds_d}{ds_f}\left\{\frac{\partial R_f}{\partial s_d} + \frac{\partial CS_F}{\partial s_d}\right\} + \frac{ds_d}{ds_f}\left\{(MR_d - MC_d) + \frac{\partial CS_D}{\partial s_d}\right\} + \frac{\partial R_d}{\partial s_f} + \frac{\partial CS_D}{\partial s_f}$$

At unconstrained equilibrium qualities, this change is positive since marginal revenue minus marginal cost of quality is zero for both firms, $\partial CS_D/\partial s_f + \partial R_d/\partial s_f > 0$, and the remaining terms on the RHS of equation (28) are all positive. However, as s_f is increased this change diminishes and eventually becomes negative. Differentiating equation (28) another time yields the following expression.

$$(29)\qquad \frac{d^2}{ds_f^2}W = (\frac{\partial MR_f}{\partial s_f} - 2b_f) + \frac{\partial^2}{\partial s_f^2}R_d + \frac{ds_d}{ds_f}(\frac{\partial MR_d}{\partial s_f}) + \frac{\partial^2}{\partial s_f^2}CS_D + \frac{\partial^2}{\partial s_f^2}CS_F + (\frac{\partial^2}{\partial s_d \partial s_f}CS_F + \frac{\partial^2}{\partial s_d \partial s_f}CS_D)\frac{ds_d}{ds_f} + (\frac{\partial R_f}{\partial s_d} + \frac{\partial CS_F}{\partial s_d} + \frac{\partial CS_D}{\partial s_d})\frac{\partial}{\partial s_f}(\frac{ds_d}{ds_f}) < 0$$

At the choice of s_f that sets the RHS of equation (28) equal to zero the RHS of equation (29) is negative. Under our assumptions, the Council's objective function has a single extremum at which it is locally strictly concave. This is verified in the appendix.

A harmonized standard will unambiguously increase domestic welfare and total welfare. However, maximizing total welfare may include decreasing foreign welfare. This is stated in Proposition 1.

Proposition 1. Moving from no regulation (the unconstrained equilibrium) to Full Harmonization will strictly increase both qualities, total welfare, and domestic welfare. Foreign welfare may be decreased. Foreign (unsubsidized) profit will be negative.

Proof. Increases of both qualities and total welfare follow directly from equation (28) in connection with inequality (18a) and the accompanying discussion. Marginal domestic welfare (with respect to a uniform standard), given by line two of equation (28), is strictly positive for all pairs $\{s_d, s_f\}$ on firm d's quality best response that lie between the unregulated equilibrium and the equilibrium under Full Harmonization. Hence, domestic welfare increases. Marginal foreign welfare, given by line one of equation (28) is first positive and then negative along firm d's quality best response between the unregulated equilibrium and the Full-Harmonization solution. See the appendix for examples where foreign welfare decreases. The proof of the profit result is also given in the appendix. QED

In deriving the results above, we have postulated that the foreign firm stays in the market with a positive quality. Clearly, there are cases where this would not be optimal. Consider the case where the foreign cost parameter b_f approaches infinity. Foreign quality s_f under no regulation will approach zero. Under Full Harmonization, a standard binding for the foreign firm will also approach zero leaving the domestic firm to provide monopoly quality. Welfare could then be improved by setting a standard above the domestic firm's monopoly quality. This case is likely to arise whenever foreign costs are very large.

5.2. Mutual Recognition

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. In this case, 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 to derive the regional standard best response. The foreign government's maximization problem has a unique solution since the objective function is strictly concave in s_f. Differentiating the foreign government's objective function with respect to s_f yields equation (30a).

(30a) $$\frac{d}{ds_f} W_F = (MR_f - MC_f) + \frac{\partial CS_F}{\partial s_f}$$

The domestic government's objective function has a single extremum at which it is locally strictly concave in s_d. Hence, the domestic government's maximization problem has a unique solution. Differentiating the domestic government's objective function with respect to s_d yields equation (30b).

(30b) $$\frac{d}{ds_d} W_D = (MR_d - MC_d) + \frac{\partial CS_D}{\partial s_d}$$

Concavity properties of the governments' objective functions are verified in the appendix.

Proposition 2. Moving from no regulation to Mutual Recognition will strictly increase both qualities and both regions' welfares.

Proof. In the absence of regulation, both firms equate marginal revenue with marginal cost. This implies that the RHS of equations (30a) and (30b) are both greater than zero. Hence, equations (30a) and (30b) in connection with Lemma 1 establish that the domestic (foreign) standard best response lies everywhere above (to the right of) the domestic (foreign) firm's unrestricted quality best response. It also follows that the move to Mutual Recognition can be replicated by: (A) a move to the right along firm d's best quality response until the RHS of equation (30a) is equal to zero; followed by (B) an upward move along the domestic regions standard best response until the RHS of equation (30b) is equal to zero. Along (A), the RHS of equation (30a) decreases from $\partial CS_F/\partial s_f$ to zero, whereas the RHS of equation (30b) equals $\partial CS_D/\partial s_d > 0$. Hence, by equation (28), both regions' welfares increase. Along (B), the RHS of equation (30b) decreases from $\partial CS_D/\partial s_d$ to zero, whereas the RHS of equation (30a) equals zero. Here, any increase in domestic quality will increase foreign welfare and marginal welfare. The responding increase in foreign quality will increase domestic welfare in spite of decreasing domestic revenue. QED

Given price competition in the last stage of the game, a benchmark quality solution can be derived by maximizing the sum of regional welfares, *i.e.* total welfare, with respect to both qualities. Maximizing total welfare with respect to a single quality results in a benchmark quality best response. Comparing these benchmark best responses to the standard best responses under different regulatory regimes further illustrates quality distortions inherent in equilibria under these regimes. Lemma 1 already implied that this benchmark is to the Northeast of the unregulated equilibrium. In addition, Lemma 2 shows that this benchmark is to the Northwest of the equilibrium under Full Harmonization and to the Northeast of the equilibrium under Mutual Recognition.

Lemma 2. Define a benchmark as the result of maximizing the sum of regional welfares, W, with respect to both qualities subject to subsequent price competition.

a) At Full Harmonization, $\partial W_D/\partial s_d = \partial CS_D/\partial s_d > 0$. Any horizontal move to the left (any reduction in s_f without reducing s_d) will always leave $\partial W_D/\partial s_d > 0$.

b) Compared to the benchmark, Full Harmonization will result in domestic quality being too low and foreign quality being too high.

c) Compared to the benchmark, Mutual Recognition will result in both domestic and foreign quality being too low.

Proof. Let world welfare be denoted by W and firm d's marginal quality best response be denoted by ds_d/dsf. See the appendix for the proof of part a).

b) Under Full Harmonization, $\partial W/\partial s_d = \partial CS_D/\partial s_d + \partial R_f/\partial s_d + \partial CS_F/\partial s_d > 0$ and $\partial W/\partial s_f = -ds_d/ds_f(\partial CS_D/\partial s_d + \partial R_f/\partial s_d + \partial CS_F/\partial s_d) < 0$ hold since the RHS of equation (28) is equal to zero. Hold s_d constant at the Full-Harmonization level and decrease s_f until $\partial W/\partial s_f = 0$. At this point, $\partial W/\partial s_d = \partial WD/\partial s_d + \partial R_f/\partial s_d + \partial CS_F/\partial s_d > 0$ by part a). It follows that s_d is too low. Hold s_f constant at the Full-Harmonization level. Then for any s_d, $\partial W/\partial s_f < 0$ holds (see the appendix). It follows that s_f is too high.

c) Under Mutual Recognition, $\partial W/\partial s_d = \partial R_f/\partial s_d + \partial CS_F/\partial s_d > 0$ and $\partial W/\partial s_f = \partial CS_D/\partial s_f + \partial R_d/\partial s_f > 0$ hold since the RHS of equations (30a) and (30b) are equal to zero. QED

Figure 6 depicts comparisons of the Mutual-Recognition quality equilibrium with the Full-Harmonization equilibrium, the benchmark solution, and the unregulated equilibrium, respectively. Note that parts b) and c) of Lemma 2 establish that s_f at the Full Harmonization equilibrium is higher than s_f at the Mutual Recognition equilibrium. Based on that result, part a) implies that s_d at the Mutual Recognition equilibrium must be higher than s_d at the Full Harmonization equilibrium. A move from Full Harmonization to Mutual Recognition involves a decrease in s_f and an increase in s_d. The latter move increases both regions' welfare, but the former increases only foreign welfare while decreasing domestic welfare. This suggests that the foreign region will prefer Mutual Recognition to Full Harmonization, but the domestic region may not. In fact, the domestic region's preference depends on relative cost. For any finite b_d, as b_f approaches infinity the difference between domestic welfare under Mutual Recognition and under Full Harmonization approaches a positive finite limit. In other words, if the domestic firm's cost advantage is large, *i.e.* b_d is small relative to b_f, Mutual Recognition will lead to higher domestic welfare. Let $MR(b_d, b_f)$ and $FH(b_d, b_f)$ be the quality equilibria as functions of cost parameters under Mutual Recognition and Full Harmonization, respectively. Define $g(b_f) = \{b_d \mid WD|MR(b_d, b_f) = WD|FH(b_d, b_f)\}$. The domestic region will prefer Mutual Recognition if bd < $g(b_f)$. This is illustrated in the appendix. Proposition 3 below summarizes the results of comparing Mutual Recognition and Full Harmonization.

Proposition 3. Moving from Full Harmonization to Mutual Recognition will strictly increase domestic quality, decrease foreign quality, and increase foreign welfare. Domestic welfare will be increased if firm d's cost advantage is large, *i.e.* if $b_d < g(b_f)$.

Proof. The results with respect to qualities follow from Lemma 2. Suppose that a uniform standard was set at the optimal Full Harmonization level. In this case, the RHS of equation (28) is equal to zero and the domestic firm chooses its quality best response by equating its marginal revenue and marginal cost. This implies that the RHS of equation (30a) is less than zero, whereas the RHS of equation (30b) is greater than zero. It follows that a gradual reduction of s_f down to the point where the RHS of equation (30a) equals zero, *i.e.* a horizontal move to the left, will increase foreign welfare and decrease domestic welfare [by equations (14a) and (23b)]. At this point, the foreign region is on its standard best response, but the domestic region is below its standard best response. The RHS of equation (30b) will still be equal to $\partial CS_D/\partial s_d > 0$. Consequently, domestic welfare can be increased by raising domestic quality which, in turn, will further increase foreign welfare. Foreign welfare is unambiguously increased, whereas domestic welfare is decreased by the reduction in foreign quality and increased by the increase in domestic quality. The lower the foreign cost disadvantage the less will foreign quality be decreased relative to the increase in domestic quality, which results in condition $g(b_f)$. QED

6. National Treatment

6.1. Asymmetric Effects of Regional Standards

Under the standard setting procedure of National Treatment, governments noncooperatively set consumer standards for their respective regions and apply these standards to all imports. In this case, each government maximizes regional welfare with respect to a minimum quality standard, taking the other government's standard as given. With both firms entering in both markets, each regional standard can only be binding, if at all, for the foreign firm. Alternatively, if the domestic standard is set high enough, it will deter entry by the foreign firm, since the domestic firm can always tolerate a higher standard than the foreign firm. In this case, the domestic standard will be set to be binding for the domestic firm. The domestic government prefers to set its regional standard such that entry by the foreign firm is deterred if the domestic cost advantage is large. This result is based on the same tradeoff that underlies the domestic regions preference with regard to Mutual Recognition and Full Harmonization. Moving from National Treatment with accomodated entry to National Treatment with deterred entry involves an increase of domestic quality and a decrease to zero of foreign quality in the domestic market.

Let $NTn(b_d, b_f)$ and$NTe(b_d, b_f)$ be the quality equilibria as functions of cost parameters under National Treatment with deterred entry and National Treatment with accomodated entry, respectively. Define $h(b_f) = \{b_d \mid WD|NTn(b_d, b_f) = WD|NTe(b_d, b_f)\}$. The domestic region will prefer National Treatment with deterred entry if $b_d < h(b_f)$. This leads to Lemma 3.

Lemma 3. Under National Treatment, domestic welfare will be higher when entry of the foreign firm is deterred than when entry is accomodated if firm d's cost advantage is large, *i.e.* if $b_d < h(b_f)$.

Proof. See the appendix.

6.2. National Treatment where the Foreign Firm Enters Both Markets

When both firms enter both markets, each regional standard can only be binding for the product with the lower quality, *i.e.* the foreign product. The domestic government has the greater incentive to set a high standard because of domestic consumers' greater willingness to pay for high quality and the domestic firm's cost advantage. Hence, the domestic standard will be binding, whereas the foreign standard will not be binding. It follows that the quality solution will lie on firm d's quality best response, which allows for utilizing some results from the analysis of Full Harmonization. The domestic government has always the incentive to increase foreign quality, but this will ultimately decrease foreign profits. If the domestic standard was set at the Full-Harmonization level, foreign profits would be negative. The foreign firm will only enter the domestic market if its profit from providing the higher quality in both markets is greater than or equal to its profit from providing the lower quality in the foreign market only. Consequently, the domestic government will set a standard such that foreign profits when entry is accomodated just equal foreign profits when entry is deterred. The foreign government would also like to increase foreign quality along firm d's quality best response, but not as much as the domestic government. Foreign welfare reaches a unique maximum along d's quality best response somewhere between the unregulated quality equilibrium and the Full-Harmonization solution. The foreign government can affect the binding (domestic) quality standard only through measures affecting the foreign firm's profits when entry is deterred, *i.e.* the foreign firm's minimum-profit requirement for entry. This means that the foreign standard will be set such that foreign profits with deterred entry are as close as possible to foreign profits with accomodated entry at the point where foreign welfare is maximized along firm d's quality best response. If foreign profits with deterred entry are lower than foreign profits with accomodated entry at the foreign-welfare-maximizing point of firm d's quality best response, the foreign government sets its standard to maximize foreign profits with deterred entry. Let an added subscript n denote non-entry variables. The foreign government's objective function is then given by equation (31a-1).

(31a-1) $$s_f = s_f \mid PI_{fn} = \mathrm{Min}[\mathrm{Max}[PI_{fn} \mid MR_{dn} = MC_d],\; PI_f \mid W_F = \mathrm{Max}[\, W_F \mid MR_d = MC_d]]$$

Let firm d's marginal quality best response when entry is deterred be denoted by $ds_d/ds_f|n$. The foreign government needs to calculate firm f's maximum profit when entry is deterred. Differentiating the appropriate objective function with respect to s_f yields equation (31a-2).

(31a-2) $$\frac{d}{ds_f} PI_{fn} = (MR_{fn} - MC_f) + \frac{ds_d}{ds_f}|n \frac{\partial R_{fn}}{\partial s_d}$$

The foreign government also needs to find the point on firm d's quality best response when entry is accomodated where foreign welfare is maximized, say MF. Differentiating the appropriate objective function with respect to s_f yields equation (31a-3).

(31a-3) $$\frac{d}{ds_f} W_F = (MR_f - MC_f) + \frac{\partial CS_F}{\partial s_f} + \frac{ds_d}{ds_f}\left\{\frac{\partial R_f}{\partial s_d} + \frac{\partial CS_F}{\partial s_d}\right\}$$

Differentiating the domestic firm's objective function with respect to s_f yields equation (31b).

(31b) $$\frac{d}{ds_f} W_D = \frac{ds_d}{ds_f}\left\{(MR_d - MC_d) + \frac{\partial CS_D}{\partial s_d}\right\} + \frac{\partial R_d}{\partial s_f} + \frac{\partial CS_D}{\partial s_f}$$

Since firm d is on its quality best response, the RHS of equation (31b) will always be positive. Denote the minimum foreign profit required for entry as PI_f^{min}. The following inequality is a binding constraint on the domestic government's objective function, since foreign profits decrease as the domestic standard is increased.

(31c) $$PI_f \geq PI_f^{min}$$

Consequently, the equilibrium under National Treatment with accomodated entry can be calculated by maximizing domestic welfare along firm d's quality best response subject to inequality (31c). It will correspond to a point on firm d's quality best response to the right of the unregulated equilibrium (NR) and to the left of the Full-Harmonization solution (FH).

Lemma 4. Under National Treatment (with accomodated entry), the foreign government will calculate foreign profits at the foreign welfare maximum along the domestic firm's quality best response, say $PI_f|MF$. It will then set a standard such that $PI_f|FH < PI_{fn} \leq PI_f|MF$.

Proof. By equations (31a-3) and (31b), domestic welfare along firm d's quality best response is steadily increasing in foreign quality, whereas foreign welfare along firm d's quality best response is maximized at a point, say MF, to the right of NR and to the left of FH. At MF, foreign profits are nonnegative and decreasing in foreign quality. Furthermore, by Proposition 1, foreign profits are negative at FH. The foreign government sets a standard such that foreign profits with deterred entry are as close as possible to foreign profits with accomodated entry at MF. It can choose a standard such that foreign profits with deterred entry are positive. QED

Proposition 4. a) Moving from no regulation to National Treatment (with accomodated entry) will strictly increase both qualities and domestic welfare. Foreign welfare may be increased. Moving from National Treatment (with accomodated entry) to Full Harmonization will strictly increase both qualities and domestic welfare. Foreign welfare may be decreased.

b) Moving from National Treatment (with accomodated entry) to Mutual Recognition will strictly increase domestic quality and stricly increase foreign welfare. Foreign quality may increase or decrease. A sufficient condition for domestic welfare to increase is that $b_d < g(b_f)$.

Proof. a) Increases of both qualities follow directly from Lemma 4, its proof and the discussion above. The welfare results follow then from Proposition 1 and its proof and examples in the appendix.

b) At National Treatment, the RHS of equation (31a-3) is less than or equal to zero. Hence, the RHS of equation (30a) is less than or equal to zero. Decreasing s_f until the RHS of equation (30a) equals zero while holding s_d constant will increase foreign welfare while decreasing domestic welfare. At this point, the foreign region is on its standard best response, but the domestic region is below its standard best response. The rest of the proof is analogous to the proof of Proposition 3. QED

6.3. National Treatment: Foreign Entry into the Domestic Market is Deterred

If the domestic cost advantage is large enough, then the domestic government prefers to set its regional standard under National Treatment so high that foreign entry is deterred. The increase in regional welfare due to increased domestic quality more than offsets the welfare loss due to the unavailability of the foreign product. The problem faced by regional governments is similar to the case of Mutual Recognition. However, domestic welfare does not include consumer surplus derived from the consumption of the foreign product and foreign welfare does not include profits derived from selling to the domestic market. The foreign government's objective function has a single extremum at which it is locally strictly concave in s_f. Hence, the foreign government's maximization problem has a unique solution. Let an added subscript n denote non-entry variables. Differentiating the foreign government's objective function with respect to s_f yields equation (32a).

$$\frac{d}{ds_f} W_{Fn} = (MR_{fn} - MC_f) + \frac{\partial CS_f}{\partial s_f} \tag{32a}$$

The domestic government's maximization problem has a unique solution since its objective function is strictly concave. Differentiating the domestic firm's objective function with respect to s_d yields equation (32b).

$$\frac{d}{ds_d} w_{Dn} = \left(MR_d - MC_d\right) + \frac{\partial CS_{Dn}}{\partial s_d} \tag{32b}$$

Concavity properties of the governments' objective functions are verified in the appendix.

Proposition 5. Moving from no regulation to National Treatment [with deterred entry, *i.e.* when $b_d < h(b_f)$] will strictly increase domestic welfare and domestic quality. Moving from National Treatment (with deterred entry) to Mutual Recognition will strictly increase both qualities and both regions' welfare.

Proof. The first results follow directly from Lemma 3 and Proposition 4. For domestic welfare to increase, domestic quality must be increased to compensate for the loss of domestic consumer surplus due to the unavailability of the foreign product.

For the comparison with Mutual Recognition, note that $MR_{Ff} < MR_f$ and $\partial CS_{Dd}/\partial s_d < \partial CS_D/\partial s_d$. Comparing equations (30a) and (30b) with equations (32a) and (32b) shows then that the domestic (foreign) standard best response under National Treatment (with deterred entry) must lie everywhere below (to the left of) the standard best response under Mutual Recognition. The quality result follows. A move from National Treatment (with deterred entry) to Mutual Recognition without adjusting qualities and standards would strictly increase both regions' welfare by allowing the foreign product to be sold in the domestic market. Given that qualities are too low, the RHS of both equations (30a) and (30b) are positive. It follows that a gradual increase of s_f up to the point where the RHS of equation (30a) equals zero, *i.e.* a horizontal move to the right, will increase both regions' welfare [domestic welfare increase follows from equations (14a) and (23b)]. At this point, the foreign region is on its standard best response, but the domestic region is below its standard best response. The rest of the proof is analogous to the proof of Proposition 3.

QED

7. Comparing Regulatory Regimes

7.1. Cost Advantage and Regulatory Preferences

The function $g(b_f)$ introduced in Proposition 3 determines whether the domestic government will prefer Mutual Recognition over Full Harmonization. The function $h(b_f)$ introduced in Lemma 3 determines whether the domestic government will prefer to deter entry under National Treatment. Taken together, these two functions can be used to distinguish four cases. If the domestic cost advantage is "large", the domestic government deters entry under National Treatment and prefers Mutual Recognition over all alternative regulatory regimes. If the domestic cost advantage is "small", the domestic government accomodates entry under National Treatment and prefers Full Harmonization over all alternative regulatory regimes. If domestic cost advantage is "intermediate", the remaining two cases result.

The effects of alternative regulatory regimes relative to the case without regulation are summarized in Table 1. A decrease (an increase) of a particular variable is denoted by "-" ("+"), whereas the question mark indicates that the direction of the effect could not be determined. It is noteworthy that Mutual Recognition unambiguously increases welfare and consumer surplus in both regions as well as both qualities. Furthermore, domestic welfare will increase for all regulatory regimes including National Treatment, since the domestic government can choose between accomodating and deterring entry. Domestic quality and foreign consumer surplus increase for all regulatory alternatives.

Table 1. Effects of Standards Under Different Regulatory Regimes

	FH	NTc*	NTn*	MR
W	+	+	?	+
W_D	+	+	?	+
W_F	?	?	?	+
CS_D	+	+	?	+
CS_F	+	+	+	+
PI_d	-	-	?	-
PI_f	-	-	-	-
s_d	+	+	+	+

s_f	+	+	?	+

* NT: e = accomodated entry, n = deterred entry

Table 2. Regulatory Preferences Under Different Cost Situations

b_d	Region	FH	NT*	MR
< g(b_f) & < h(b_f)	W_D	≤2	≤2	1
* NT w/o entry	W_F	≤2	≤2	1
< g(b_f) & > h(b_f)	W_D	2	3	1
* NT w/ entry	W_F	3	2	1
> g(b_f) & < h(b_f)	W_D	1	3	2
* NT w/o entry	W_F	≤2	≤2	1
> g(b_f) & > h(b_f)	W_D	1	≤2	≤2
* NT w/ entry	W_F	3	2	1

The domestic and foreign welfare rankings of alternative regimes under different cost situations are shown in Table 2. The numbers denote the rankings, where "1" is the choice leading to the highest welfare, etc. A "≤2" indicates that the precise rank ("2" or "3") could not be determined. Note that the foreign government prefers Mutual Recognition over all alternative regulatory regimes regardless of relative cost. Under National Treatment, the foreign government will never deter entry by the domestic firm and has no direct influence on the domestic government's decision concerning entry deterrence of the foreign firm. Hence, the domestic government's preference will determine, how the number of equilibria in the first-stage game changes when relative cost changes.

7.3. The Council's Decision

In Figure 5, the first stage of the game where governments (or their representatives) choose one regulatory regime in the Council was illustrated. This regime is either chosen by unanimous vote or a default rule, namely applying Mutual recognition, takes effect. Table 3 lists the Nash equilibria in the first-stage game for each of the four cost cases. In the fourth case, only a conditional statement can be made, since the ranking of domestic welfare under National Treatment with accomodated entry and Mutual Recognition could not be determined. Since the foreign government always prefers the default rule Mutual Recognition, this is the only possible outcome of this game. Note that even with a different default rule, Mutual Recognition (cell 9) would remain a Nash equilibrium as long as $b_d \leq g(b_f)$.

Table 3. Equilibria in the First-Stage Game Under Different Cost Situations

b_d	Condition	Equilibria
$< g(b_f)$ & $< h(b_f)$		{2, 3, 4, 6, 7, 8, 9}
$< g(b_f)$ & $> h(b_f)$		{2, 3, 4, 6, 7, 8, 9}
$> g(b_f)$ & $< h(b_f)$		{3, 4, 6, 7, 9}
$> g(b_f)$ & $> h(b_f)$	$W_D\|NT^* > W_D\|MR$	{3, 4, 6, 7, 9}
* NT w/ entry	$W_D\|NT^* < W_D\|MR$	{3, 6, 9}

7.4. An Example Where Entry Occurs Under National Treatment

This example shows a case where both regions prefer Mutual Recognition over all their available alternatives and the domestic region would not deter entry under National Treatment. The numerical results are summarized in Table A.1 in the appendix. Figure 7 shows firms' quality best responses and governments' standard best responses against the background of isowelfare curves for both regions together. The domestic firm has a cost advantage, *i.e.* $b_d = 0.4 < 0.6 = b_f$. Since $h(b_f) < b_d < g(b_f)$, entry occurs under National Treatment, but both regions prefer Mutual Recognition over all other alternatives. Comparisons with domestic and foreign isowelfare curves, respectively, are shown in Figures A.1 and A.2 in the appendix. (A case where the domestic region would prefer Full Harmonization over Mutual Recognition would be given, *e.g.*, with $b_d = 0.5 < 0.6 = b_f$.)

Under National Treatment, the domestic government accomodates entry. The foreign government sets a non-binding standard and the domestic government sets a standard above the foreign quality level in the unregulated equilibrium. Both qualities, consumer surplus, the number of customers served, and domestic welfare are increased, while profits will decrease. Foreign welfare is increased.

Under Full Harmonization, a global minimum quality standard is set substantially above the unregulated foreign quality level (and still above the foreign quality level under National Treatment). The domestic firm's quality choice is above the unregulated case and the case of National Treatment. Profits of both firms are decreased below the levels at National Treatment (the foreign firm's unsubsidized profits are negative). National welfare of the domestic region is increased beyond the level at National Treatment, national welfare of the foreign region is lower than in the unregulated case, and total welfare is higher than under National Treatment. Under Mutual Recognition, the domestic government sets a binding minimum quality standard above the unregulated domestic quality level and above the chosen domestic quality levels under National Treatment and under Full Harmonization. The foreign government sets a binding standard above the unregulated foreign quality level (but below the optimal standard under National Treatment and under Full Harmonization). Profits of both firms are decreased (but less than under National Treatment and Full Harmonization). The number of customers served in both regions increases (but less than under National Treatment and under Full Harmonization). Consumer surplus in both regions increases more than under National Treatment but less than under Full Harmonization.

7.5. Effects of Changing Assumptions about Relative Costs and Market Sizes

Assumptions about market sizes are embedded in the specification of demands, *i.e.* $t \sim U[0, u_D]$ in the domestic region and $t \sim U[0, u_F]$ in the foreign region, where $u_D = 2u_F = 2$. A specific assumption about costs is that $b_d < b_f$. In addition, it is assumed that relative costs are such that only one Nash equilibrium results where the domestic firm produces high quality.

The existence of the unregulated equilibrium where the low-cost producer produces high quality is independent of relative cost. For identical costs and when the cost difference is not to large, *i.e.* when b_f/b_d is close to 1, there will always be two equilibria. The second equilibrium, where the high-cost producer produces high quality will vanish if b_f/b_d gets much larger or much smaller than one or if one firm is unable to provide any quality higher than its competitor's switchpoint quality (faces infinite cost of providing that quality). The location of quality best responses depends on the firms' own costs and on combined market size in both regions. Relative market size does not matter as long as combined market size is constant.[22]. The relative location of quality best responses is even independent of combined market size and depends only on relative costs.

It follows that the welfare results of Lemma 1 are independent of b_d, b_f, u_D, and u_F. However, with two pure-strategy equilibria, standards could be used to prohibit one of them. This would alter the game between governments. Hence the maintained assumption of a unique market equilibrium without regulation is nontrivial.

The effects of changing any of the parameters b_d, b_f, u_D, or u_F on results about alternative minimum quality standard arrangements[23] can be illustrated using Figures 7, A.1 and A.2. In Figure 7, the relative locations of the equilibria without regulation (NR), under National Treatment with accomodated entry (NT), under Full Harmonization (FH), and under Mutual Recognition (MR), and the benchmark solution (FB) are not significantly altered by changes in either of the four parameters. More specifically, the domestic standard best response under Mutual Recognition d(MR) will always lie above the domestic firm's quality best response d. Similarly, f(MR) will always lie to the right of f. The benchmark quality choices d(BM) and f(BM) lie always above d(MR) and to the right of f(MR), respectively. Furthermore, NT will always lie on d to the right of f(MR) and FH will always lie on d to the right of NT. The comparison of National Treatment with deterred entry and Mutual Recognition cannot be shown in Figure 7, but an analogous generalization holds. The domestic (foreign) standard best response under Mutual Recognition will always lie above (to the right of) the domestic (foreign) standard best response under National Treatment with deterred entry.

The results establishing when the domestic region prefers MR over FH, MR over NT with accomodated entry, and NT with deterred entry over NT with accomodated entry depend on a relative cost condition in addition to the properties listed above. They are based an constant relative market size. With either a decrease in relative cost or an increase in relative market size, the domestic region is more likely to prefer MR over FH, MR over NT with accomodated entry, and NT with deterred entry over NT with accomodated entry. Other results hold generally, since they are independent of relative cost and relative market size. These are, in particular, the result establishing that Mutual Recognition improves welfare of both regions when compared to the unregulated case, and the result that the foreign region prefers Mutual Recognition over all available alternatives.

8. Summary and Conclusions

This paper has shown that concerns about adverse consequences of minimum quality standards might not be entirely valid. Whether a particular region will gain or lose from the introduction of a standard setting procedure depends on the procedure chosen. Within the framework of this model, welfare of the "foreign" region, measured as the sum of profits and consumer surplus, will always be largest under Mutual Recognition. This leads to Mutual Recognition being the sole equilibrium outcome since it is the default procedure. In particular, this could indicate that the economically weaker members in the EC could be better off resisting the harmonization of product standards in the Council of Ministers of the EC. The "domestic" region's welfare will be largest under Mutual Recognition if its industry has a large cost advantage. This could indicate that Mutual Recognition of standards is more likely to prevail for industries with large cost differences.

In the absence of a quality standard, there exist at most two pure-strategy unregulated equilibria. In either equilibrium, one firm sells high quality whereas the other sells low quality. The resulting market

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[22]By equations (10) and (11a) through (11d), profit and revenue are functions of combined market size only. Note that combined market size is measured as $u_D^2 + u_F^2$.

[23]Conditional on the uniqueness of the equilibrium in the industry subgame.

equilibrium will generally not be optimal from the point of view of either regional government, since governments will prefer higher quality levels than those chosen in equilibrium. However, the nature of governments' choices will depend on the standard setting procedure agreed upon. Under various standard setting procedures, there will exist some combination of minimum quality standards that will increase welfare in both regions. This holds in particular for the cases of Full Harmonization, National Treatment, and Mutual Recognition. Under any of these alternatives, standards can always be found that increase welfare in both regions. The analysis is therefore extended to include the choice between these standard setting procedures by governments and the subsequent setting of standards to allow a comparison of the effects of alternative standard setting procedures.

I employ a number of restricting assumptions designed to capture stylized facts about the EC as well as to simplify further analysis. In the two-region model, one (the "domestic") region is assumed have a larger demand (market size) than the other ("foreign") region. The producer in this region is assumed to have a cost advantage guaranteeing a single pure-strategy industry-equilibrium in the last two stages of the game. Under Full Harmonization, a standard can be set such that entry by the foreign producer is deterred. This case is excluded by assumption. I obtain results under Full Harmonization assuming that the council calculates its standard best response conditional on both firms remaining in the market. If a firm were to earn negative profits at the so calculated Full-Harmonization solution, its government will pay a lump-sum subsidy equal to minus profits if that firm stays in the market. While the true Full-Harmonization solution would incorporate a nonnegativity constraint for profits, the obtained solution provides bounds on domestic and foreign welfare and thus permits welfare comparisons. Even with these assumptions, the results obtained do not permit a full characterization of all possible outcomes. Nevertheless, Mutual Recognition emerges as one regulatory alternative that always improves welfare in both regions when compared to the case without regulation. This is due to three features of Mutual Recognition. It allows each regional government to maximize regional welfare with respect to a standard for its own industry. Since each regional standard increases the quality of exports into the other region, each region gains from the other region's standard. Since each regional standard does not apply to the other region's industry, it cannot be used to deter entry.

The results obtained are conditional on the uniqueness of the equilibrium in the industry game. They are mainly driven by the nature of duopolistic competition and governments' scope for using standards as a strategic policy instrument. In addition, asymmetries with respect to costs of providing quality and with respect to market sizes influence some of the results. Some questions for further research are directly related to the assumptions employed. If there is more than one industry equilibrium, governments may be able to affect firms' choices with regard to being the high or low-quality provider. In this case, it is possible that there will also be more than one standards equilibrium under National Treatment or under Mutual Recognition. If firms have to bear a quality-independent sunk cost in addition to quality-dependent costs, then it is possible that an equilibrium where only one firms enters the market coexists with a duopoly-equilibrium. Again, this alters not only the firms' game but also the game played by governments. A comprehensive analysis of the model presented here will in any case require some additional research.

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Appendix

Quality Best Responses

Let t = h, o. The slopes of both branches of the quality best response in inequalities (18a) and (18b), *i.e.*, $ds_i/ds_j|_t = -(\partial(\partial PI_t/\partial s_i)/\partial s_j)/(\partial(\partial PI_t/\partial s_i)/\partial s_i)$ are:

(A.1a)
$$\frac{ds_i}{ds_j}\Big|_h = (20 s_i s_j (5 s_i + s_j)) / (256 b_i s_i^4 - 256 b_i s_i^3 s_j + 100 s_i s_j^2 + 96 b_i s_i^2 s_j^2 + 20 s_j^3 - 16 b_i s_i s_j^3 + b_i s_j^4) > 0$$

(A.1b)
$$\frac{ds_i}{ds_j}\Big|_o = (5 s_i s_j (7 s_i + 8 s_j)) \; / \; (b_i s_i^4 - 16 b_i s_i^3 s_j + 35 s_i s_j^2 + 96 b_i s_i^2 s_j^2 + 40 s_j^3 - 256 b_i s_i s_j^3 + 256 b_i s_j^4) > 0$$

In equations (A.1a) and (A.1b), the numerators are non-negative. The denominators are always greater than zero given that s_i is greater (smaller) than s_j. Hence, the reaction functions are upward sloping. In addition, the slopes of both reaction functions are less than one. The effects of a change in cost of quality, represented by a change in b_i, on the locations of both branches of the quality best response in inequalities (19a) and (19b), *i.e.*, $ds_i/db_i|_t = -(\partial(\partial PI_t/\partial s_i)/\partial b_i)/(\partial(\partial PI_t/\partial s_i)/\partial s_i)$ are given by equations (A.2a) and (A.2b):

(A.2a)
$$\frac{ds_i}{db_i}\Big|_h = (s_i(-4 s_i + s_j)^4) / (-256 b_i s_i^4 + 256 b_i s_i^3 s_j - 100 s_i s_j^2 - 96 b_i s_i^2 s_j^2 - 20 s_j^3 + 16 b_i s_i s_j^3 - b_i s_j^4) < 0$$

(A.2b)
$$\frac{ds_i}{db_i}\Big|_o = (s_i(-s_i + 4 s_j)^4) / (-(b_i s_i^4) + 16 b_i s_i^3 s_j - 35 s_i s_j^2 - 96 b_i s_i^2 s_j^2 - 40 s_j^3 + 256 b_i s_i s_j^3 - 256 b_i s_j^4) < 0$$

The numerators are clearly non-negative. The denominators are always smaller than zero given that s_i is greater (smaller) than s_j!

Concavity of the Foreign Firm's Profits under Full Harmonization

Equation (A.3) is equation (26) satisfying the domestic firm's unrestricted profit- maximization condition, *i.e.* the second-order partial derivative of the foreign firm's profits along the domestic firm's quality best response. Foreign firm's profits are concave in foreign quality.

(A.3)
$$\frac{\partial^2}{\partial s_f^2} PI_f = 2/2560 s_d^7 + 16384\, b_f s_d^8 - 2240\, s_d^6 s_f - 45056\, b_f s_d^7 s_f + 1840\, s_d^5 s_f^2 + 87040\, b_f s_d^6 s_f^2 + 1220\, s_d^4 s_f^3 - 93952\, b_f s_d^5 s_f^3 - 1095 s_d^3 s_f^4 + 72128 b_f s_d^4 s_f^4 + 1625 s_d^2 s_f^5 - 30160 b_f s_d^3 s_f^5 - 120 s_d s_f^6 + 5964 b_f s_d^2 s_f^6 - 10 s_f^7 - 441 b_f s_d s_f^7)) / (s_d(-4 s_d + s_f)^3 (16 s_d^2 - 16 s_d s_f + 21 s_f^2) < 0$$

Effects on Consumer Surplus under Full Harmonization

A uniform minimum quality standard will make all consumers in both regions weakly better off and some consumers strictly better off. Let i= D, F, u_D=2, and u_F=1. In region i, consumers with incomes in the segment $[u_i, t_{ih}]$ will purchase high quality, consumers with incomes in the segment $[t_{ih}, t_{il}]$ will purchase low quality, and all other consumers will not purchase. Let the slope of firm d's quality best response be denoted by ds_d/ds_f. Equations (A.4b) and (A.4d) show that market participation in both regions will increase. Equations (A.4a) and (A.4c) show that the segment of consumers buying high quality will increase in both markets. Equations (A.4b), (A.4d), (A.4e), and (A.4f) show that utility per unit bought will increase in both regions for both qualities.

(A.4a)
$$\frac{d}{ds_f} t_{Dl} = \frac{-4 s_d}{(-4 s_d + s_f)^2} + \frac{4 s_f}{(-4 s_d + s_f)^2} \frac{ds_d}{ds_f} < 0$$

(A.4b)
$$\frac{d}{ds_f} t_{Df} = \frac{d}{ds_f} \frac{p_{Df}}{s_f} = \frac{-6 s_d}{(-4 s_d + s_f)} + \frac{6 s_f}{(-4 s_d + s_f)^2} \frac{ds_d}{ds_f} < 0$$

(A.4c) $$\frac{d}{ds_f}t_{Fd} = \frac{-2s_d}{(-4s_d+s_f)^2} + \frac{2s_f}{(-4s_d+s_f)^2}\frac{ds_d}{ds_f} < 0$$

(A.4d) $$\frac{d}{ds_f}t_{Ff} = \frac{d}{ds_f}\frac{p_{Ff}}{s_f} = \frac{-3s_d}{(-4s_d+s_f)^2} + \frac{3s_f}{(-4s_d+s_f)^2}\frac{ds_d}{ds_f} < 0$$

(A.4e) $$\frac{d}{ds_f}\frac{p_{Dd}}{s_d} = \frac{-12s_d}{(-4s_d+s_f)^2} + \frac{12s_f}{(-4s_d+s_f)^2}\frac{ds_d}{ds_f} < 0$$

(A.4f) $$\frac{d}{ds_f}\frac{p_{Fd}}{s_d} = \frac{-6s_d}{(-4s_d+s_f)^2} + \frac{6s_f}{(-4s_d+s_f)^2}\frac{ds_d}{ds_f} < 0$$

Concavity of the Council's Objective Function under Full Harmonization

Equation (A.5) is equation (29) satisfying equation (28) and the domestic firm's unrestricted profit-maximization condition. *I.e.*, equation (A.5) is the second-order condition of maximizing world welfare along the domestic quality best response. The Council's objective function has a single extremum at which it is locally strictly concave in s_f. It can be shown that the Council's objective function becomes concave for all s_f higher than its unrestricted equilibrium value if b_f is "sufficiently high."

(A.5) $$\frac{\partial^2}{\partial s_f^2}w_F = (5(-1280s_d^7 + 3200s_d^6s_f - 5568s_d^5s_f^2 + 4680s_d^4s_f^3 - 4431s_d^3s_f^4 + 2088s_d^2s_f^5 - 4s_ds_f^6 - 8s_f^7)) / (2s_d(4s_d-s_f)^2s_f(16s_d^2 - 16s_ds_f + 21s_f^2)^2) < 0$$

Foreign Profit is Negative at Full Harmonization

Foreign zero-profit cost, $C_f|_0$, is just equal to revenue. According to equation (28), $MC_f > MR_f + \partial CS_F/\partial s_f + \partial R_d/\partial s_f + \partial CS_D/\partial s_f$ at Full Harmonization. Hence, $C_f > (MR_f + \partial CS_F/\partial s_f + \partial R_d/\partial s_f + \partial CS_D/\partial s_f)s_f/2$. It follows that $C_f > C_f|_0$.

(A.6a) $$c_f|_0 = \frac{5s_d(s_d-s_f)s_f}{(4s_d-s_f)^3}$$

(A.6b) $$c_f > \frac{5s_d^2s_f(-20s_d+17s_f)}{4(-4s_d+s_f)^3}$$

(A.6c) $$c_f - c_f|_0 = \frac{5s_ds_f(-4s_d^2 - 3s_ds_f + 4s_f^2)}{4(-4s_d+s_f)^3} > 0$$

Concavity of Governments' Objective Functions under Mutual Recognition

The foreign government's objective function is globally concave. The domestic government's objective function has a single extremum at which it is locally strictly concave in s_d. This can be verified by differentiating equations (30a) and (30b) with respect to qualities:

(A.7a) $$\frac{\partial^2}{\partial s_f^2}w_F = -\left(\frac{s_d^2(28s_d+65s_f)}{(-4s_d+s_f)^4}\right) - 2b_f < 0$$

(A.7b) $$\frac{\partial^2}{\partial s_d^2}W_D = \frac{4(2s_d-5s_f)s_f^2}{(-4s_d+s_f)^4} - 2b_d$$

Let s_d be the welfare-maximizing choice of the domestic government, *i.e.* the RHS of equation (30b) equals zero. Then, equation (A.7b) becomes:

(A.7c) $$\frac{\partial^2}{\partial s_d^2}W_D = \frac{4s_d(-112s_d^2 + 112s_ds_f - 39s_f^2)}{(4s_d-s_f)^4} < 0$$

Calculations for Proof of Lemma 2

a) At Full Harmonization, $\partial W_D/\partial s_d = \partial CS_D/\partial s_d > 0$. Let $s_d|_{MR}$ and $s_d|_{FH}$ be s_d at the Mutual Recognition solution and the Full Harmonization solution, respectively. I establish that a horizontal move to the left (reduction in s_f without reducing s_d) will always leave $\partial W_D/\partial s_d > 0$, *i.e.* $s_d|_{MR} > s_d|_{FH}$ must hold. Equation (A.8a) shows $\partial W_D/\partial s_d$ at $\{s_d \to s_d|_{FH}, s_f \to x0\}$ calculated as its value at Full Harmonization minus the loss from reducing s_f to x0. It is positive for all $x0 \leq s_f$ if $s_f \leq 0.77 * s_d$. It can be shown that the condition on s_f is satisfied for any Full Harmonization equilibrium. First, note that any Full Harmonization solution must be to the left of the domestic firm's switchpoint, *i.e.* $s_d|_{FH}$ must be less than s_d at the switchpoint. (If this was not satisfied, the domestic firm would want to be the low-quality producer with a quality lower than the chosen minimum quality standard.) Since s_f/s_d increases along the domestic quality best response as s_f increases, $s_f \leq 0.77 * s_d$ holds at the Full Harmonization solution since it holds at the domestic firm's switchpoint. This can be verified by deriving an upper bound for the switchpoint expressed in terms of its high-quality best response.

(A.8a)

$$\frac{\partial MW_D}{\partial s_f} = (4(20x0^3 s_d^3 + 80x0^2 s_d^4 - 384x0 s_d^5 + 512 s_d^6 -$$
$$15x0^3 s_d^2 s_f - 60x0^2 s_d^3 s_f + 288x0 s_d^4 s_f - 384 s_d^5 s_f +$$
$$10x0^3 s_d s_f^2 - 60x0^2 s_d^2 s_f^2 + 228x0 s_d^3 s_f^2 - 304 s_d^4 s_f^2 -$$
$$5x0^2 s_d s_f^3 + 21x0 s_d^2 s_f^3 - 28 s_d^3 s_f^3))/$$
$$((-x0 + 4s_d)^3 (4s_d - s_f)^3) > 0 \quad \text{for } s_f < 0.77 s_d$$

b) Let firm d's marginal quality best response be denoted by ds_d/ds_f. Denote MC_f and s_f at the Full-Harmonization solution as $MC_f|_{FH}$ and $s_f|_{FH}$, respectively. Define $MC_f|_{BM} = (MR_f + \partial CS_F/\partial s_f + \partial R_d/\partial s_f + \partial CS_D/\partial s_f)$. $MC_f|_{FH} = (MR_f + \partial CS_F/\partial s_f + \partial R_d/\partial s_f + \partial CS_D/\partial s_f) + ds_d/ds_f * (MR_d - MC_d + \partial CS_F/\partial s_d + \partial R_f/\partial s_d + \partial CS_D/\partial s_d)$ where $MR_d = MC_d$ holds. At the benchmark, $MC_f|_{FH} > MC_f|_{BM}$. $MC_f|_{BM}$ is increasing in s_d and approaches a finite limit as s_d approaches infinity. $MC_f|_{FH}$ is always greater than this limit. It follows that $MC_f|_{FH} > (MR_f + \partial CS_F/\partial s_f + \partial R_d/\partial s_f + \partial CS_D/\partial s_f)$ for any $s_d > 0$.

(A.8b)

$$MC_f|_{FH} = \frac{5(80s_d^4 - 8s_d^3 s_f + 105 s_d^2 s_f^2 - 56 s_d s_f^3 - 4 s_f^4)}{2(4s_d - s_f)^2 (16 s_d^2 - 16 s_d s_f + 21 s_f^2)}$$

(A.8c)

$$MC_f|_{BM} = \frac{5 s_d^2 (20 s_d - 17 s_f)}{2(4 s_d - s_f)^3}$$

Inspection of equation (A.8c) shows that the limit of $MC_f|_{BM}$ as s_d approaches infinity is equal to 25/32.

(A.8d)

$$\frac{\partial}{\partial s_d} MC_f|_{BM} = \frac{5 s_d s_f (4 s_d + 17 s_f)}{(-4 s_d + s_f)^4} > 0$$

(A.8e)

$$MC_f|_{FH} - \text{Limit}_{\infty}[MC_f|_{BM}] =$$
$$\frac{(1792 s_d^3 - 720 s_d^2 s_f + 24 s_d s_f^2 - 169 s_f^3)}{32(4s_d - s_f)^2 (16 s_d^2 - 16 s_d s_f + 21 s_f^2)} > 0$$

Derivation of the Cost Condition $g(b_f)$ for Proposition 3

Define $g(b_f) = \{b_d \mid W_D|_{MR}(b_d, b_f) = W_D|_{FH}(b_d, b_f)\}$. The domestic region will prefer Mutual Recognition if $b_d < g(b_f)$. From equations (28) and (30a), we have that for any finite b_d the limits of $s_f|_{MR}$ and $s_f|_{FH}$ as b_f approaches infinity are equal to zero. Hence the limit of ($W_D|_{MR}$ - $W_D|_{FH}$) as b_f approaches infinity is equal to (($W_D|_{MR}$ - $W_D|_{FH}$)$|s_f = 0$) = (($W_D|_{MR}$ - $W_D|_{NR}$)$|s_f = 0$) > 0 (by equation (30b)).

For any $\{b_d, b_f\}$, a decrease in b_f will increase s_f more under FH than under MR (by equations (28) and (30a)). Let $dW_D/ds_f|_{MR}$ and $dW_D/ds_f|_{FH}$ be the effect of a change in s_f at MR and FH, respectively. Note that $\partial R_d/\partial s_f + \partial CS_D/\partial s_f$ is less at MR than at FH, since s_d is larger and s_f is smaller at MR than at FH. It follows that $dW_D/ds_f|_{MR} = \partial R_d/\partial s_f + \partial CS_D/\partial s_f < dW_D/ds_f|_{FH} = \partial R_d/\partial s_f + \partial CS_D/\partial s_f + ds_d/ds_f * \partial CS_D/\partial s_d$. Hence, a decrease in b_f will decrease ($W_D|_{MR}$ - $W_D|_{FH}$).

Derivation of the Cost Condition $h(b_f)$ for Lemma 5

Define $h(b_f) = \{b_d \mid W_D|_{NTn}(b_d, b_f) = W_D|_{NTe}(b_d, b_f)\}$. The domestic region will prefer to deter entry if $b_d < g(b_f)$. From equations (31a-1) through (32a), we have that for any finite b_d the limits of $s_f|_{NTn}$ and $s_f|_{NTe}$ as b_f approaches infinity are equal to zero. Hence the limit of ($W_D|_{NTn}$ - $W_D|_{NTe}$) as b_f approaches infinity is equal to (($W_D|_{NTn}$ - $W_D|_{NTe}$)$|s_f = 0$) = (($W_D|_{MR}$ - $W_D|_{NR}$)$|s_f = 0$) > 0 (by equation (30a)).

For any $\{b_d, b_f\}$, an increase in b_f will decrease s_f under both NTn and NTe. This will increase MR_d in equation (32b) leading to an increase in s_d and $W_D|_{NTn}$. $W_D|_{NTe}$ decreases, since s_d is forced down the domestic quality best response. Consequently, ($W_D|_{NTn}$ - $W_D|_{NTe}$) increases. Similarly, ($W_D|_{NTn}$ - $W_D|_{NTe}$) decreases with a decrease in b_f.

Concavity of Governments' Objective Functions under National Treatment (Entry Deterred)

The domestic government's objective function is globally concave. The foreign government's objective function has a single extremum at which it is locally strictly concave in s_f. This can be verified by differentiating equations (32b) and (32a) with respect to qualities:

(A.9a)
$$\frac{\partial^2}{\partial s_f^2} W_{Dn} = (2(-256 b_d s_d^4 + 256 b_d s_d^3 s_f - 20 s_d s_f^2 - 96 b_d s_d^2 s_f^2 - 4 s_f^3 + 16 b_d s_d s_f^3 - b_d s_f^4)) \,/\, (-4 s_d + s_f)^4 < 0$$

Let s_f be the welfare-maximizing choice of the foreign government, *i.e.* the RHS of equation (32a) equals zero. Then, equation (A9b) becomes:

(A.9b)
$$\frac{\partial^2}{\partial s_d^2} W_{Fn} = \frac{9 s_d^2 (-4 s_d + 3 s_f)}{2(4 s_d - s_f)^3 s_f} < 0$$

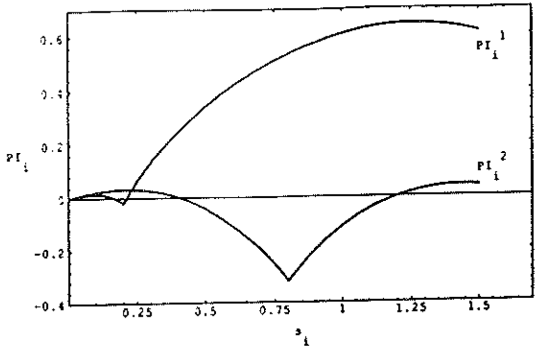
A Numerical Example

The cost parameters are $b_d = 0.4$ and $b_f = 0.6$. For this case, the domestic region prefers to accomodate entry under National Treatment. Table A.1 and Figures 7, A.1 and A.2 present numerical results under no regulation (NR), the benchmark case (BM), National Treatment (NT, with accomodated entry), Full Harmonization (FH) and Mutual Recognition (MR).

Table A.1. Outcomes Under Different Regulatory Regimes - An Example

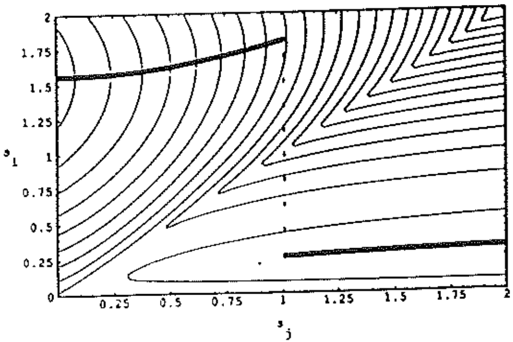
	NR	BM	NT	FH	MR
s_d	1.573	2.351	1.607	1.698	2.187
s_f	0.219	0.620	0.432	0.744	0.419
s_d-s_f	1.354	1.731	1.175	0.954	1.768
p_{Dd}	1.403	1.853	1.259	1.072	1.857
p_{Df}	0.098	0.244	0.169	0.235	0.178
p_{Fd}	0.701	0.927	0.630	0.536	0.928
p_{Ff}	0.049	0.122	0.085	0.117	0.089
t_{Dd}	0.964	0.929	0.928	0.877	0.950
t_{Df}	0.446	0.394	0.392	0.316	0.425
t_{Fd}	0.482	0.465	0.464	0.439	0.475
t_{Ff}	0.223	0.197	0.196	0.158	0.212
q_{Dd}	1.036	1.071	1.072	1.123	1.050
q_{Df}	0.518	0.535	0.536	0.561	0.525
q_{Fd}	0.518	0.535	0.536	0.561	0.525
q_{Ff}	0.259	0.268	0.268	0.281	0.263
PI_d	0.827	0.269	0.655	0.351	0.525
PI_f	0.034	-0.067	0.002	-0.167	0.011
CS_D	0.991	1.791	1.233	1.656	1.495
CS_F	0.248	0.448	0.308	0.414	0.374
W_D	1.818	2.060	1.888	2.008	2.020
W_F	0.282	0.381	0.310	0.247	0.385
W	2.101	2.441	2.198	2.255	2.405

($b_d = 0.4$, $b_f = 0.6$)



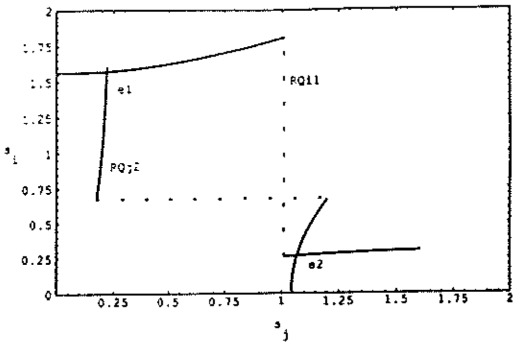
$b_j = 0.5 \qquad s_j^1 = 0.2 \qquad s_j^2 = 0.8$

Figure 1. Profit Functions



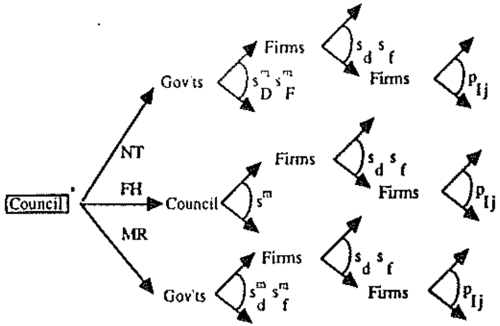
$b_i = 0.4$

Figure 2. Isoprofit Curves and Quality Response



$b_i = 0.4 \qquad b_j = 0.6$

Figure 3. Quality Equilibria - Different Firms



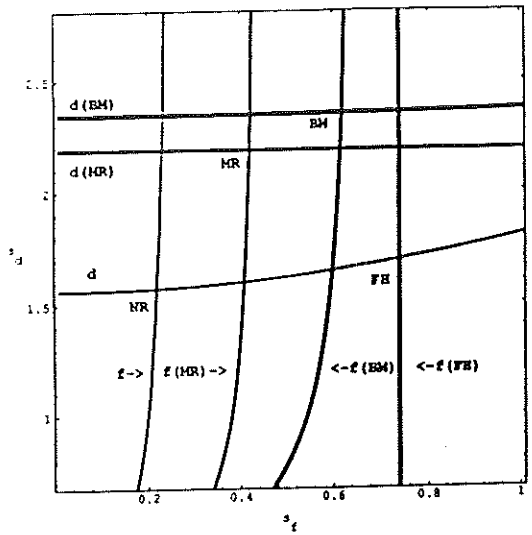
where NT = National Treatment
FH = Full Harmonization
MR = Mutual Recognition
s_I^m = the minimum quality standard for region I where I = D, F.
s_j^m = the minimum quality standard for firm j where j = d, f.
s_j = the quality level chosen by firm j where j = d, f.
p_{Ij} = prices set in each region by each firm. I = D, F and j = d, f.
*) The first stage of the game -the Council's decision- is illustrated on the next page.

Figure 4. The Complete Game (with Quality Standards)

		F		
		NT	FH	MR
D	NT	1 NT	2 MR^d	3 MR^d
	FH	4 MR^d	5 FH	6 MR^d
	MR	7 MR^d	8 MR^d	9 MR

where D = the domestic government (representative);
F = the foreign government (representative);
NT = National Treatment;
FH = Full Harmonization;
MR = Mutual Recognition.
Superscript d denotes outcome by default.

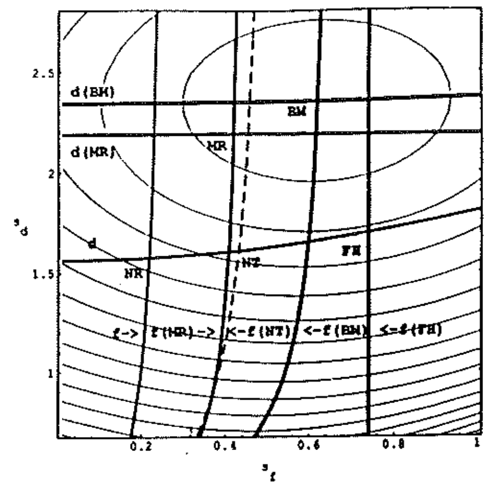
Figure 5. The First-Stage Game: The Council's Decision



where $b_d = 0.4$, $b_f = 0.6$;

d = firm d's quality best response;
f = firm f's quality best response;
d(BM) = welfare-maximizing quality choice for firm d;
f(BM) = welfare-maximizing quality choice for firm f;
f(FH) = minimum quality standard under Full Harmonization;
d(MR) = region D's quality standard under Mutual Recognition;
f(MR) = region F's quality standard under Mutual Recognition;
NR = No-Regulation quality equilibrium;
BM = Benchmark quality equilibrium;
FH = Full-Harmonization quality equilibrium;
MR = Mutual-Recognition quality equilibrium.

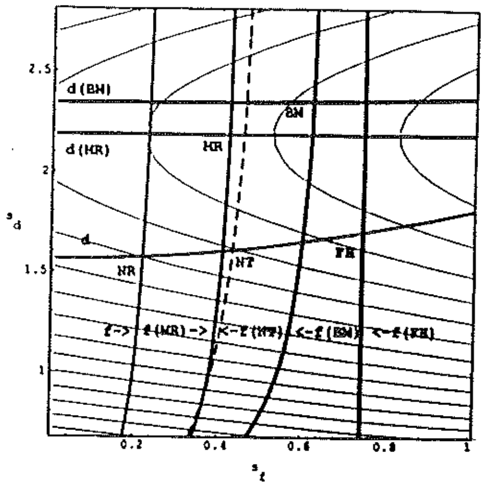
Figure 6. FH vs. MR : Quality Best Responses



where $b_d = 0.4$, $b_f = 0.6$;

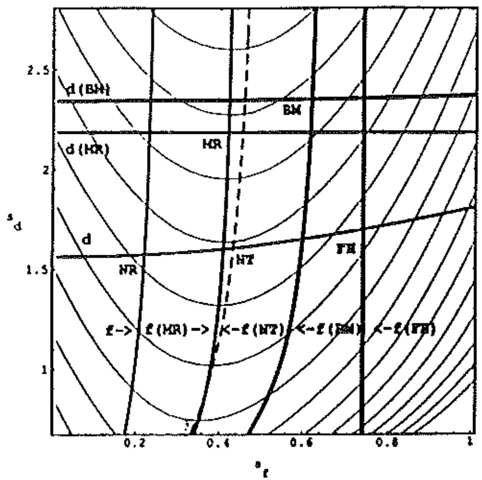
d = firm d's quality best response;
f = firm f's quality best response;
d(BM) = welfare-maximizing quality choice for firm d;
f(BM) = welfare-maximizing quality choice for firm f;
f(FH) = minimum quality standard under Full Harmonization;
d(MR) = region D's quality standard under Mutual Recognition;
f(MR) = region F's quality standard under Mutual Recognition;
f(NT) = firm f's domestic-market-entry condition under National Treatment;
NR = No-Regulation quality equilibrium;
BM = Benchmark quality equilibrium;
FH = Full-Harmonization quality equilibrium;
MR = Mutual-Recognition quality equilibrium;
NT = National Treatment quality equilibrium.

Figure 7. World Welfare and Quality Best Responses



where $b_d = 0.4$, $b_f = 0.6$;
d = firm d's quality best response;
f = firm f's quality best response;
d(BM) = welfare-maximizing quality choice for firm d;
f(BM) = welfare-maximizing quality choice for firm f;
f(FH) = minimum quality standard under Full Harmonization;
d(MR) = region D's quality standard under Mutual Recognition;
f(MR) = region F's quality standard under Mutual Recognition;
f(NT) = firm f's domestic-market-entry condition under National Treatment;
NR = No-Regulation quality equilibrium;
BM = Benchmark quality equilibrium;
FH = Full-Harmonization quality equilibrium;
MR = Mutual-Recognition quality equilibrium;
NT = National Treatment quality equilibrium.

Figure A.1. Domestic Welfare and Quality Best Responses



where $b_d = 0.4$, $b_f = 0.6$;
d = firm d's quality best response;
f = firm f's quality best response;
d(BM) = welfare-maximizing quality choice for firm d;
f(BM) = welfare-maximizing quality choice for firm f;
f(FH) = minimum quality standard under Full Harmonization;
d(MR) = region D's quality standard under Mutual Recognition;
f(MR) = region F's quality standard under Mutual Recognition;
f(NT) = firm f's domestic-market-entry condition under National Treatment;
NR = No-Regulation quality equilibrium;
BM = Benchmark quality equilibrium;
FH = Full-Harmonization quality equilibrium;
MR = Mutual-Recognition quality equilibrium;
NT = National Treatment quality equilibrium.

Figure A.2. Foreign Welfare and Quality Best Responses

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