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Can Taxing Foreign Competition Harm the Domestic Industry?

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by

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Abstract

The answer to the question in the title is yes for the case of ad-valorem taxes, a foreign industry that produces a vertically differentiated good of higher quality, and costs that take the form of quality-dependent fixed costs for both the foreign and domestic firm. The domestic industry loses profits due to the foreign industry's lowering of product quality which intensifies price competition. This result carries through to the case of additional constant marginal costs, if this cost component does not increase too fast with increases in product quality produced. However, it does not hold with quality-dependent marginal costs. In this latter case, the foreign firm will reduce output rather than quality, which tends to reduce foreign competition.

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Can Taxing Foreign Competition Harm the Domestic Industry?

1. Introduction

According to the standard trade theory results, taxing the foreign competition will help the domestic firm, hurt domestic consumers, and (for a small country) reduce domestic welfare. The relevant analysis assumes perfect competition or oligopolistic competition in horizontally differentiated products. However, an important property of international markets is the presence of vertical quality differences ("high" vs. "low" product quality) between substitutable products. Product differentiation of this type is an important dimension in international trade, since trade in differentiated but substitutable products (intra-industry trade) has grown most in the last decades. In this context, product quality is a strategic variable for the firm that can be influenced by trade policy.[1]

The conceptual economic framework that explicitly includes quality aspects into the analysis is provided by models of vertical product differentiation. Using this approach, I show that the domestic industry is generally harmed for the case of ad-valorem taxes, a foreign industry that produces a vertically differentiated good of higher quality, and costs that take the form of quality-dependent fixed costs for both the foreign and domestic firm. The domestic industry loses profits due to the foreign industry's lowering of product quality which intensifies price competition. However, domestic welfare is increased due to the tariff-revenue effect. This result carries through to the case of additional constant marginal costs, if this cost component does not increase too fast with increases in product quality produced. However, it does not hold with quality-dependent marginal costs. In this latter case, the foreign firm will reduce output rather than quality, which tends to reduce foreign competition. The traditional results will obtain for the case of a foreign industry producing lower quality than the domestic industry. With quality-dependent fixed costs, domestic welfare will fall, since increased profits and revenues are not sufficient to offset consumers' losses. Since profits of the domestic high-quality firm are relatively higher with quality-dependent variable cost, welfare can be increased by a tariff in this case. An especially noteworthy case arises with quality-dependent variable costs, a domestic low-quality producer and covered markets. Here, the domestic consumers as well as domestic industry will win from protection leading to an unambiguous welfare improvement. This is mainly due to the foreign firm's response of reducing output rather than quality. Since competition is relaxed by this, the domestic industry increases quality substantially leading to an increase in average quality sold.

For most of the model variations presented below, analytical solutions are available (or are straightforward to obtain) if they do not contain a variable cost component (or quantity-dependent tax). However, in the presence of quantity-dependent costs or taxes, analytical solutions (if they can be obtained) involve lengthy expressions that are at the least hard to interpret. However, using the analytical results presented so far in the literature as an interpretative guideline, numerical results can be explained sensibly by looking at their graphical representations. This is the methodological course taken in this paper.

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[1] See Mintz (1973), Levinsohn (1988), Feenstra (1993), Menzler-Hokkanen (1994).

The remainder of the paper is organized as follows. Section 2 describes the basic analytical framework, some main results about market behavior, and the simulations. Section 3 reviews the results of the simulations. Section 4 concludes.

2. Vertical Product Differentiation

The standard model of duopolistic competition with endogenous product qualities has been developed since the beginning of the 80s (Mussa/Rosen 1978, Gabszewicz/Thisse 1979, Shaked/Sutton 1982, Ronnen 1991). Consumers have identical preferences and different incomes. The income differences lead to differences in the willingness to pay for a particular product quality. Two firms (domestic and foreign) offer products of different qualities in one (domestic) market. The firms bear quality-dependent costs and compete in qualities and prices in a two-stage industry game. Since higher product differentiation reduces substitutability and price competition, even identical firms will offer distinct qualities in the resulting market equilibrium. Trade will take place since the foreign firm operates in the domestic market. (In the two-market extension, both firms operate in both markets.) National governments can use trade policy to improve the strategic position of domestic industries.[2] There is also the possibility of strategic noncooperative interaction between two national governments.

2.1. The Benchmark: Model 1

There are two firms, the domestic firm d and the foreign firm f, both competing in the domestic market. If both firms remain in the market, then they produce distinct goods, sold at prices p_d and p_f, respectively. The two products carry a single quality attribute denoted by s_d and s_f, respectively. Either firm faces production costs that are increasing, convex (quadratic) functions of quality, the exact level of which depending on quality chosen and a quality cost parameter b. Marginal costs are equal to zero for both firms.[3] Total costs of firm i are then:

$$c_i = b_i \, s_i^2 \tag{1.1}$$

In the domestic market, there is a continuum of consumers distributed uniformly over the interval [0, T] with unit density. Each consumer purchases at most one unit of either firm d's product or firm f's product. The higher a consumer's income parameter t, the higher is her (his) reservation price. Consumer t's utility is given by equation (2) if good i is purchased.[4] Consumers who do not purchase receive zero utility.

$$u_t = s_i \, t - p_i \tag{2}$$

The domestic government and firms d and f play a three-stage game[5]. In the first stage, the government sets an ad-valorem tariff on foreign imports. In the second stage, firms determine

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[2]See e.g. Brander/Spencer 1984, Krishna 1989.
[3]These assumptions on costs are changed for the alternative model specifications introduced below.
[4] Consumers who do not purchase receive zero utility.
[5]In this formulation, firm i not entering the market is equivalent to firm i choosing $s_i = 0$. The entry decision by firms is made simultaneously when choosing quality.

qualities to be produced and incur costs c_i (i = d, f). In the third stage, firms choose prices simultaneously (Bertrand competition). Since the derivation of market equilibria is generally known and straightforward, it is relegated to the Appendix.

2.2. Alternative Model Specifications

Alternative model specifications vary predominantly with respect to the cost specification in equation (1.1). In model version 2, equation (1.1) is replaced by equation (1.2) below where both firms have to incur identical non-zero marginal costs of production (determined by parameter d) after paying a quality-dependent fixed costs.

$$c_i = b_i s_i^2 + d q_i \tag{1.2}$$

$$c_i = b_i s_i^2 + d_i q_i \tag{1.3}$$

$$c_i = b_i s_i^2 q_i \tag{1.4}$$

In model 3, equation (1.1) is replaced by equation (1.3), where firms' marginal costs of production d_i are different. In model 4 (equation (1.4)), firms do not incur fixed costs, but face quality-dependent marginal costs of production. In model 5, the cost equation (1.1) applies, but the government chooses a specific tariff instead of an ad-valorem tariff as instrument. Finally, model 6 is the special case of model 4 with covered markets. I.e., cost equation (1.4) applies and consumers are uniformly distributed over an interval $[t_o, T]$ such that $t_o \geq p_o/s_o > 0$ in the resulting market equilibrium.

2.3. General Results and Model Behavior

This section discusses some general results with respect to model behavior and its response to changes in the assumptions about market structure, conduct and costs as well as basic results about responses to taxes, subsidies and trade policy. These results build the interpretational framework applied to the simulations presented below.

The cost structure in combination with assumptions about the distribution of consumers as well as the form of last-stage market competition (Bertrand or Cournot) determines the structure of product qualities as well as firms' profits in equilibrium.[6] Relative to Model 1 (the benchmark model), Cournot competition will reduce quality differentiation substantially. Similarly, the presence of variable costs will reduce quality differentiation, especially if these cost components rise with quality. In the benchmark model, the high-quality firm has substantially higher profits. A change of assumptions leading to less quality differentiation generally also leads to less profit differentiation. The benchmark model leads to identical rankings of qualities and firms' profits, respectively. Changes of product qualities induced by trade policy that lead to lower product differentiation will

[6]Results presented in Irmen/Thisse (1996) may suggest that the results carry over to the case of multiple quality attributes in the sense that they hold for one attribute while there will be no (significant) differentiation in all other attributes. Exploratory calculations also suggest that basic results about quality and profit differentiation may carry over to the N-firm case. However, this needs to be checked on a case-by-case basis. E.g. Cremer/Thisse (1991) or Scarpa (1996) suggest cases where the duopoly results do not apply in an N-firm framework.

generally reduce profits of both firms but increase their market shares. This is possible since market coverage is increased by this policy (absolutely more consumers purchase products) (Ronnen 1991, Lutz 1996). The ranking of firms' profits, however, remains unchanged. However, if the market is covered already in unregulated equilibria (see Shaked/Sutton 1982 for the appropriate condition), the same policy will lead to an increase of the market share of the low-quality firm and a decrease of the market share of the high-quality firm (Boom 1995, Crampes/Hollander 1995). Furthermore, in the benchmark model, the high-quality firm can increase its market share by lowering price without increasing total cost. This possibility is greatly reduced in the presence of variable costs. As a result, the case of market coverage and variable costs (model 6) quadratic in quality leads to identical profits and market shares for both firms (Crampes/ Hollander 1995). This means that the choice of higher quality does not any more entail a strategic advantage for the respective firm. Moreover, trade policy will now lead to overproportional losses of the high-quality firm.

Since the setup presented in this paper to analyze trade policy does not include a foreign market, it is largely comparable to the case of nonuniform taxes in Cremer/Thisse (1994). Their treatment of uniform taxes also provides some basis for the simulation results presented below. Their model setup corresponds to Model 6 presented here, i.e. covered markets, quality-dependent marginal costs and an ad-valorem tax. In an unregulated equilibrium, low quality is too low, high quality is too high, and quality differentiation is too high compared to a first-best allocation. A uniform tax decreases both qualities, both prices, and the degree of quality differentiation. A small uniform tax is welfare improving, since the procompetitive effect of decreasing product differentiation and the positive effect of reducing high quality overcompensates the negative effect of reducing low quality. With respect to the simulations presented below, this is somewhat like a combination of the effects of case 6.A. (where a tariff is levied on foreign high quality) and the effects of case 6.B. (where the tariff is on low quality). Allowing nonuniform taxes makes it possible to increase welfare from any given level of uniform taxes by increasing the tax on the low-quality product and decreasing the tax on the high-quality product. This corresponds to results of the simulations presented here, where a tariff on foreign low quality generally yields lower welfare increases than a tariff on foreign high quality.[7]

2.4. Simulations

Analytical solutions to the models introduced above are very cumbersome, mainly due to the presence of the tax-variables and variable cost components. However, without tax-variables (or when taxes are zero), analytical solutions for models 1 and 6 are easily obtained. These are presented in the Appendix.

The paper presents 12 simulations, two for each model alternative. A distinction is made between the case of low quality produced domestically (A) and high quality produced domestically (B). Thus, e.g., simulation 1.B shows the (benchmark) Model 1 where high quality is produced by the home firm. For models 1 through 5, market size equals T=1 and cost parameter b=0.5. In Model 2, both firms bear additional constant marginal costs of d=0.004. In Model 3, the marginal cost parameters are d_h=0.005 and d_l=0 for the high- and low-quality firm, respectively. In Model 6, the market is covered and market size equals T- t_o=0.4 (T=1.1, t_o=0.7), and b=2/3. This parameter choice ensures a covered market for the relevant range of policies applied.

The results are summarized in 14 figures per simulation, showing domestic welfare, qualities, quality ratio, profits, consumer surplus, government revenue, prices, price/quality ratios, and quantities, respectively, where the tariff is gradually increased (on the horizontal axis) starting from the free-trade level.

Although analytical results are not presented, alternative calculations suggest that changes in parameters for each simulation (other than cost differences between firms) would not alter the qualitative results.

3. Taxing Foreign Competition

In this section, I review the simulation results. The qualitative results are grouped into five classes, each of which may be the outcome of one or more of the 12 simulations performed.

3.1. When an Industry Should Not Request Tariff Protection

In simulations 1.A, 2.A and 3.A, the foreign competition produces the higher quality and firms have to bear quality-dependent fixed costs. The tariff on the foreign firm induces a sharp reduction of foreign (high) quality in order to reduce cost and the adverse effect of the (ad-valorem) tariff. This is offset by an increase in quantity. Both effects increase competitive pressure on the home firm, which therefore reacts likewise by reducing quality and increasing quantity. Therefore, both firms' profits fall. The sharp reduction in quality differentiation results in reduced prices per unit of quality (and reduced absolute prices). However, the price reduction is not sufficient to offset the adverse effect of quality reduction on consumer surplus. The relatively high tariff revenues on the foreign firm's import are sufficient to offset the reductions in domestic profits and consumer surplus, so that a tariff can increase total domestic welfare. If the foreign firm incurs marginal costs in addition to fixed cost, it will still reduce quality substantially but may not increase quality.

3.2. Domestic Industry Gains from Protection at the Expense of Welfare

In simulations 1.B, 2.B and 3.B the foreign industry produces the low-quality good. This leads to roughly opposite effects when compared to the previous case. The foreign firm decreases quality, thereby reducing competition, which allows the domestic high-quality firm to simultaneously decrease quality but increase price. Foreign price decreases less than proportionally, leading to increased price per quality for both goods. Since quantities sold of both goods decrease also, consumers are substantially worse off. The receipts from taxing the foreign firm's relatively low import revenue are only a fraction of consumer losses. Even with domestic profit increases, they are not sufficient to offset consumer losses and reduced domestic welfare results.

[7]In three of the simulations, taxing foreign low quality will even lead to welfare decreases.

3.3. Revenue-Driven Welfare Increases due to Protection

In simulations 4.A and 5.A, the foreign competition produces the higher quality but tariffs have a less pro-competitive effect than in the simulations presented in Section 3.1. This makes these cases most comparable to the situation with Cournot competition presented in Herguera/Kujal/Petrakis (1995). A tariff leads to both quality downgrading and decrease of quantity for the foreign firm. The domestic low-quality firm can therefore react with increases in both quality and quantity. Consumer surplus is reduced since increases in low quality do not fully compensate for decreases in high quality. The main source of welfare improvement is government revenues from taxing imports.

3.4. Profit-Driven Welfare Increases due to Protection

In simulations 4.B, 5.B, and 6.B, the foreign firm produces low quality. A tariff on the foreign firm will lead to reduced foreign quality and quantity. The former allows the domestic firm to profitably reduce quality while the latter allows increases in quantity. This leads to substantial profit increases effectively overcompensating consumer surplus losses due to overall decreased qualities and increased quality-adjusted prices. Revenues from taxing relatively low imports contribute little to welfare.

3.5. A Case of Protection where Domestic Consumers Win!

In simulation 6.A, variable costs are quality-dependent and the market is covered. This leaves total quantity sold (of both qualities) unchanged as a result of a tariff. The foreign firm produces high quality. Since the domestic firm cannot gain additional market share at the low end of the market by reducing quality, it will now react on a reduction of high quality by increasing its own quality to gain market share in the center of the market from the foreign competitor. Therefore, the foreign firm will only insignificantly reduce quality (and price) and instead reduce quantity sold. The domestic firm now gains by both increasing quality and price, which also leads to a substantial reduction in quality differentiation. Consumers gain through reduced price per quality of the foreign good and through increased quality of the domestic good. As a result domestic welfare can be increased while making both consumers and the domestic industry better off!

3.6. More About Robustness

Herguera/Kujal/Petrakis (1995) show that Cournot competition will slightly alter some of the results due to the lower level of competition when compared to price competition in our benchmark simulation. For the case of a foreign high-quality firm, a tariff leads to both quality downgrading and loss of market share for the foreign firm. The domestic low-quality firm can therefore react with increases in both quality and market share. The important point here, is that the differences in results are due to reduced price competition and not to the Cournot case per se. For that reason, the results of simulations 4.A. and 5.A. are comparable to those in Herguera/Kujal/Petrakis, where competitive pressure is lower than in the benchmark because of quality-dependent variable costs in the former and because of using specific tariffs in the latter case, respectively.

3.7. Discussion

The notion that taxing foreign competition leads to quality-downgrading seems, at first glance, to be counterintuitive as well as not to be supported by empirical evidence. The standard case cited is the development of the US car market during the 1980s, where Japanese imports where subjected to both quantity constraints and tariffs. However, Japanese car manufacturers reacted by quality upgrading.

To my knowledge, there is no closure yet on the debate whether quality upgrading was induced by tariffs, VERs, or a combination of both. Goldberg (1992, 1994) performed trade-policy simulations using an econometric model of US car demand, coming to the conclusion that quotas lead to quality upgrading, while tariffs might lead to downgrading. Since the quotas on Japanese cars where severely binding, observed upgrading does not necessarily force the conclusion that tariffs must have had that effect. This interpretation could also be supported theoretically based on Herguera/Kujal/Petrakis.

4. Conclusions

The purpose of this paper was to demonstrate that the direction of international vertical differentiation can be a major determinant of the effectiveness of trade policy. This was demonstrated for the case of tariffs. However, the results are likely to hold for any policy that has similar effects on quality differentiation and market shares. The simulation results were presented graphically and interpreted in accordance with existing analytical results.

The method of simulations was chosen, since more intuitive insights are likely to be gained from the obtained graphical solutions than from lengthy and complicated analytical expressions. Exploratory alternative calculations as well as the consistency of the conclusions with the literature suggest robustness of the results for the tariff case as well as their likely applicability to many cases with other policy instruments.

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Appendix

(All calculations are available upon request.)

A.1. The Benchmark Model

This appendix demonstrates the derivation of the market equilibria for the model presented in Section 2.1. Firms d and f play a two-stage game[8]. In the first stage, firms determine qualities to be produced and incur costs c_i (i = d, f). In the second stage, firms choose prices simultaneously.[9]

Price Competition

To solve the game, consider first the demand faced by the high-quality and low-quality firm, respectively. Let h and o stand for high and low quality, respectively. These demands are then given by:[10]

$$q_h = T - \left(\frac{p_h - p_o}{s_h - s_o}\right), \quad q_o = \frac{p_h - p_o}{s_h - s_o} - \frac{p_o}{s_o} \qquad \text{(A.3.1)}$$

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

$$p_h = \frac{2Ts_h(s_h - s_o)}{4s_h - s_o}, \quad p_o = \frac{T(s_h - s_0)s_o}{4s_h - s_o} \qquad \text{(A.4.1)}$$

Note that for all $s_h > s_o$, $T > t_h > t_o > 0$ will hold, *i.e.*, equation (A.4.1) is in fact an unconstrained price equilibrium.

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

$$\Pi_h = \frac{4T^2 s_h^{\,2}(s_h - s_0)}{(4s_h - s_0)^2} - b_h s_h^{\,2}, \quad \Pi_o = \frac{T^2 s_h (s_h - s_o) s_o}{(4s_h - s_o)^2} - b_o s_o^{\,2} \qquad \text{(A.5.1)}$$

[8]In this formulation, firm i not entering the market is equivalent to firm i choosing $s_i = 0$. The entry decision by firms is made simultaneously when choosing quality.
[9]To derive solutions, we will use the concept of subgame-perfect equilibrium, computing the solutions for each stage in reverse order. Both firms choose their respective product quality from the same interval [0, ∞). The resulting market equilibria will include some consumers in the lower segment of the interval [0, T] not valuing quality enough to buy any product. This guarantees an interior solution of the price game.
[10]Let $t_h = (p_h - p_o)/(s_h - s_o)$ and $t_o = p_o/s_o$. Consumers with $t = p_o/s_o$ will be indifferent between buying the low-quality product and not buying at all. Consumers with $t = (p_h - p_o)/(s_h - s_o)$ will be indifferent between buying either the high-quality or the low-quality product. Consumers with $T \geq t > t_h$ will buy high quality, consumers with $t_h > t > t_o$ will buy low quality, and consumers with $t < p_o/s_o$ will not buy at all.

Similarly, consumer surplus[11] can be expressed in the following way:

$$CS = \frac{T^2 {s_h}^2 \left(4s_h + 5s_o\right)}{2\left(-4s_h + s_o\right)^2} \qquad \text{(A.6.1)}$$

<u>Properties of the Revenue and Consumer Surplus Functions</u>

Let R_i denote firm i's revenue function. Let h and o denote high and low quality, respectively.

$$\frac{\partial R_h}{\partial s_h} \geq 0; \quad \frac{\partial R_0}{\partial s_o} \geq 0 \text{ for } s_o \leq \frac{4s_h}{7}; \quad \frac{\partial R_h}{\partial s_o} < 0, \quad \frac{\partial R_o}{\partial s_h} > 0; \qquad \text{(A.7.1)}$$

$$\frac{\partial^2 R_h}{\partial {s_h}^2} \leq 0; \qquad \frac{\partial^2 R_o}{\partial {s_o}^2} \leq 0; \qquad \frac{\partial^2 R_h}{\partial s_h \partial s_o} > 0; \qquad \frac{\partial^2 R_o}{\partial s_o \partial s_h} > 0.$$

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

$$\frac{\partial CS_I}{\partial s_h} > 0 \text{ for } s_o < \frac{4s_h}{5}; \quad \frac{\partial CS_I}{\partial s_o} > 0; \quad \frac{\partial^2 CS_I}{\partial {s_h}^2} > 0; \quad \frac{\partial^2 CS_I}{\partial {s_o}^2} > 0; \quad \frac{\partial^2 CS_I}{\partial s_o \partial s_h} < 0.$$

<u>Quality Competition</u>

To derive the firms' quality best responses, we investigate each firm's profit function, given the other firm's quality choice, and taking into account the behavior in the price-setting subgame. Given the order of qualities, the profit functions in equations (A.5.1) are concave in the respective firm´s own quality. The profit-maximizing choices form a Nash-equilibrium in qualities, where both marginal profit functions evaluate to zero. The first order conditions for the high and low quality firm, respectively, are then given as:

$$4T^2 s_h (4{s_h}^2 - 3s_h s_o + 2{s_o}^2 -) / (4s_h - s_o)^3 = 2b_h s_h$$

$$T^2 {s_h}^2 (4s_h - 7s_o) / (4s_h - s_o)^3 = 2b_o s_o \qquad \text{(A.9.1)}$$

The slopes of the high and low quality firms' quality best responses can be calculated (using the implicit function theorem) as $ds_i/ds_j = -(\partial(\partial\Pi_i/\partial s_i)/\partial s_j)/(\partial(\partial\Pi_i/\partial s_i)/\partial s_i)$, where i is either high or low quality and j is the other quality. Both slopes are positive, but less than one.

From the properties of the revenue functions and the slopes of the quality best responses, it can be derived that the two qualities are strategic complements. Furthermore, a forced increase of the low quality will reduce product differentiation and increase price competition.

[11] Consumer surplus is defined as $\{\int(t^* s_h - p_h)dt + \int(t^* s_o - p_o)dt\}$ where the first integral goes from t_h to T and the second goes from t_o to t_h.

Divide the first order conditions given in (A.9), rearrange and write $s_h = r\, s_o$ and $b_o = a\, b_h$ to obtain:

$$\frac{4(2-3r+4r^2)}{4r^2-7r}=\frac{r}{a}$$

For a=1 (i.e. $b_o = b_h = b$) r = 5.25123 while for a=2 (i.e. $b_o = 2\, b_h = 2\, b$) r = 9.14152. Using r to express s_h in terms of s_o and substituting for s_h in the first equation of (A.9.1) allows for calculating the equilibrium qualities for any given value of T and b. (However, the ratio of cost parameters a must be fixed.)

The resulting equilibrium qualities for identical firms (i.e. $b_h = b_o = b$) are then:[12]
$s_h = 0.126655\, T^2 / b$ and $s_o = 0.0241192\, T^2 / b$

The resulting equilibrium profits for identical firms (i.e. $b_h = b_o = b$) are then:
$\Pi_h = 0.012219\, T^4 / b$ and $\Pi_o = 0.0007637\, T^4 / b$

A.2. Model 6: Variable Costs and Covered Markets

This appendix demonstrates the derivation of the market equilibria for Model 6 presented in Section 2.2.[13] Firms d and f play a two-stage game. In the first stage, firms determine qualities to be produced and incur costs c_i (i = d, f). In the second stage, firms choose prices simultaneously. Cost is determined by equation (1.4) and consumers are uniformly distributed over an interval $[t_o, T]$ such that $t_o \geq p_o/s_o > 0$ in the resulting market equilibrium.[14]

Price Competition

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

$$q_h = T-(\frac{p_h-p_o}{s_h-s_o}), \quad q_o=\frac{p_h-p_o}{s_h-s_o}-t_o \qquad \text{(A.3.2)}$$

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

$$\begin{aligned} p_h &= [2c(s_h)+c(s_o)+(2T-t_o)(s_h-s_o)], \\ p_o &= [c(s_h)+2c(s_o)+(2t_o-T)(s_h-s_o)] \end{aligned} \qquad \text{(A.4.2)}$$

[12]Note that T^2/b enters in a multiplicative way and therefore does not affect the calculations.
[13]See also Crampes/Hollander (1995).
[14]See Boom (1995, p. 104) and Shaked/Sutton (1982, p. 4f) for the condition for covered markets.

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

$$\Pi_h = \frac{4t^2 s_h^{\,2}(s_h - s_0)}{(4s_h - s_0)^2} - b_h s_h^{\,2}, \quad \Pi_o = \frac{1}{9(T - t_o)}(s_h - s_o)(g + T - 2t_o)^2 \qquad \text{(A.5.2)}$$

where $g = [c(s_h) - c(s_o)](s_h - s_o)$ for $s_h > s_o$.

Quality Competition

To derive the firms' quality best responses, we investigate each firm's profit function, given the other firm's quality choice, and taking into account the behavior in the price-setting subgame. Given the order of qualities, the profit functions in equations (A.5.2) are concave in the respective firm´s own quality. The profit-maximizing choices form a Nash-equilibrium in qualities, where both marginal profit functions evaluate to zero. The first order conditions for the high and low quality firm, respectively, are then given as:

$$2T - t_o + g(s_h, s_o) - 2c'(s_h) = 0$$

$$2t_o - T + g(s_h, s_o) - 2c'(s_o) = 0 \qquad \text{(A.9.2)}$$

The slopes of the high and low quality firms' quality best responses can be calculated (using the implicit function theorem) as $ds_i/ds_j = -(\partial(\partial\Pi_i/\partial s_i)/\partial s_j)/(\partial(\partial\Pi_i/\partial s_i)/\partial s_i)$, where i is either high or low quality and j is the other quality.

Equilibrium qualities can be calculated for any given value of T, t_o and b. (However, the ratio of cost parameters a must be fixed.)

The resulting equilibrium qualities for identical firms (i.e. $b_h = b_o = b$) are then:

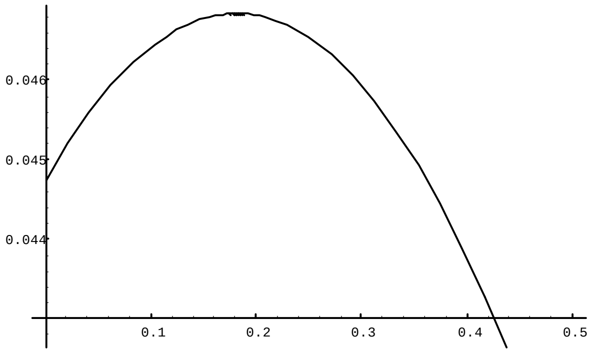
$$s_h = (5T - t_o)/(8b) \text{ and } s_o = (5t_o - T)/(8b)$$

where

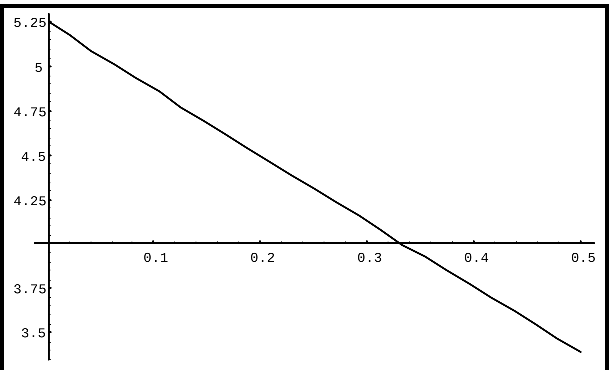
$$s_h/s_o = (5T - t_o)/(5t_o - T).$$

Figures

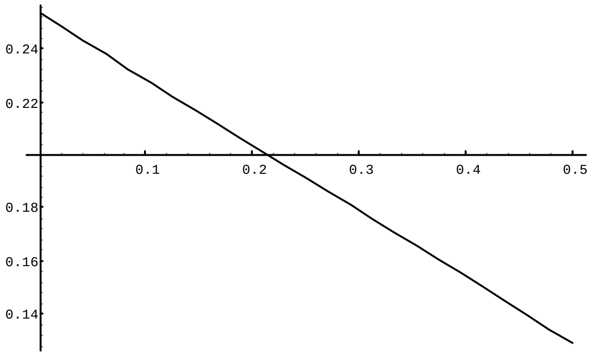
Case 1.A. Quality-Dependent Fixed Costs without Variable Costs
(Foreign High-Quality Firm)



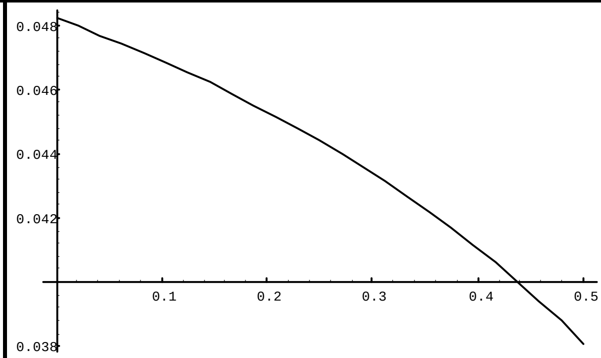
1.A.1. Welfare



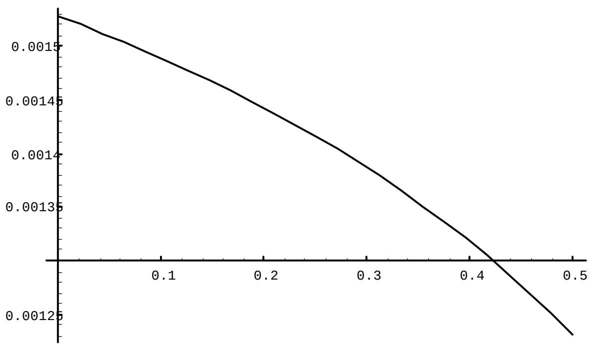
1.A.2. Quality Ratio



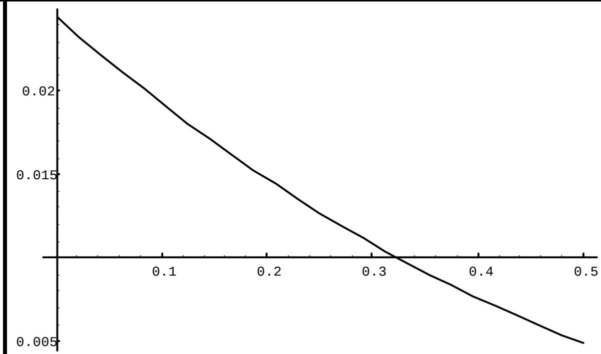
1.A.3. High Quality



1.A.4. Low Quality



1.A.5. Low-Quality Profits



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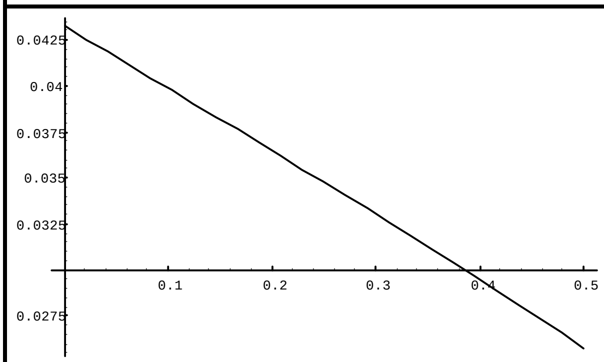
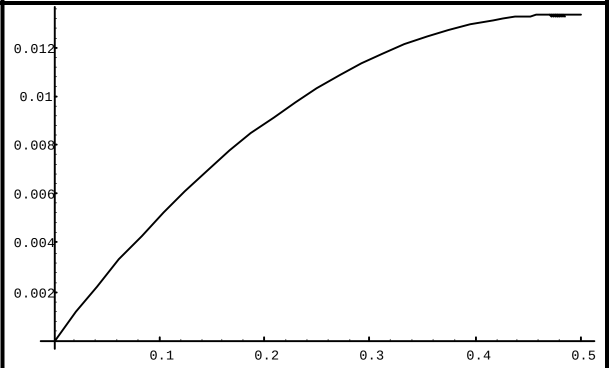
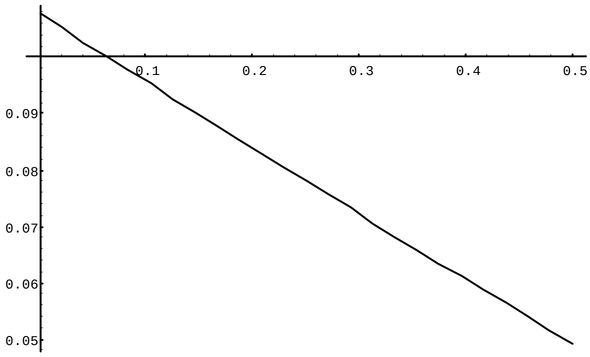


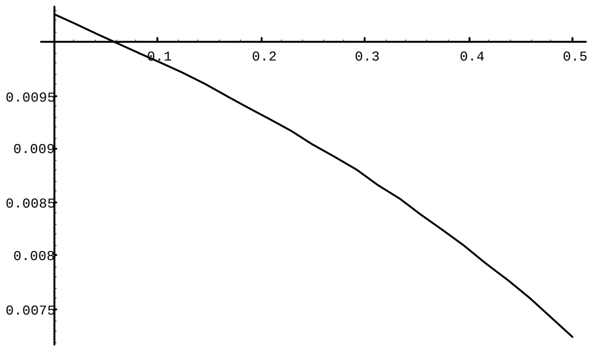
1.A.7. Consumer Surplus



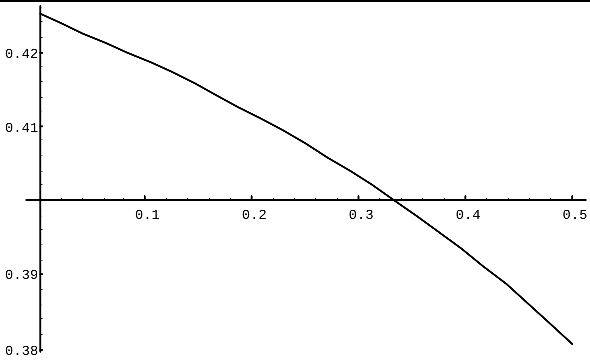
1.A.8. Government Revenue



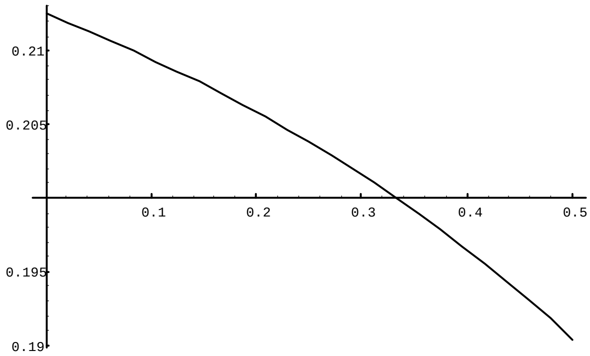
1.A.9. High-Quality Price



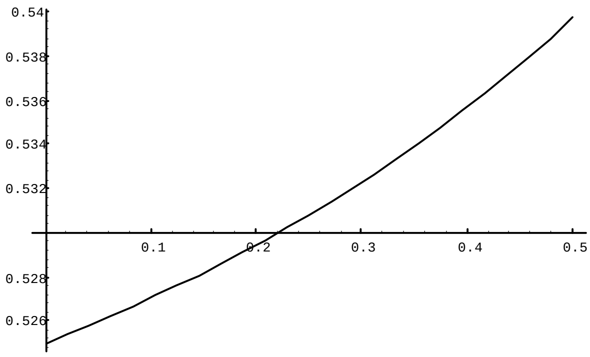
1.A.10. Low-Quality Price



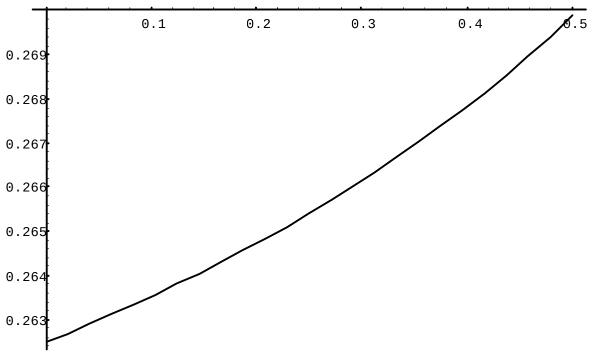
1.A.11. High Price/Quality Ratio



1.A.12. Low Price/Quality Ratio

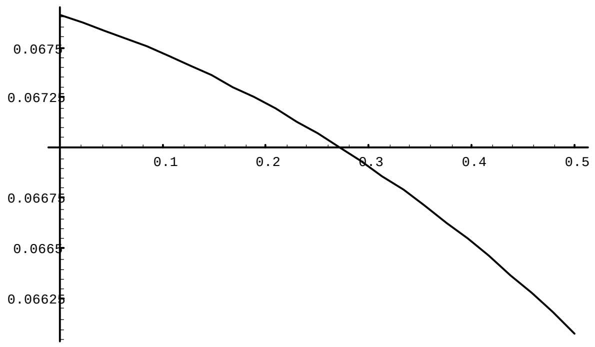


1.A.13. High-Quality Quantity

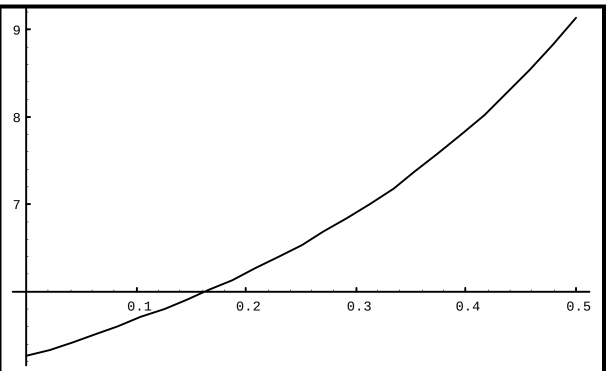


1.A.14. Low-Quality Quantity

Case 1.B. Quality-Dependent Fixed Costs without Variable Costs
(Foreign Low-Quality Firm)



1.B.1. Welfare



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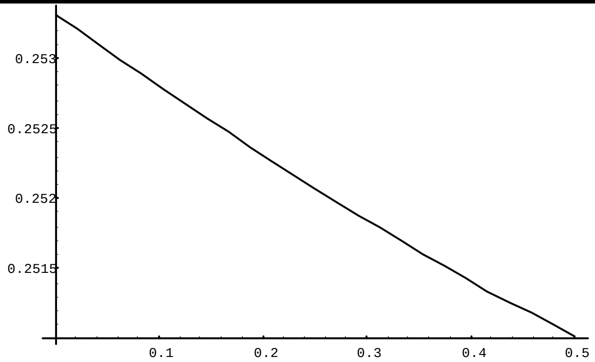
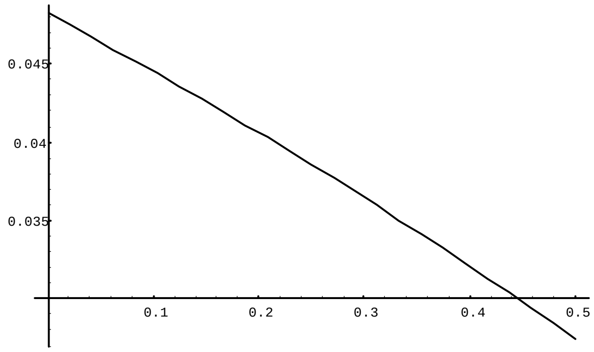
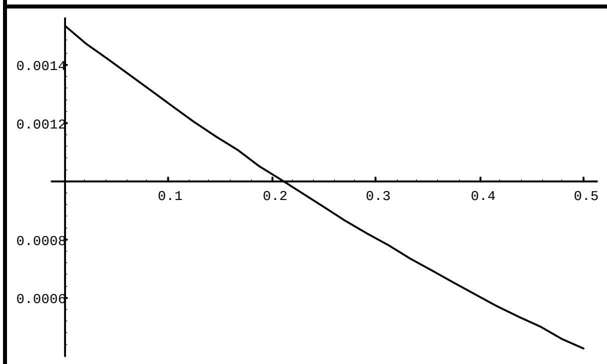


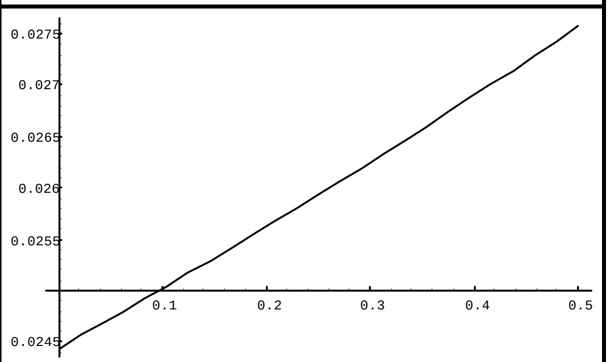
1.B.3. High Quality



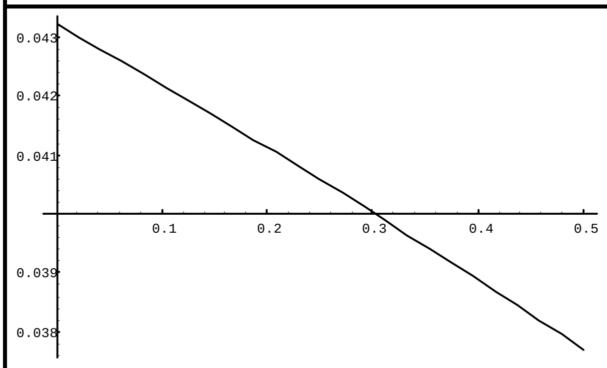
1.B.4. Low Quality



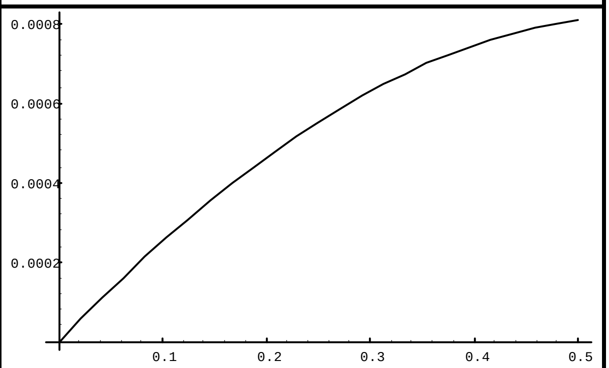
1.B.5. Low-Quality Profits



1.B.6. High-Quality Profits



1.B.7. Consumer Surplus



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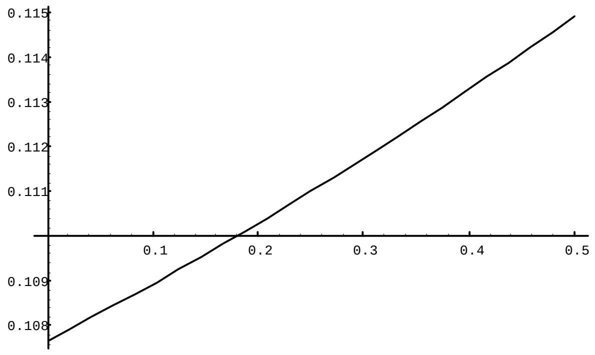
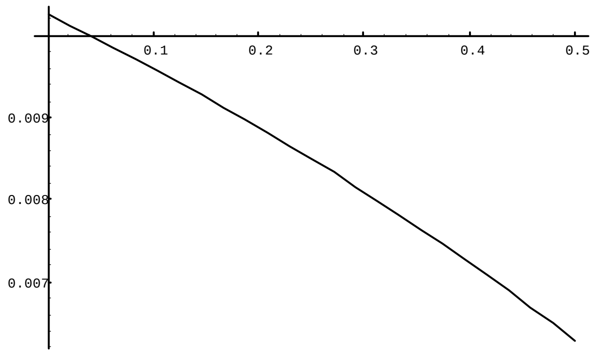


1.B.9. High-Quality Price



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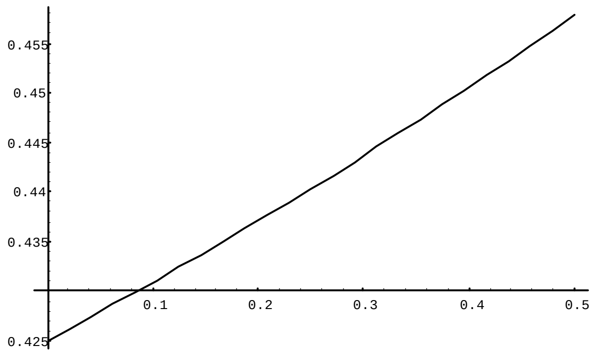

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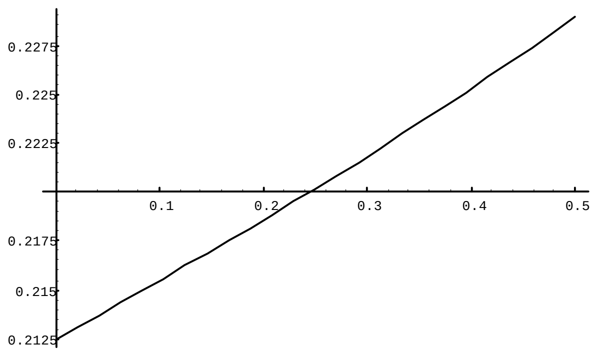
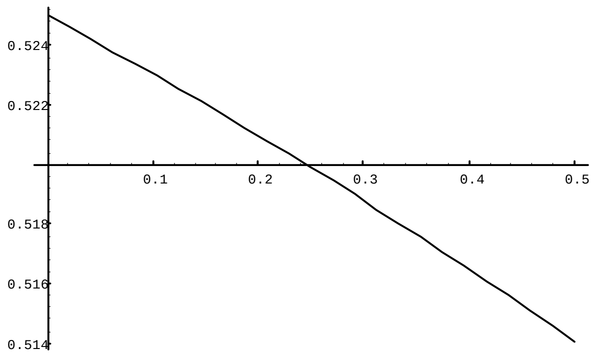
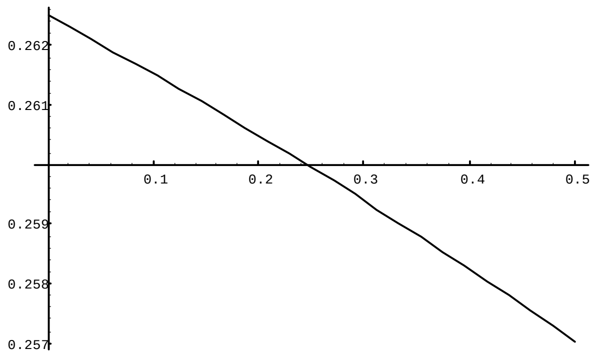


1.B.12. Low Price/Quality Ratio

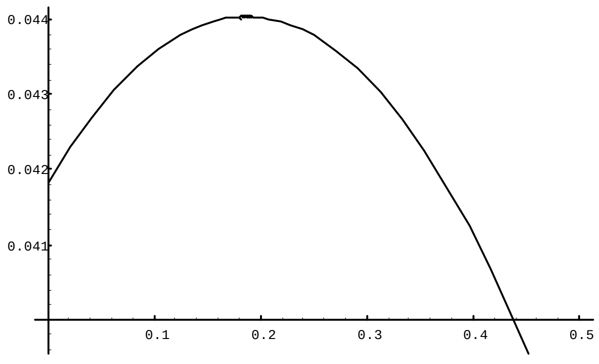


1.B.13. High-Quality Quantity

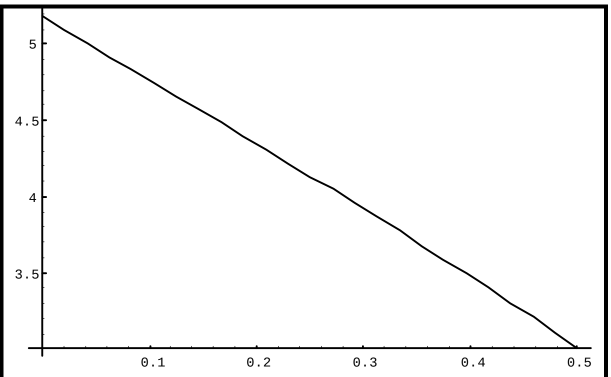


1.B.14. Low-Quality Quantity

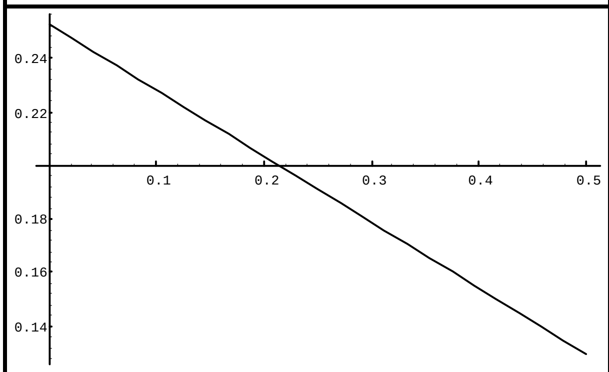
Case 2.A. Quality-Dependent Fixed Costs with Equal Variable Costs
(Foreign High-Quality Firm)



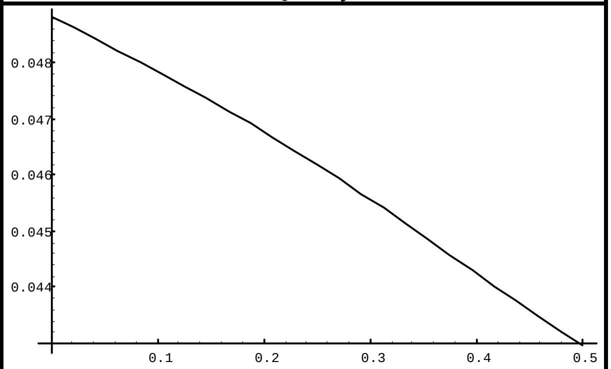
2.A.1. Welfare



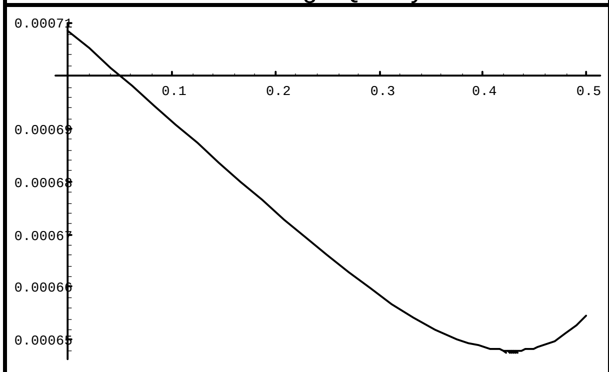
2.A.2. Quality Ratio



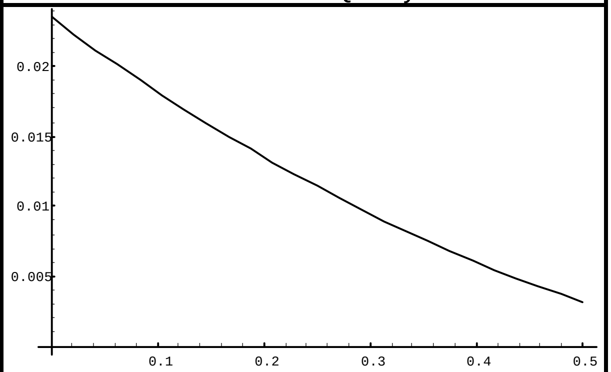
2.A.3. High Quality



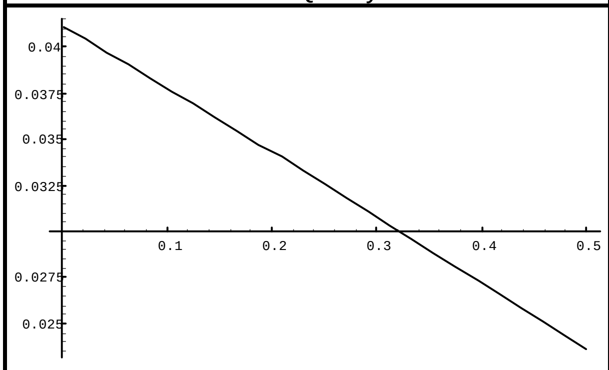
2.A.4. Low Quality



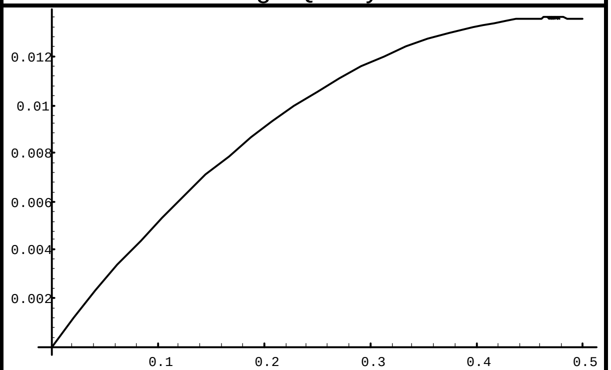
2.A.5. Low-Quality Profits



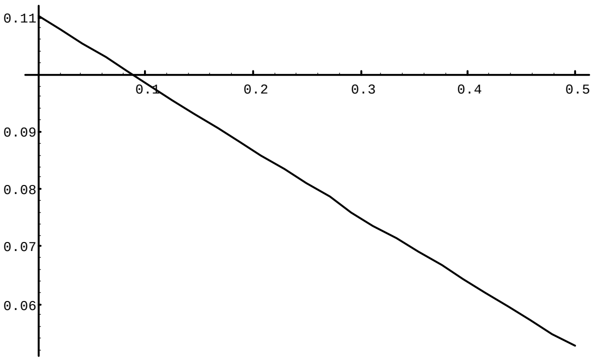
2.A.6. High-Quality Profits



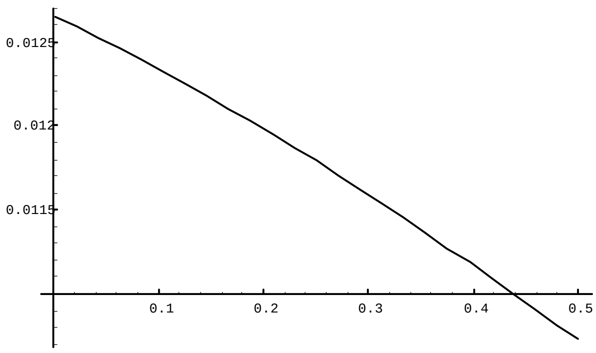
2.A.7. Consumer Surplus



2.A.8. Government Revenue



2.A.9. High-Quality Price



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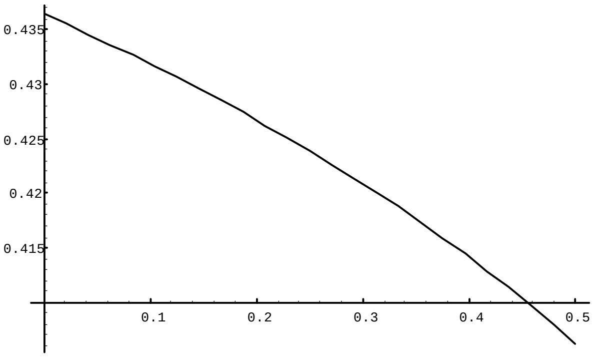
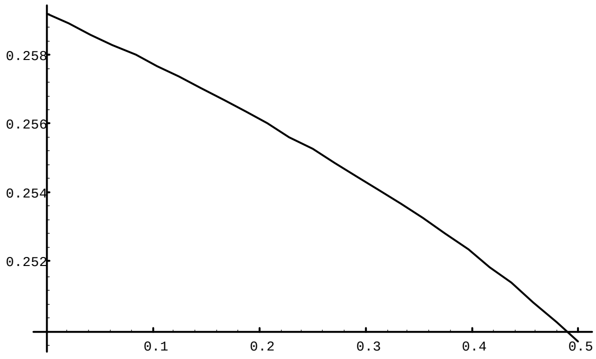


2.A.11. High Price/Quality Ratio



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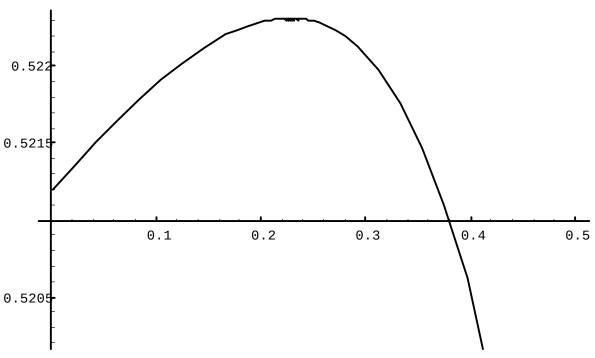
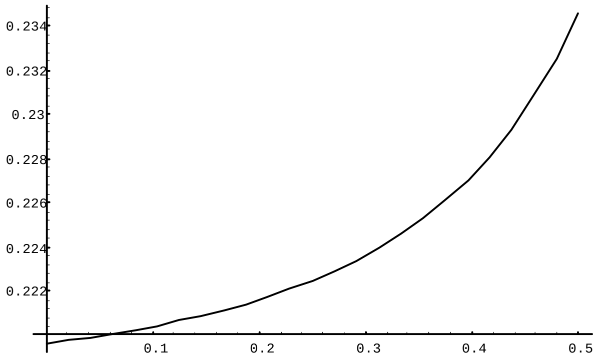
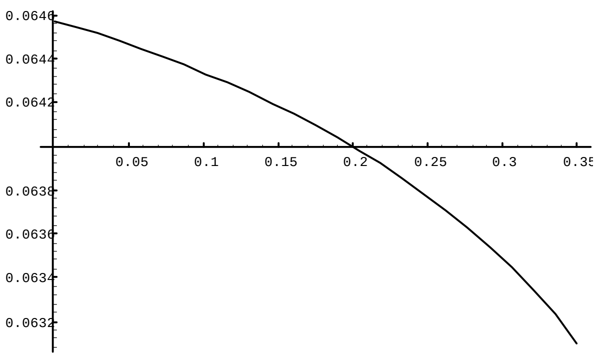


2.A.13. High-Quality Quantity

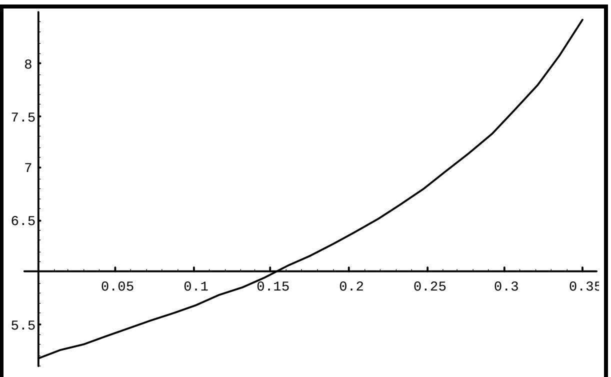


2.A.14. Low-Quality Quantity

Case 2.B. Quality-Dependent Fixed Costs with Equal Variable Costs
(Foreign Low-Quality Firm)



2.B.1. Welfare



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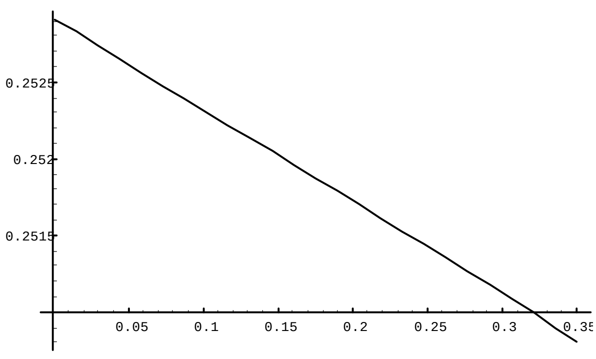
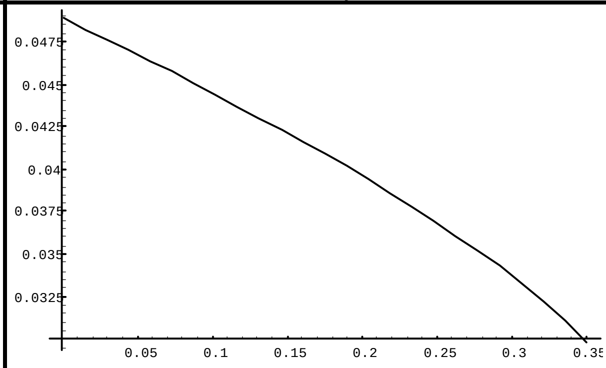


2.B.3. High Quality



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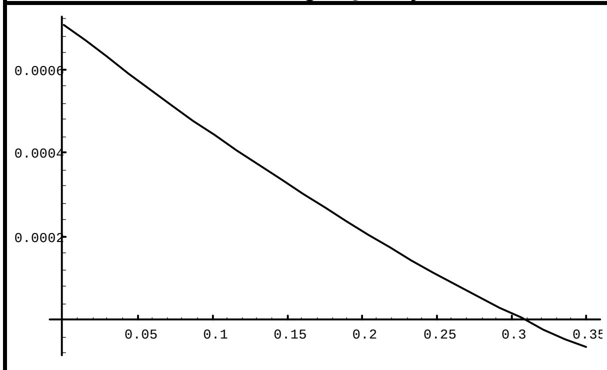
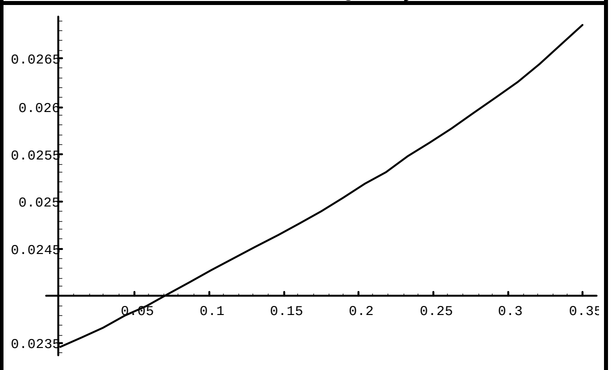
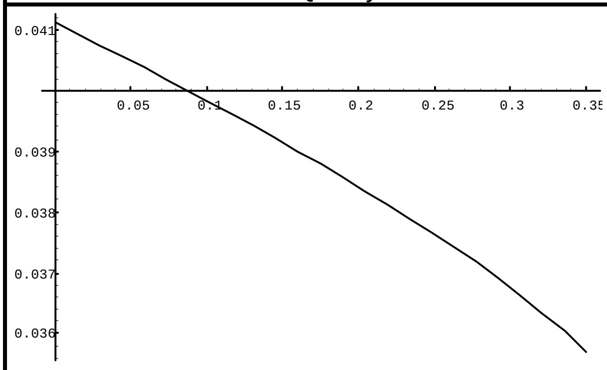


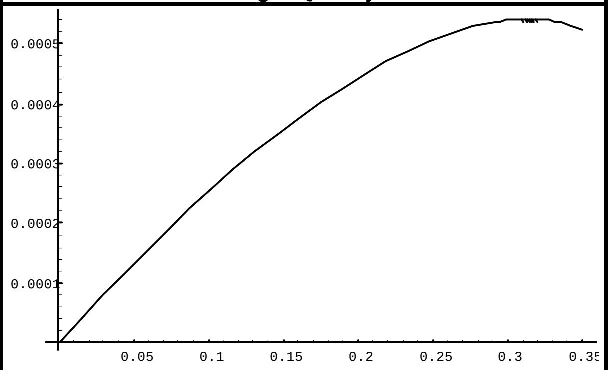
2.B.5. Low-Quality Profits



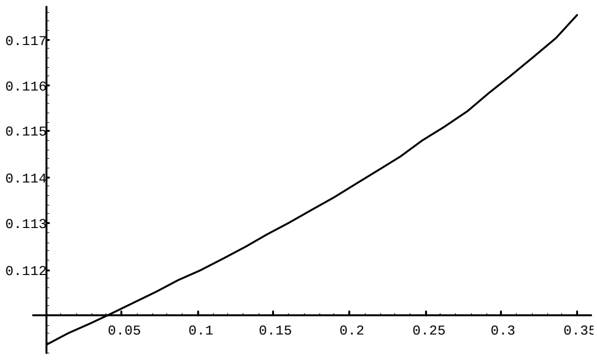
2.B.6. High-Quality Profits



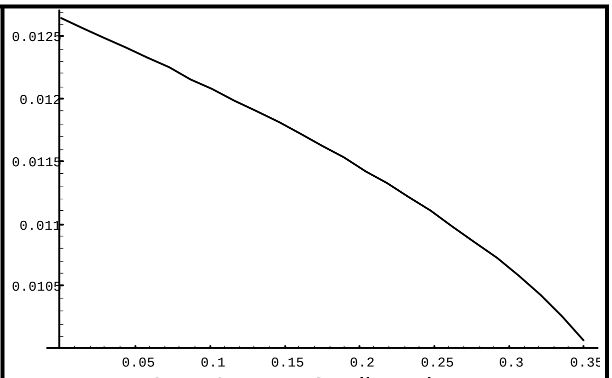
2.B.7. Consumer Surplus



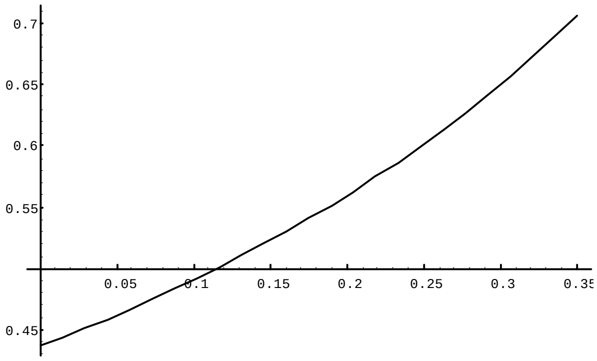
2.B.8. Government Revenue



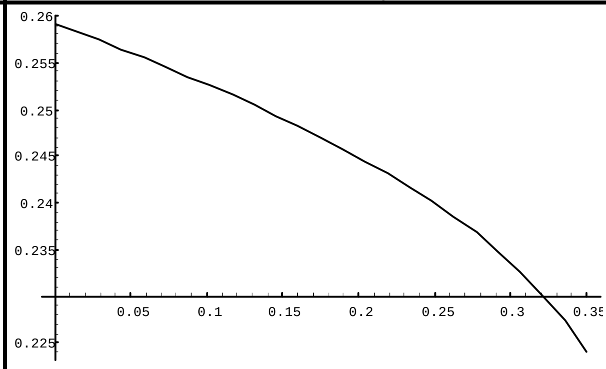
2.B.9. High-Quality Price



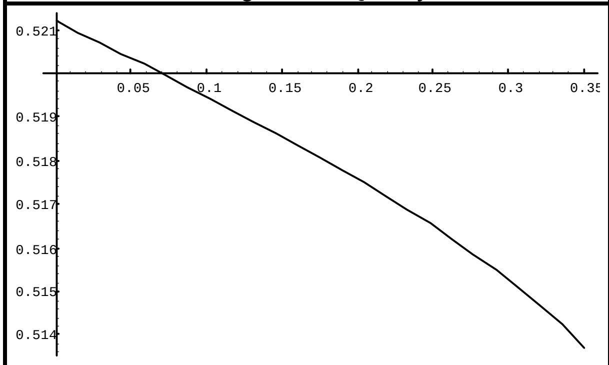
2.B.10. Low-Quality Price



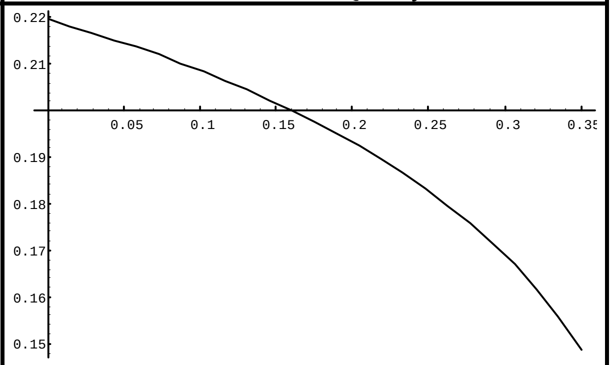
2.B.11. High Price/Quality Ratio



2.B.12. Low Price/Quality Ratio

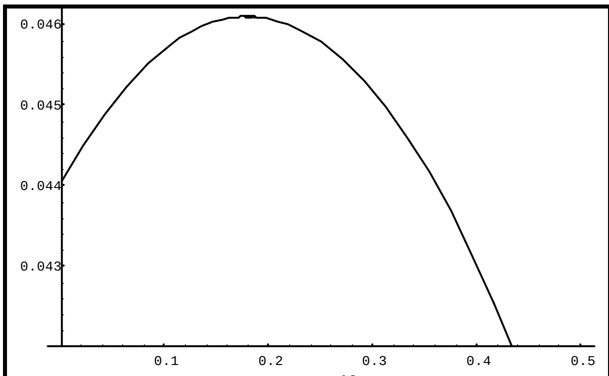


2.B.13. High-Quality Quantity

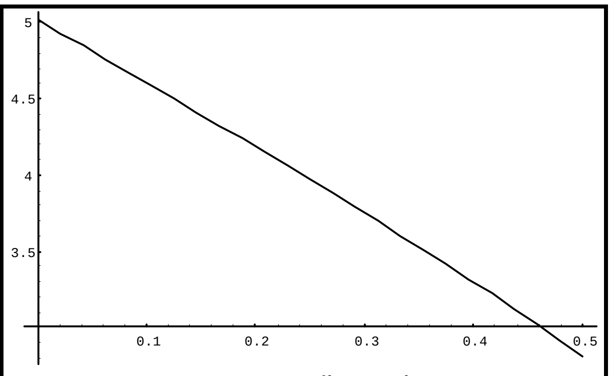


2.B.14. Low-Quality Quantity

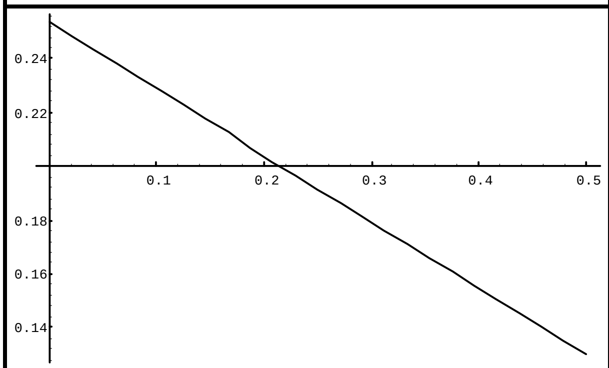
Case 3.A. Quality-Dependent Fixed Costs with Unequal Variable Costs
(Foreign High-Quality Firm)



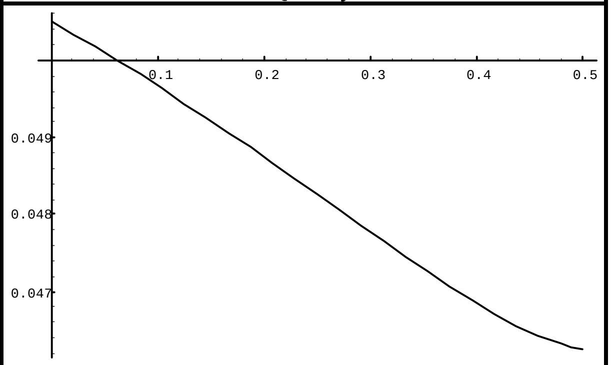
3.A.1. Welfare



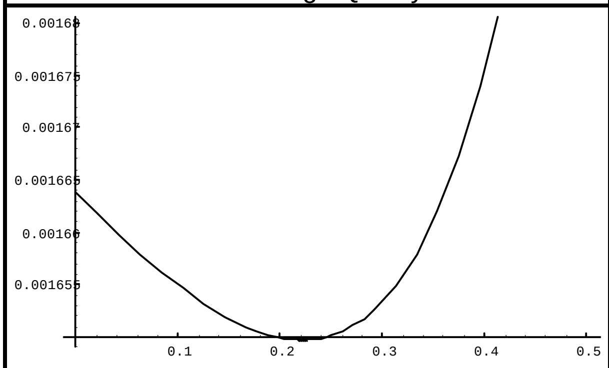
3.A.2. Quality Ratio



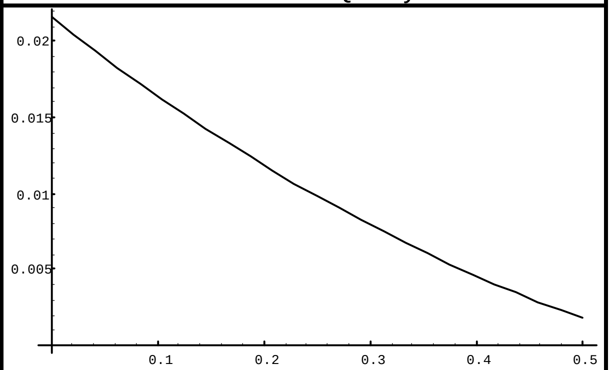
3.A.3. High Quality



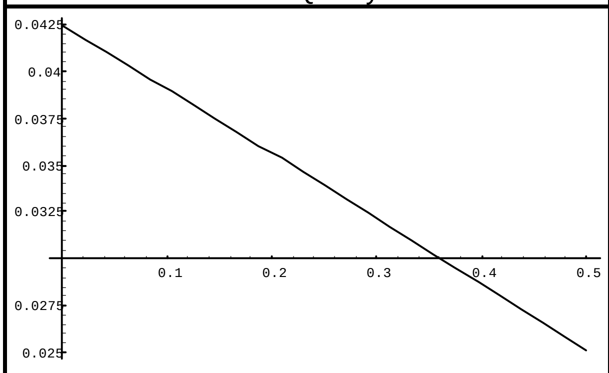
3.A.4. Low Quality



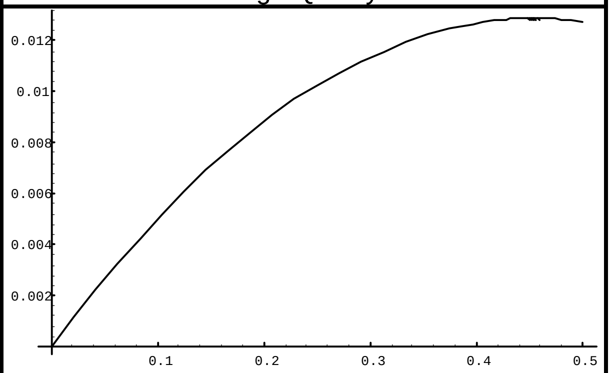
3.A.5. Low-Quality Profits



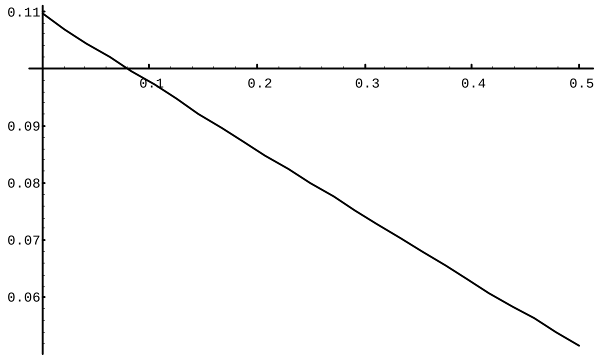
3.A.6. High-Quality Profits



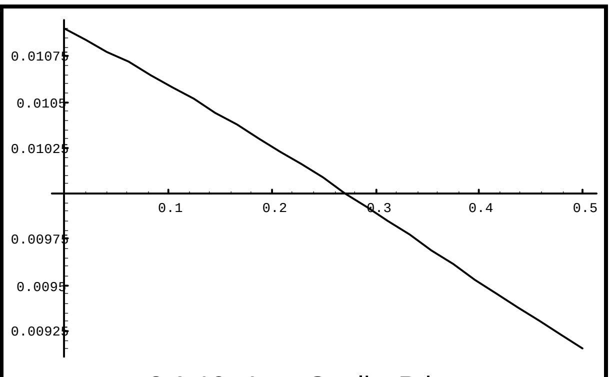
3.A.7. Consumer Surplus



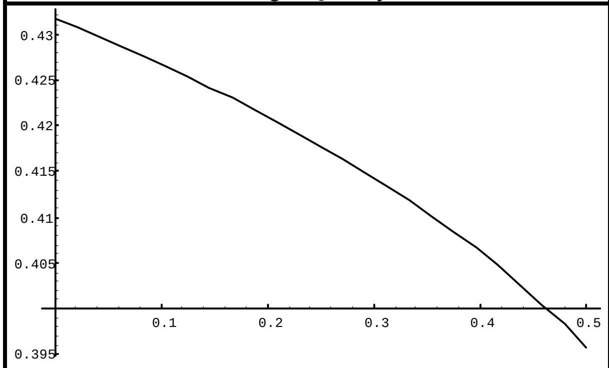
3.A.8. Government Revenue



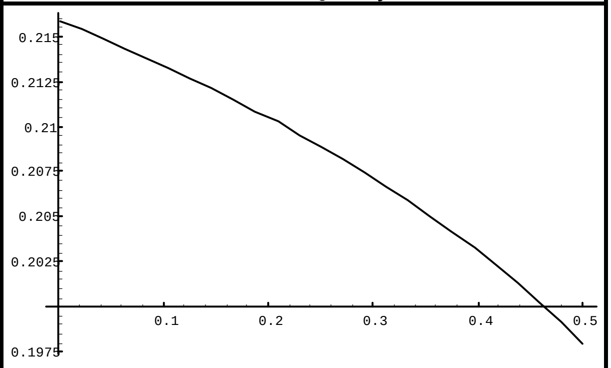
3.A.9. High-Quality Price



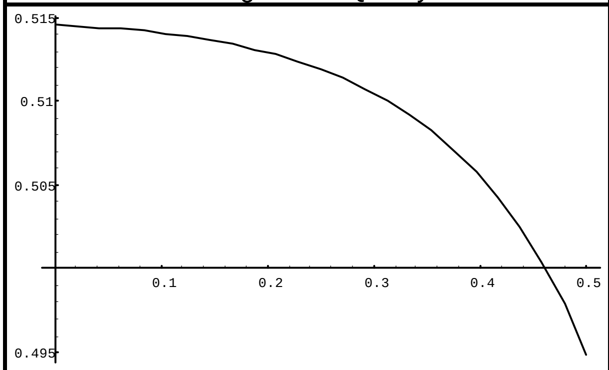
3.A.10. Low-Quality Price



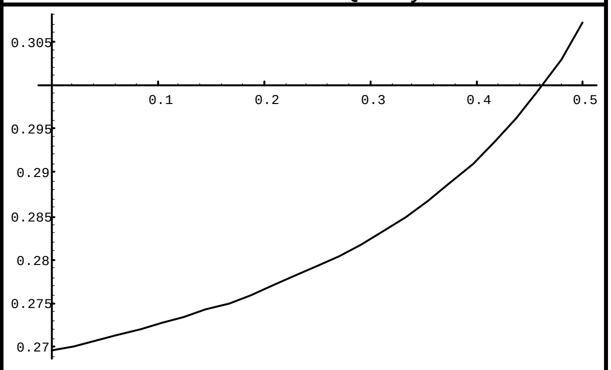
3.A.11. High Price/Quality Ratio



3.A.13. Low Price/Quality Ratio

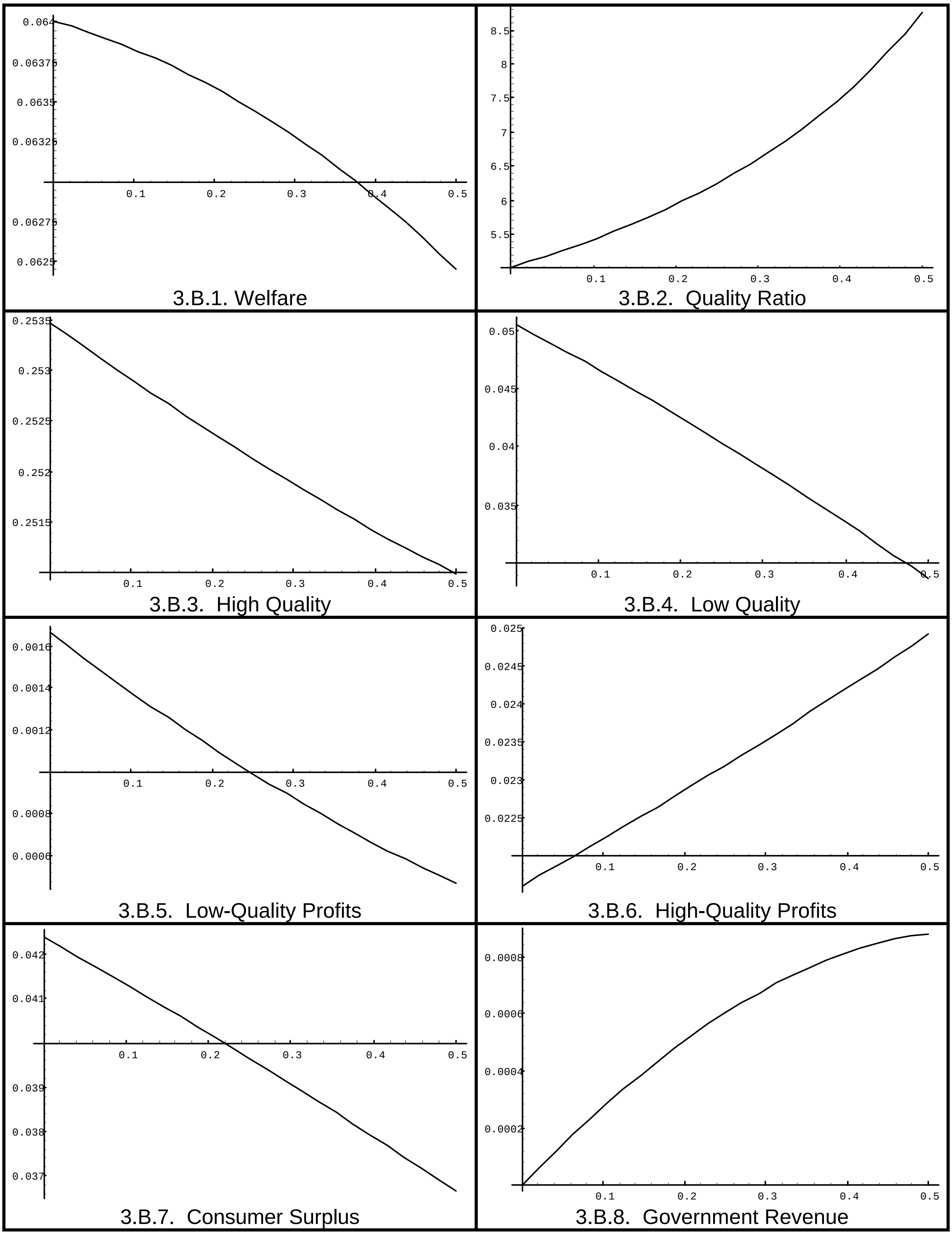


3.A.13. High-Quality Quantity



3.A.14. Low-Quality Quantity

Case 3.B. Quality-Dependent Fixed Costs with Unequal Variable Costs
(Foreign Low-Quality Firm)



3.B.1. Welfare

3.B.2. Quality Ratio

3.B.3. High Quality

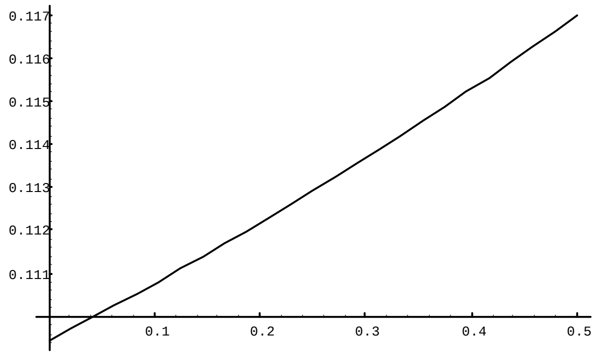
3.B.4. Low Quality

3.B.5. Low-Quality Profits

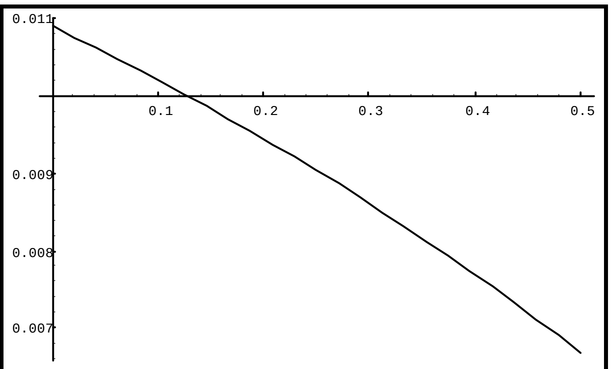
3.B.6. High-Quality Profits

3.B.7. Consumer Surplus

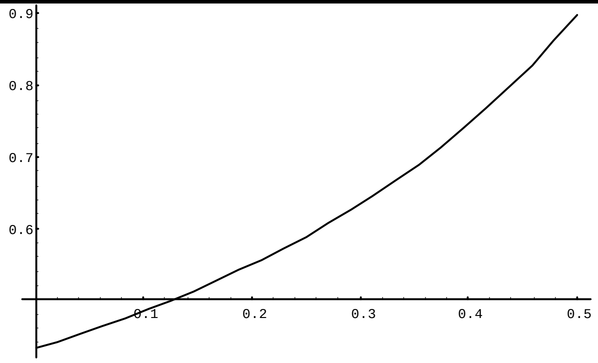
3.B.8. Government Revenue



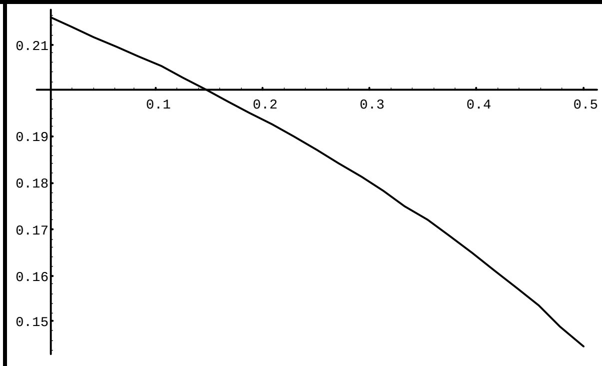
3.B.9. High-Quality Price



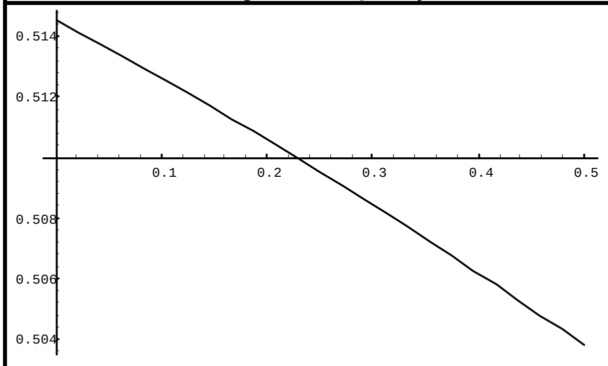
3.B.10. Low-Quality Price



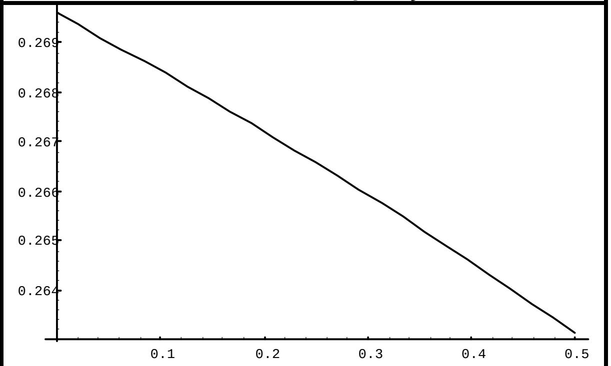
3.B.11. High Price/Quality Ratio



3.B.13. Low Price/Quality Ratio

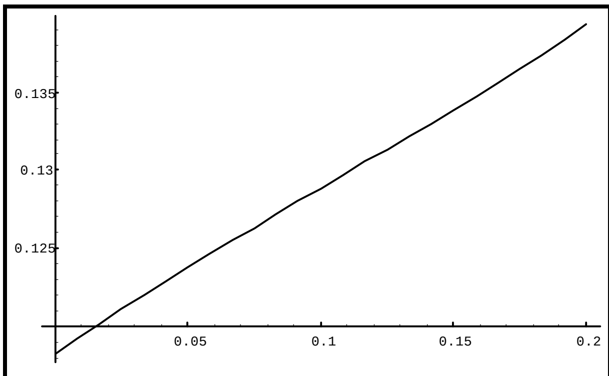


3.B.13. High-Quality Quantity

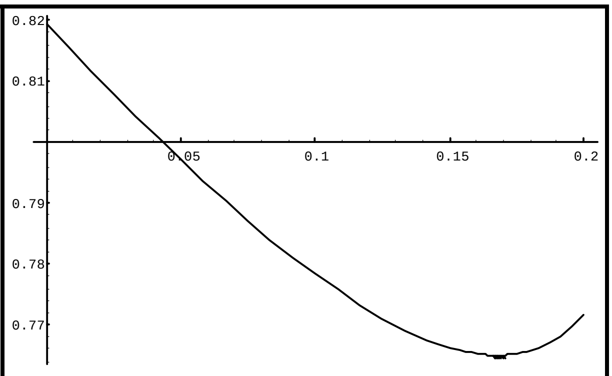


3.B.14. Low-Quality Quantity

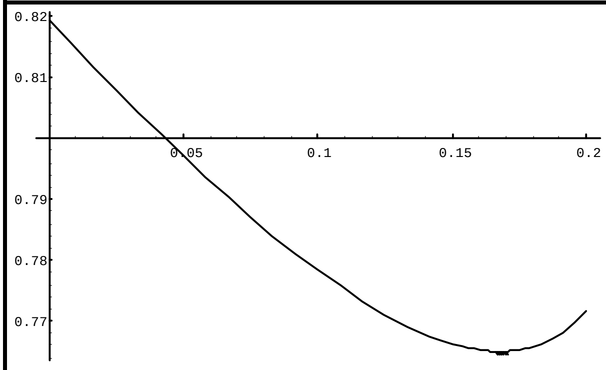
Case 4.A. Quality-Dependent Variable Costs
(Foreign High-Quality Firm)



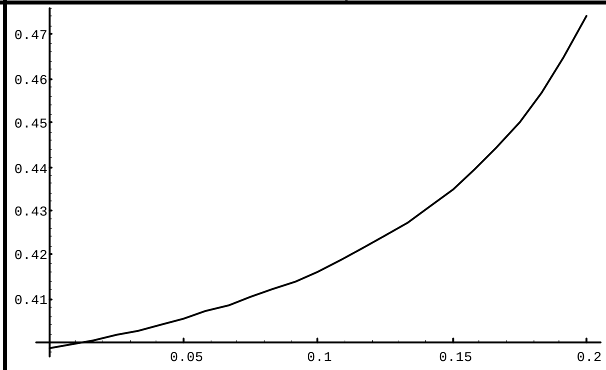
4.A.1. Welfare



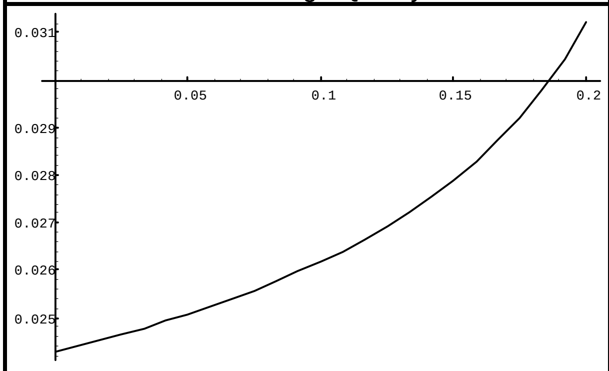
4.A.2. Quality Ratio



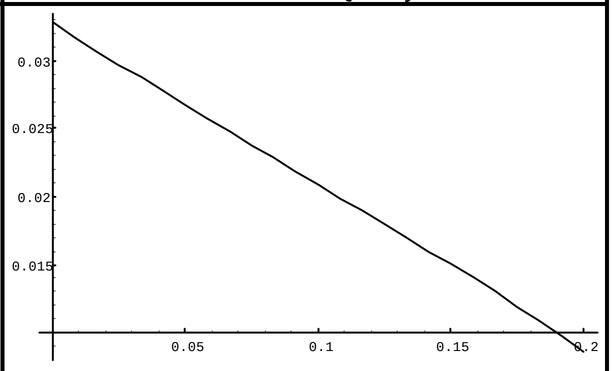
4.A.3. High Quality



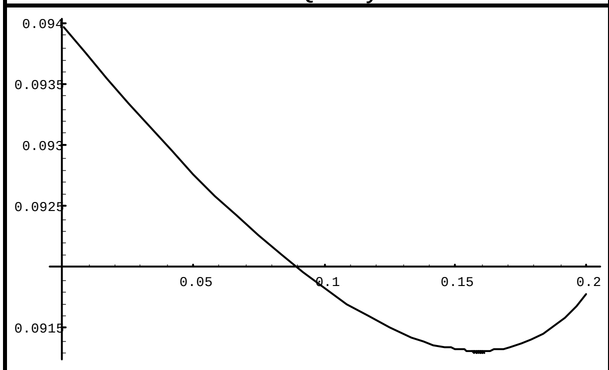
4.A.4. Low Quality



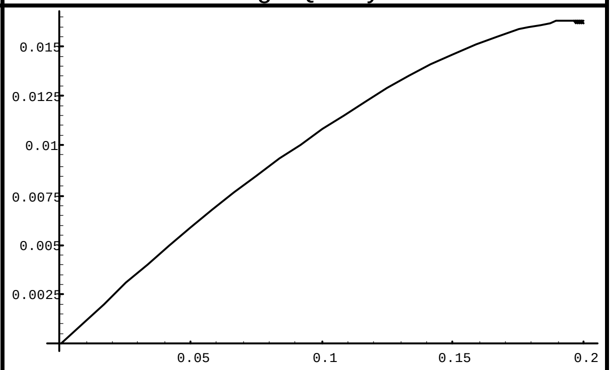
4.A.5. Low-Quality Profits



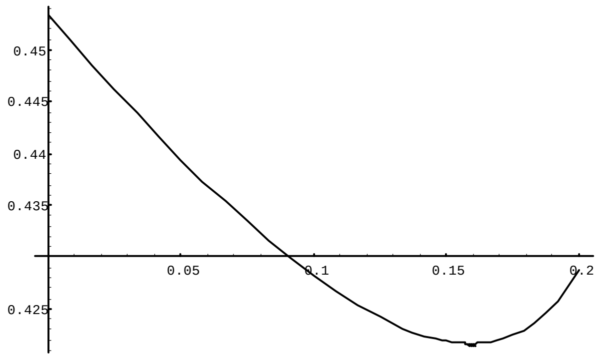
4.A.6. High-Quality Profits



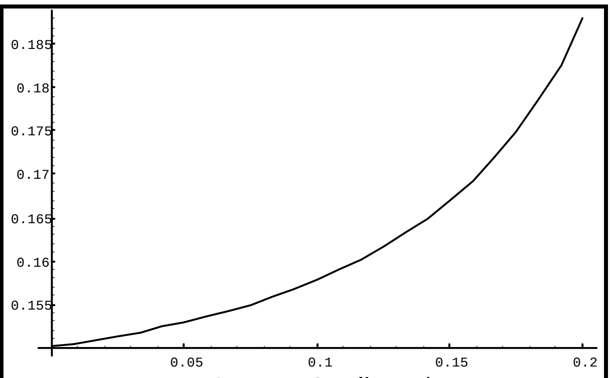
4.A.7. Consumer Surplus



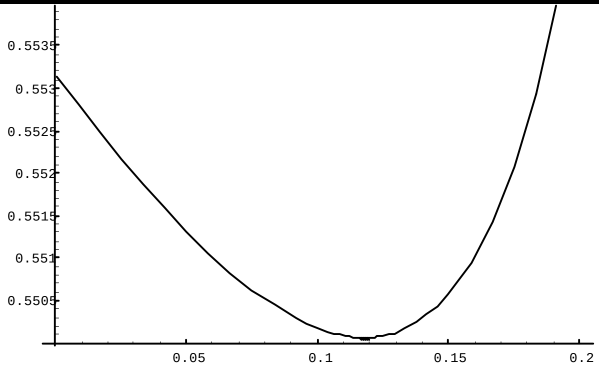
4.A.8. Government Revenue



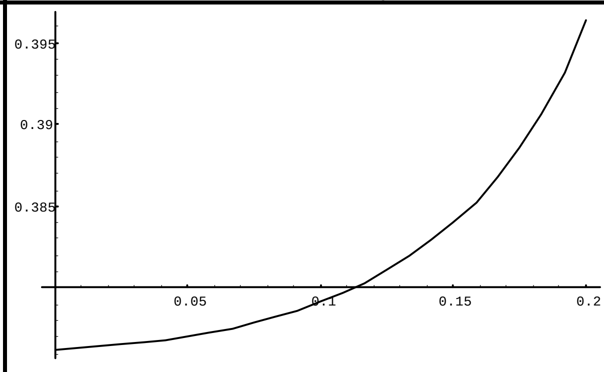
4.A.9. High-Quality Price



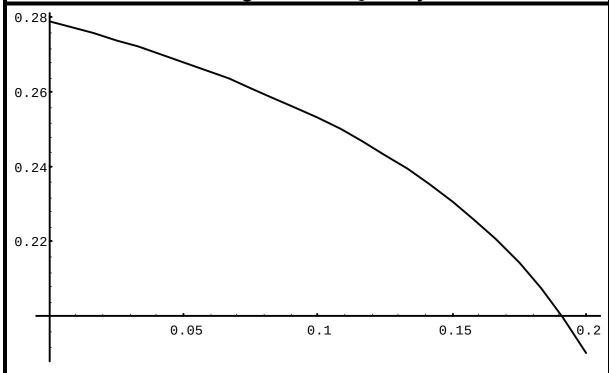
4.A.10. Low-Quality Price



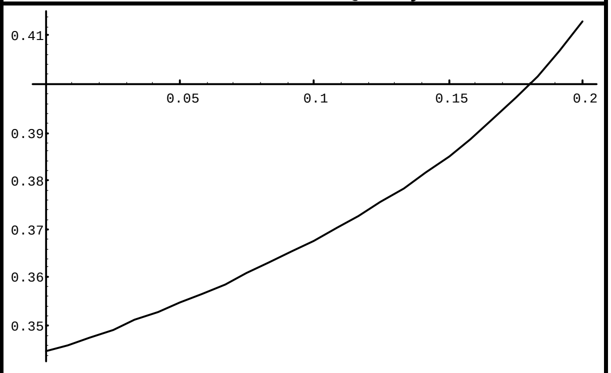
4.A.11. High Price/Quality Ratio



4.A.13. Low Price/Quality Ratio

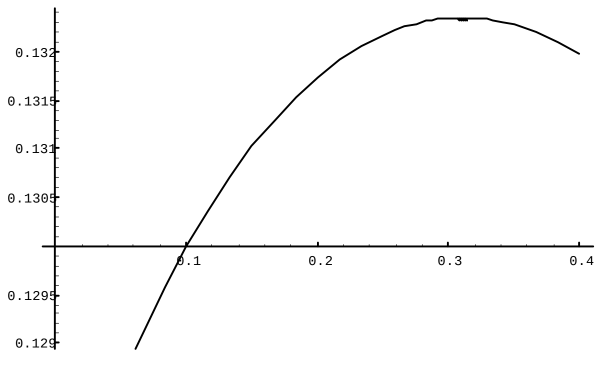


4.A.13. High-Quality Quantity

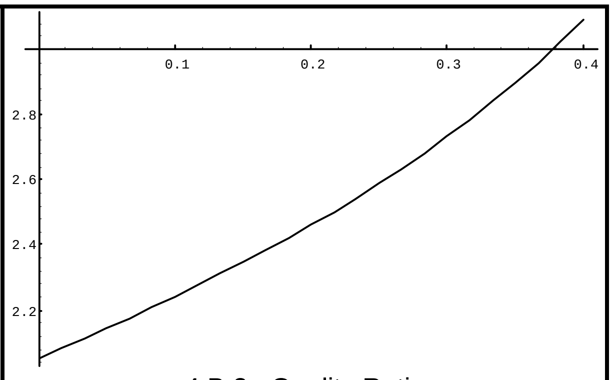


4.A.14. Low-Quality Quantity

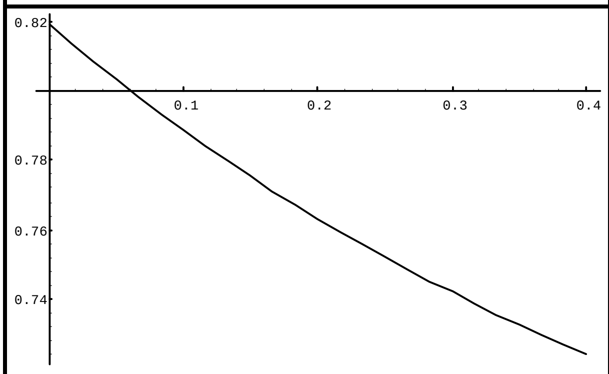
Case 4.B. Quality-Dependent Variable Costs
(Foreign Low-Quality Firm)



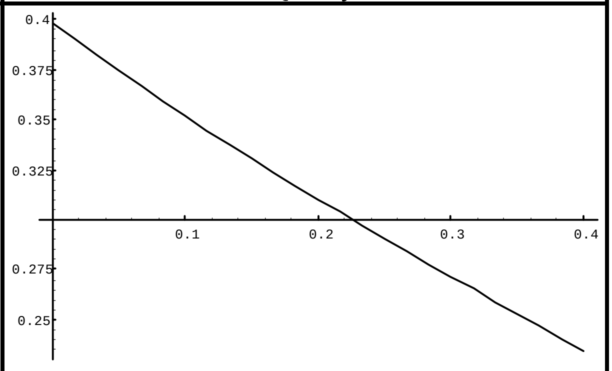
4.B.1. Welfare



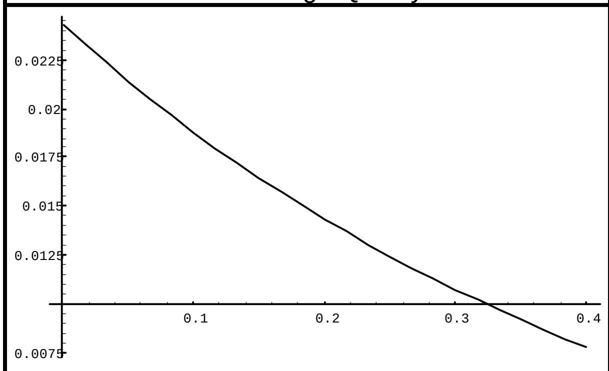
4.B.2. Quality Ratio



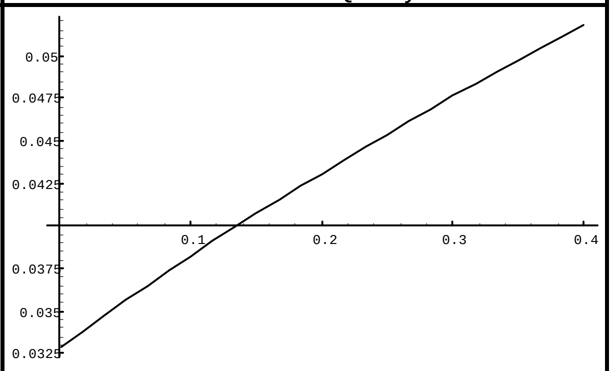
4.B.3. High Quality



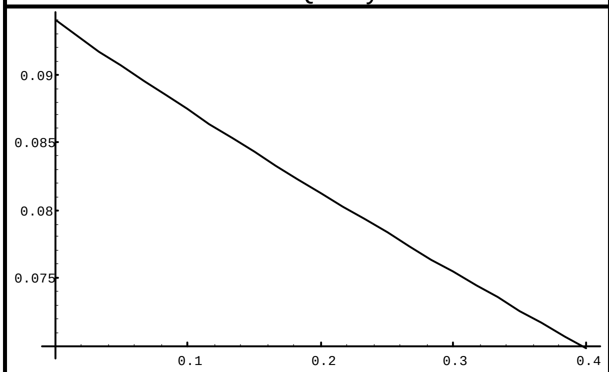
4.B.4. Low Quality



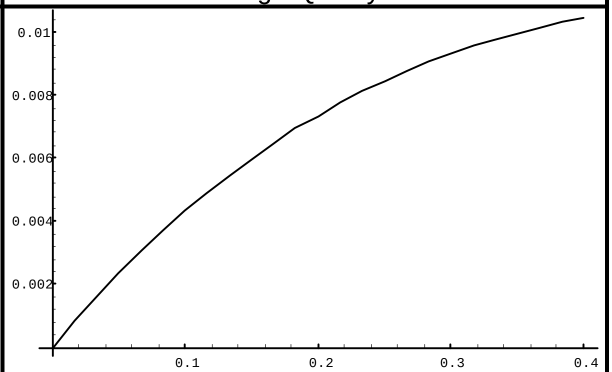
4.B.5. Low-Quality Profits



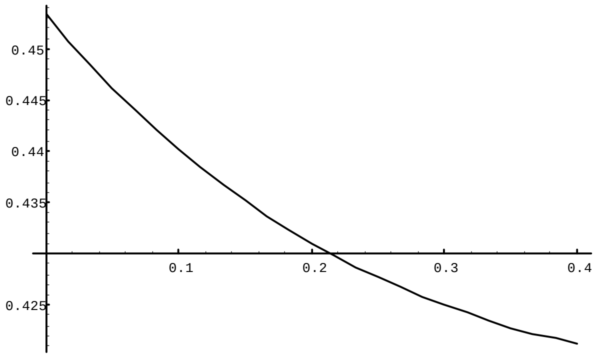
4.B.6. High-Quality Profits



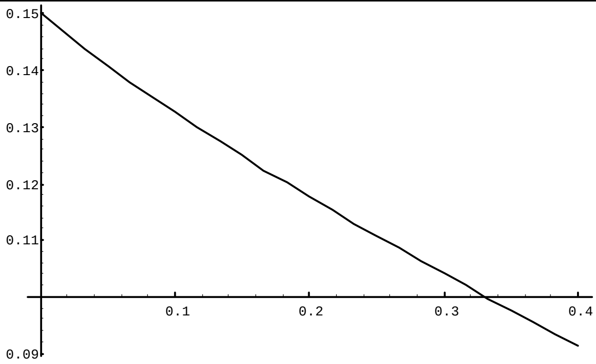
4.B.7. Consumer Surplus



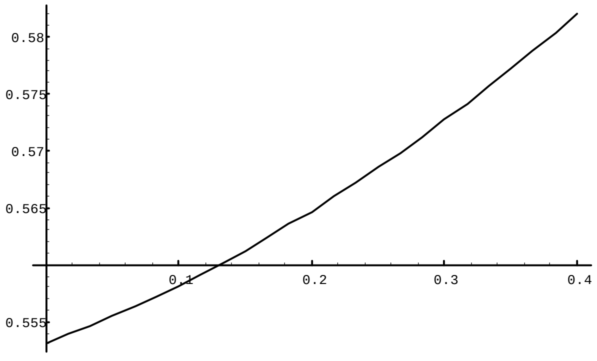
4.B.8. Government Revenue



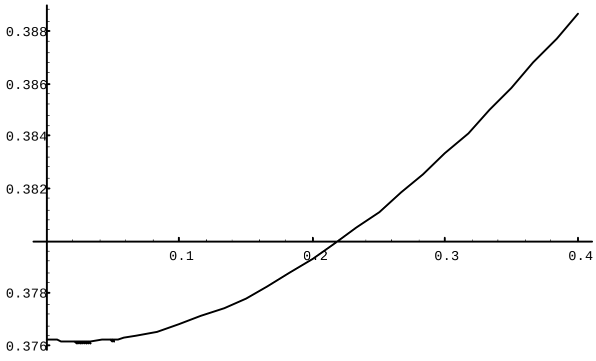
4.B.9. High-Quality Price



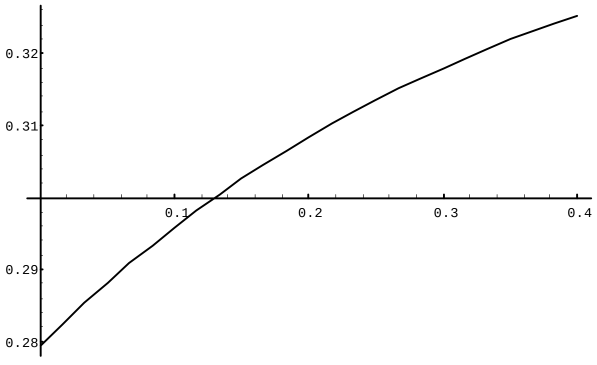
4.B.10. Low-Quality Price



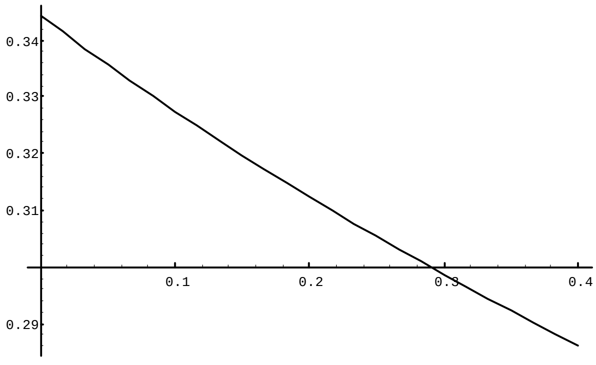
4.B.11. High Price/Quality Ratio



4.B.13. Low Price/Quality Ratio

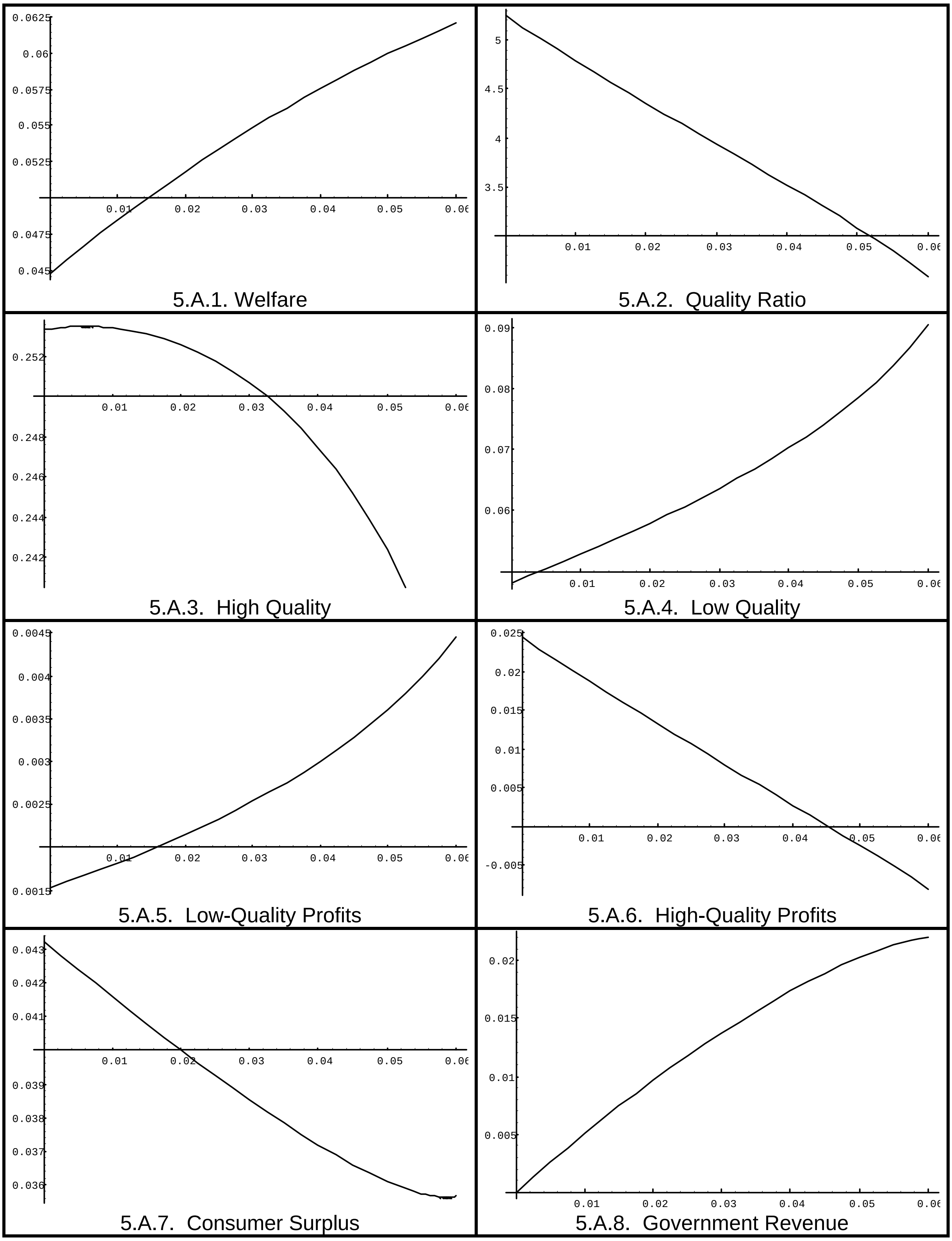


4.B.13. High-Quality Quantity



4.B.14. Low-Quality Quantity

Case 5.A. Specific Tariffs and Quality-Dependent Fixed Costs
(Foreign High-Quality Firm)



5.A.1. Welfare

5.A.2. Quality Ratio

5.A.3. High Quality

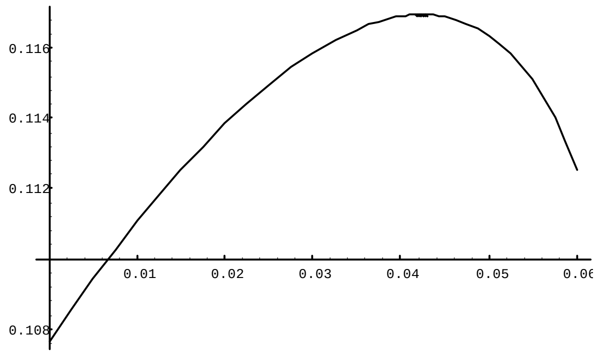
5.A.4. Low Quality

5.A.5. Low-Quality Profits

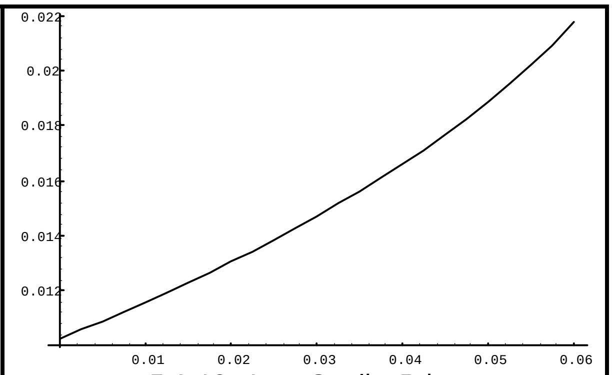
5.A.6. High-Quality Profits

5.A.7. Consumer Surplus

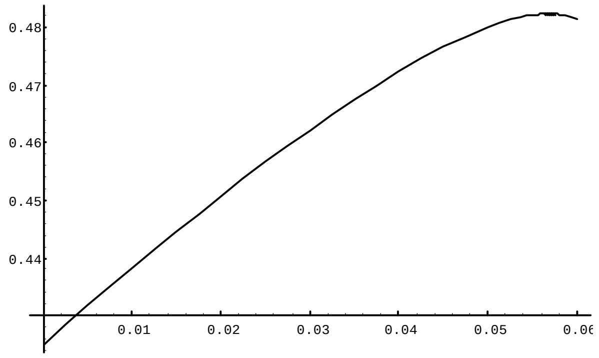
5.A.8. Government Revenue



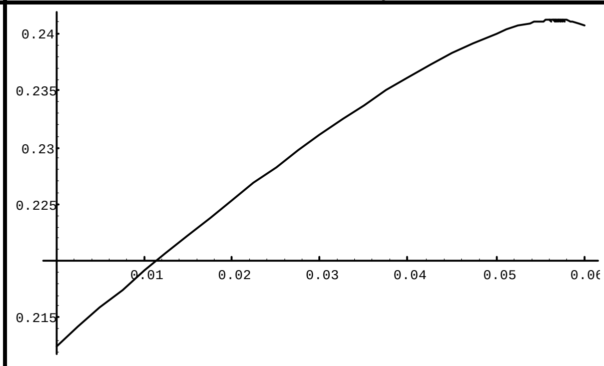
5.A.9. High-Quality Price



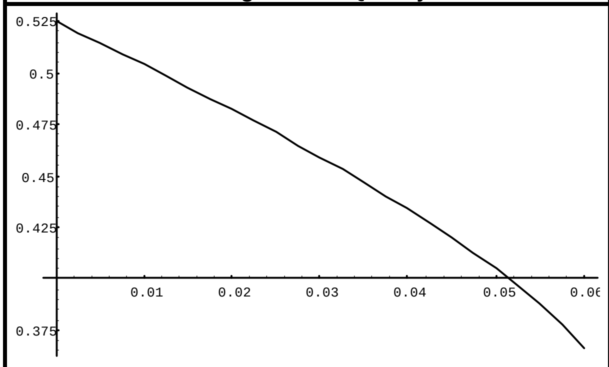
5.A.10. Low-Quality Price



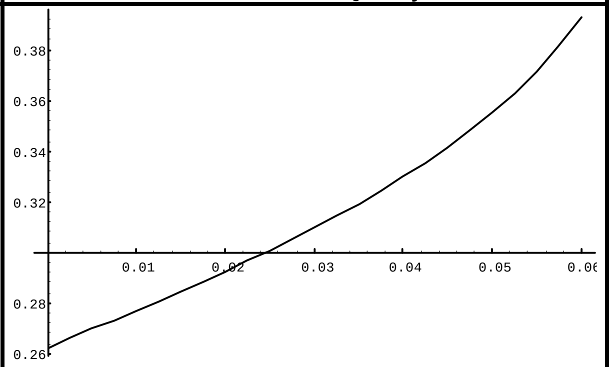
5.A.11. High Price/Quality Ratio



5.A.13. Low Price/Quality Ratio

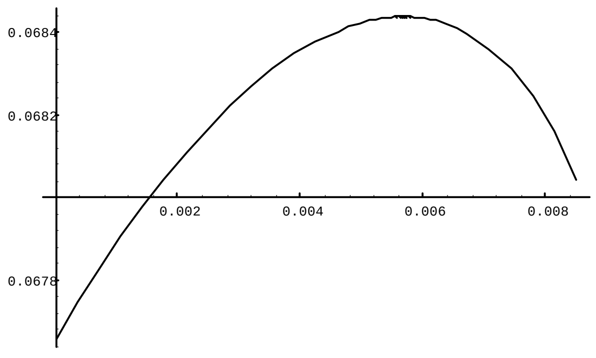


5.A.13. High-Quality Quantity

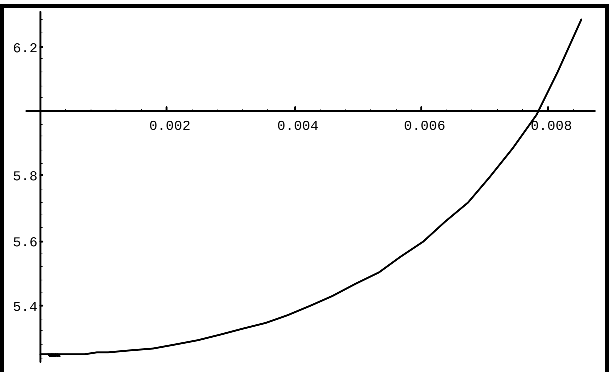


5.A.14. Low-Quality Quantity

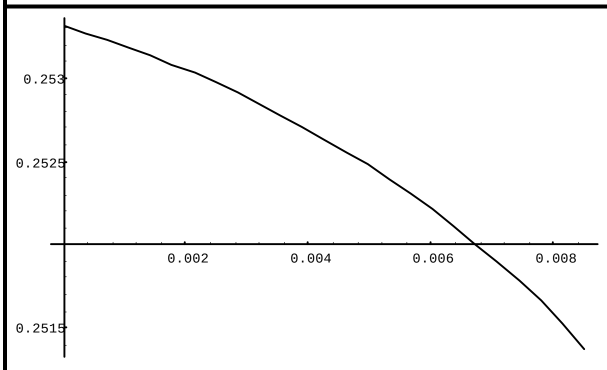
Case 5.B. Specific Tariffs and Quality-Dependent Fixed Costs
(Foreign Low-Quality Firm)



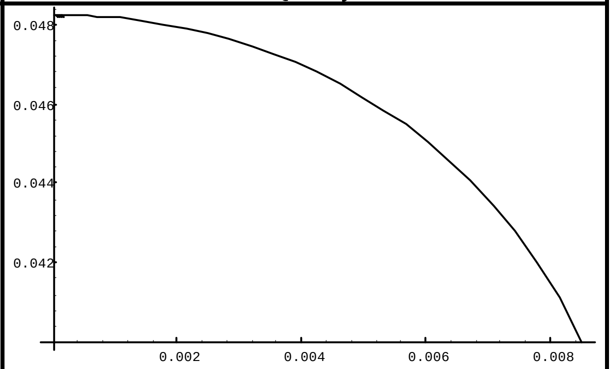
5.B.1. Welfare



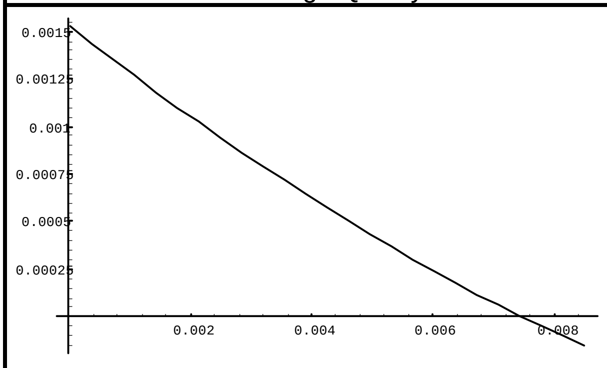
5.B.2. Quality Ratio



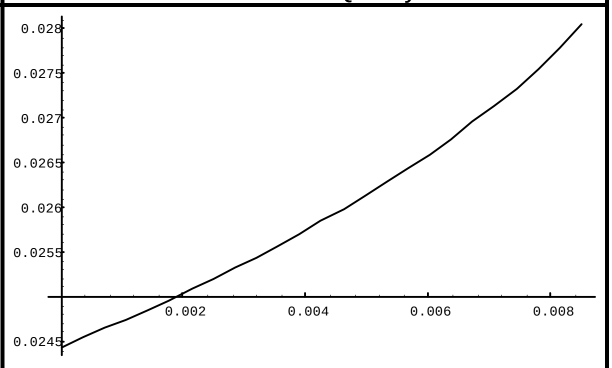
5.B.3. High Quality



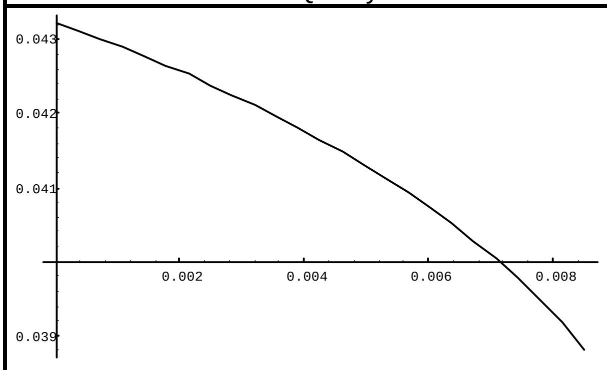
5.B.4. Low Quality



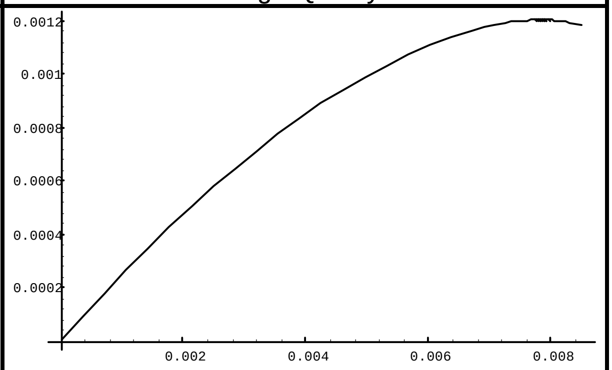
5.B.5. Low-Quality Profits



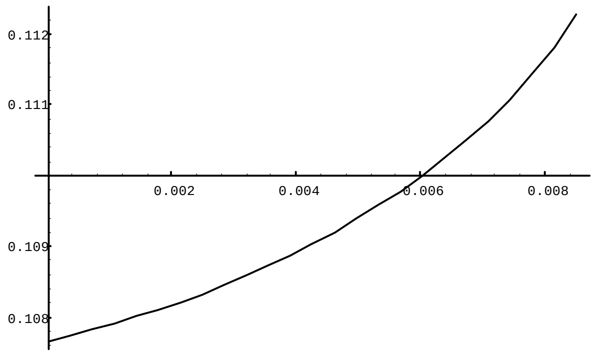
5.B.6. High-Quality Profits



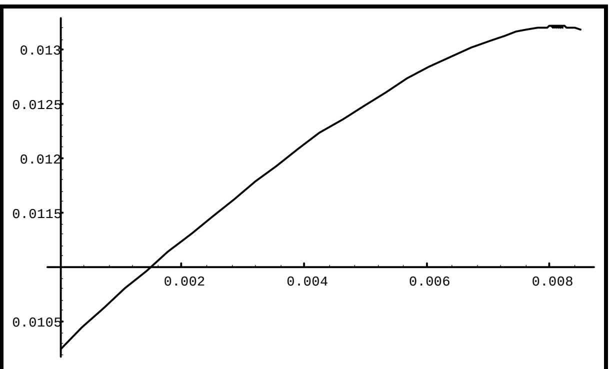
5.B.7. Consumer Surplus



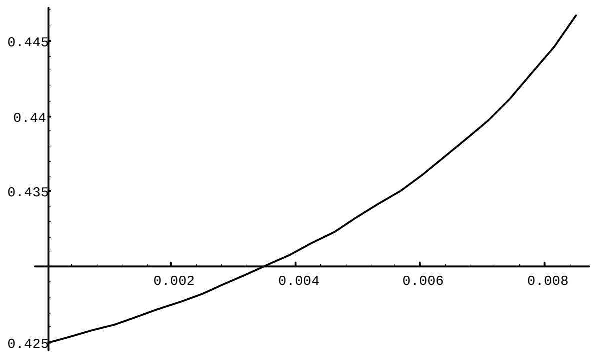
5.B.8. Government Revenue



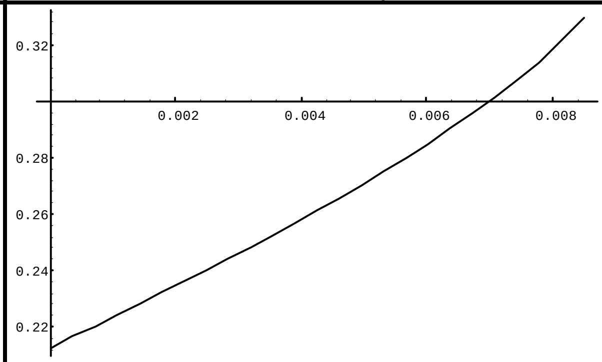
5.B.9. High-Quality Price



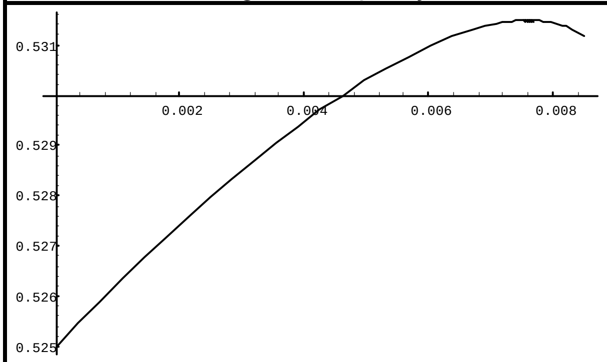
5.B.10. Low-Quality Price



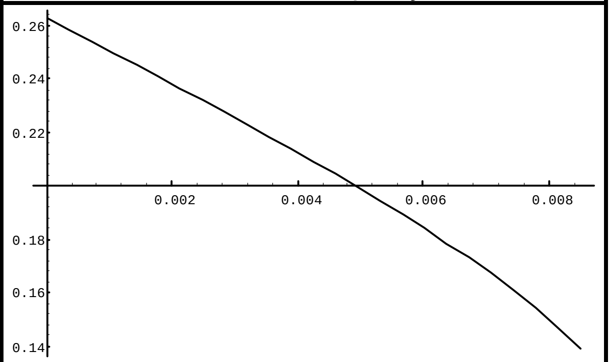
5.B.11. High Price/Quality Ratio



5.B.13. Low Price/Quality Ratio

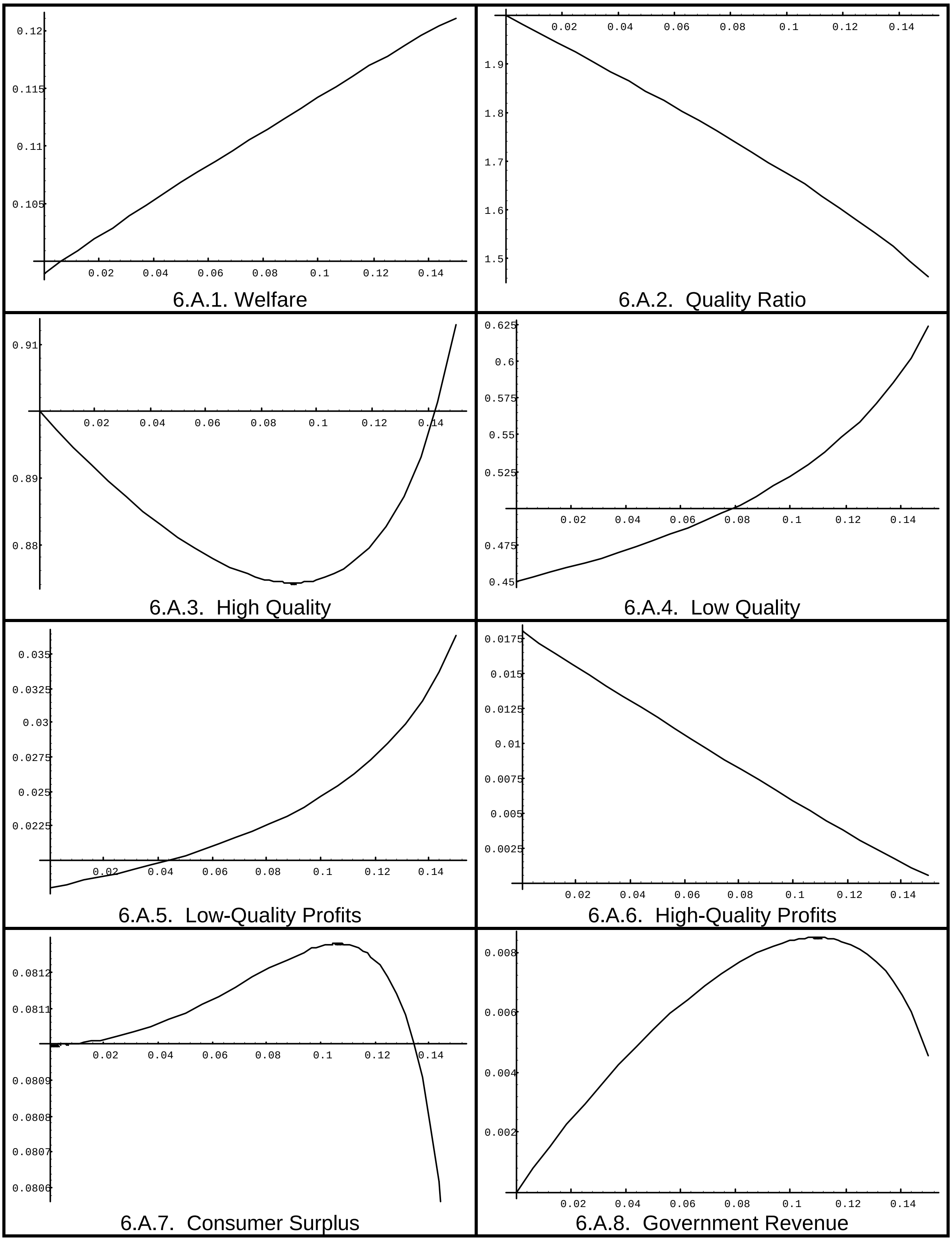


5.B.13. High-Quality Quantity



5.B.14. Low-Quality Quantity

Case 6.A. Quality-Dependent Variable Costs / Covered Market
(Foreign High-Quality Firm)



6.A.1. Welfare

6.A.2. Quality Ratio

6.A.3. High Quality

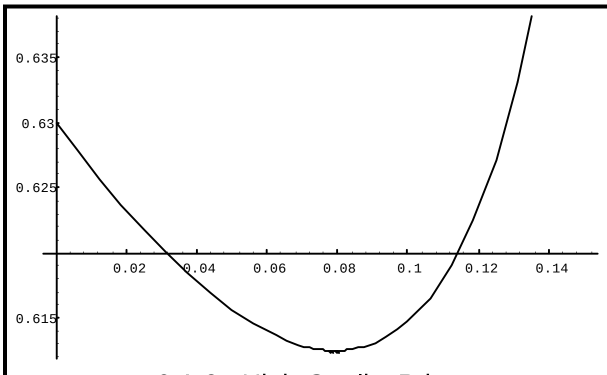
6.A.4. Low Quality

6.A.5. Low-Quality Profits

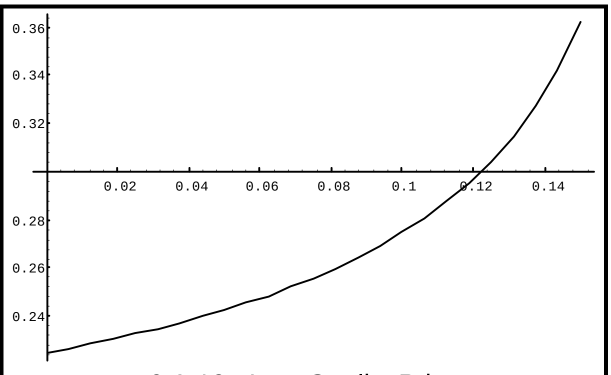
6.A.6. High-Quality Profits

6.A.7. Consumer Surplus

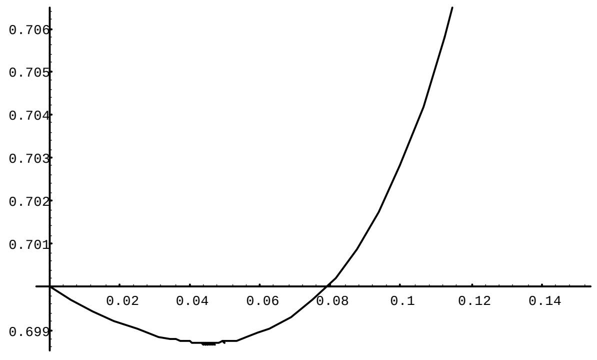
6.A.8. Government Revenue



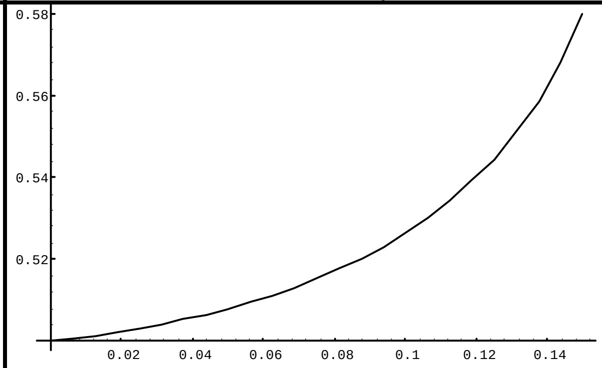
6.A.9. High-Quality Price



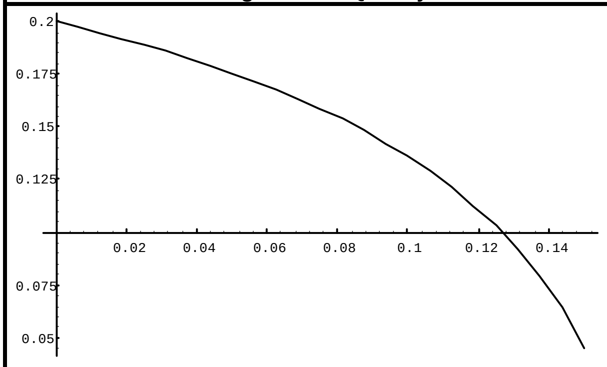
6.A.10. Low-Quality Price



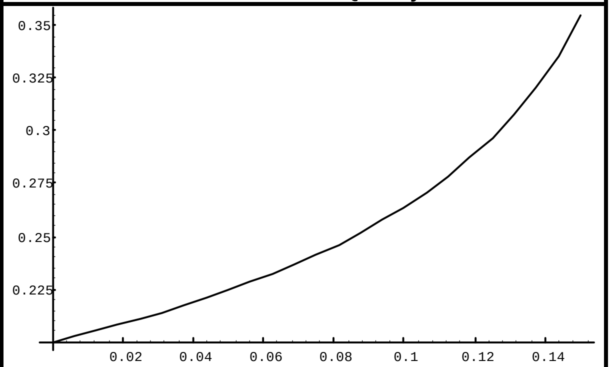
6.A.11. High Price/Quality Ratio



6.A.13. Low Price/Quality Ratio

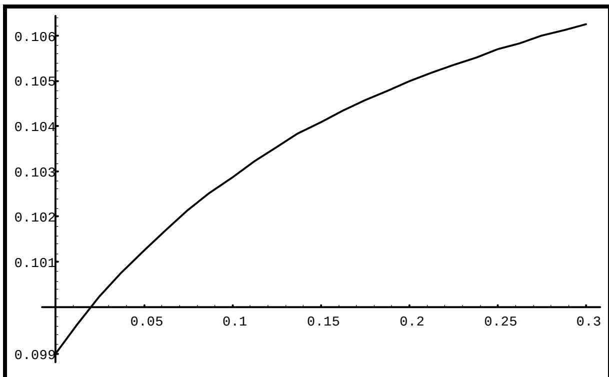


6.A.13. High-Quality Quantity

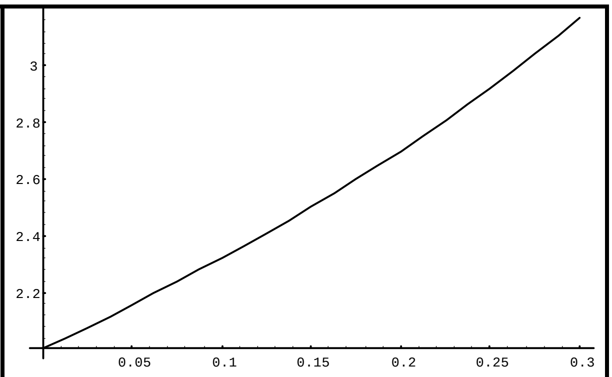


6.A.14. Low-Quality Quantity

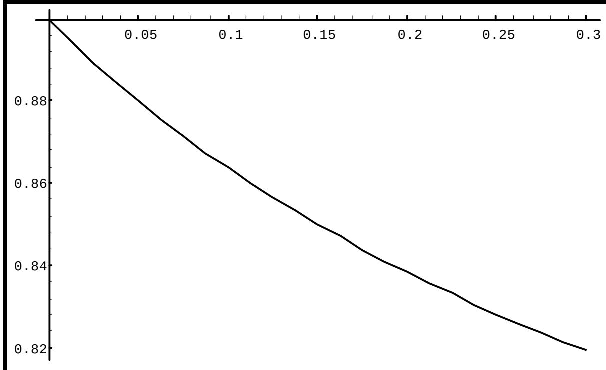
Case 6.B. Quality-Dependent Variable Costs / Covered Market
(Foreign Low-Quality Firm)



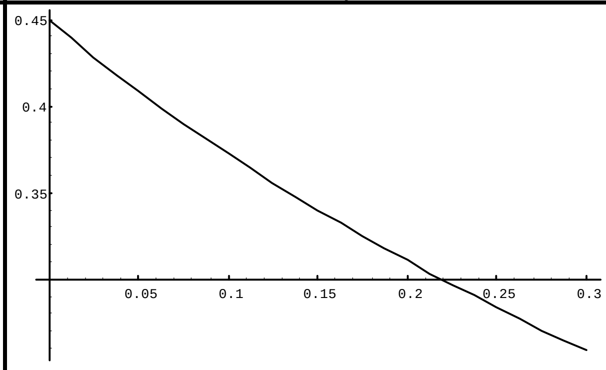
6.B.1. Welfare



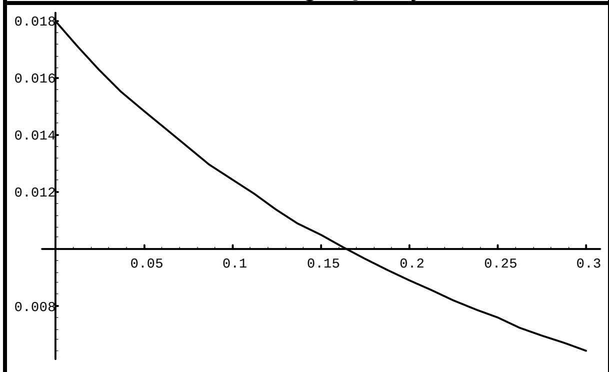
6.B.2. Quality Ratio



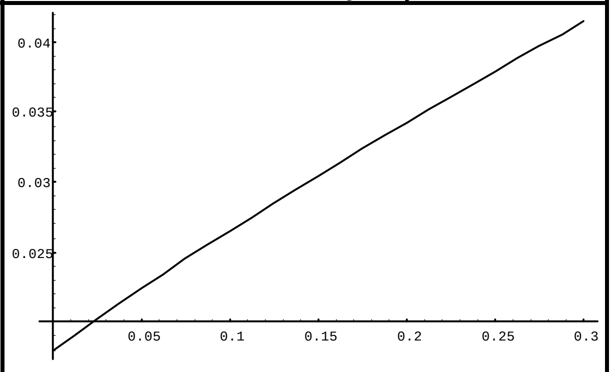
6.B.3. High Quality



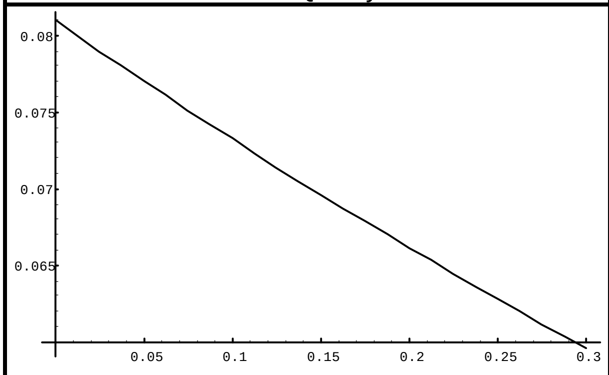
6.B.4. Low Quality



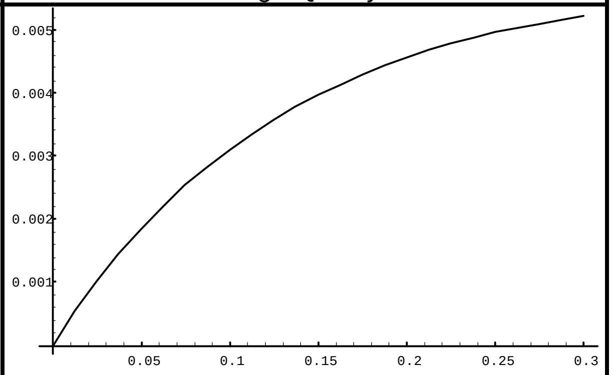
6.B.5. Low-Quality Profits



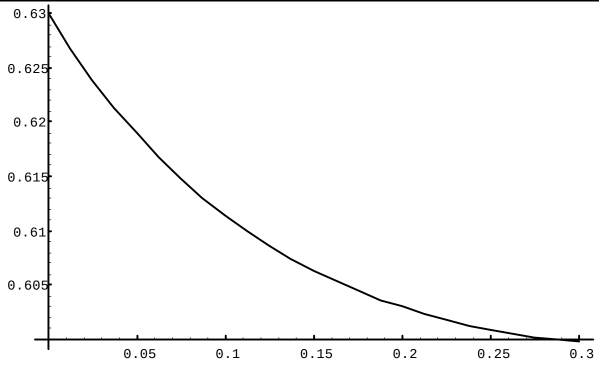
6.B.6. High-Quality Profits



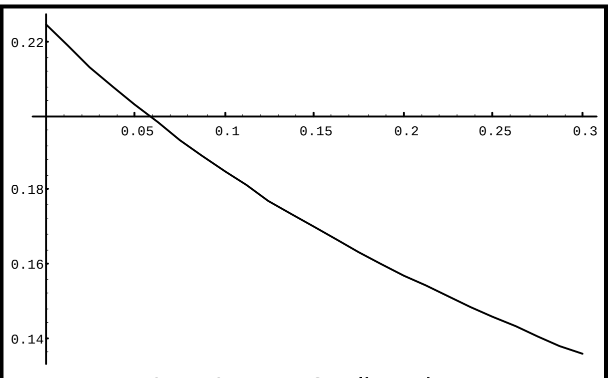
6.B.7. Consumer Surplus



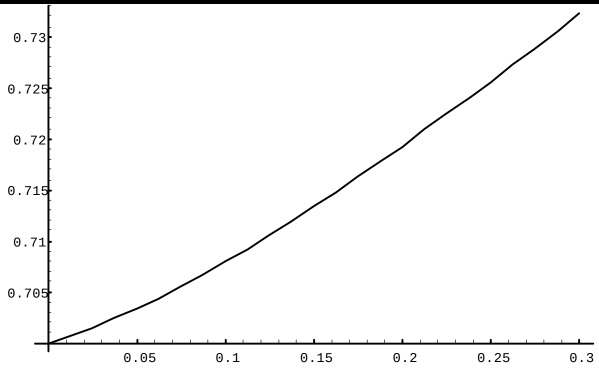
6.B.8. Government Revenue



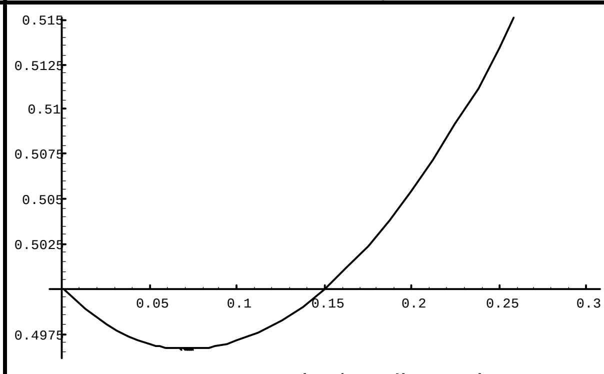
6.B.9. High-Quality Price



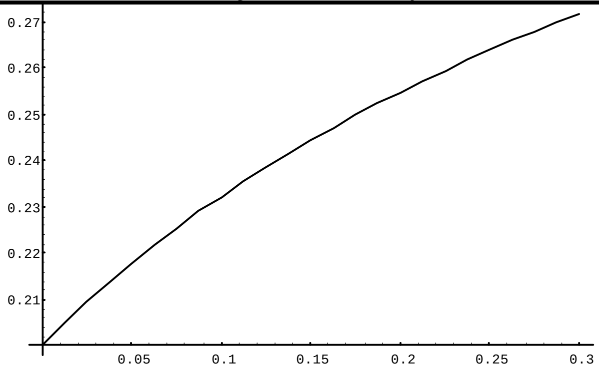
6.B.10. Low-Quality Price



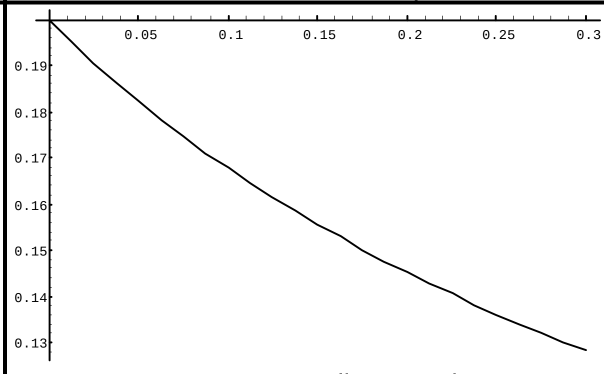
6.B.11. High Price/Quality Ratio



6.B.13. Low Price/Quality Ratio



6.B.13. High-Quality Quantity



6.B.14. Low-Quality Quantity

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