Chapter 2
"Antitrust Policy" Versus "Industrial Policy"

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Put in the context of international trade, what is viewed as an industrial policy in the existing literature may be thought of as a type of antitrust policy to seek for a beggar-thy-neighbor effect by permitting (or promoting) its manufacturing sector to take anti-competitive actions. This study demonstrates that in order to retaliate against such an industrial policy, a country may suppress competition in its service sector. For this purpose, we build a simple partial equilibrium version of the Sanyal-Jones model and demonstrate that a state in which a country suppresses competition in its manufacturing sector at the same time that its trading partner country suppresses competition in its service sector can be supported as a Nash equilibrium. In our setting, antitrust policy on the service sector is an effective policy tool only for retaliation. In other words, perfect competition can be maintained throughout the world unless the exporting country adopts an anti-competitive industrial policy, thereby triggering a retaliatory action.

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1 Introduction

Since Yano (2001) and Yano and Dei (2003), a number of studies have investigated the role of competition policy as a substitute for tariff policy, creating a favorable terms-of-trade effect. The most notable finding in the literature may be the asymmetric effect of competition policy between trading countries. That is to say, if one country can benefit from suppressing competition in its retail (service) sector, it is optimal for the trading partner country to maintain perfect competition in that country's retail sector. Under such circumstances, as Yano and Honryo (2011a) show, it is extremely difficult to harmonize competition policies internationally.

This result shows that suppression of competition in the service sector can be used as a self-benefiting beggar-thy-neighbor policy whereas it is no use as a defensive policy against another country's adoption of such a policy. This leads to a natural question as to whether or not an anti-competitive policy on service sector in the real world should always be characterized as a self-benefiting aggressive policy. Since the 1980s, for example, the U.S. government has drastically eased the strict use of antitrust law on its banking industry. As a result, many mega banks, which the U.S. did not have in the previous era, have been created. Should such a change be characterized as the unilateral adoption of a beggar-thy-neighbor policy?

In order to investigate this issue, we focus on the interaction between industrial policy and antitrust policy. We follow the standard literature on Japanese economy by referring to a country's controlling the manufacturing sector's degree of competition as industrial policy, which has been regarded as a driving force of the Japanese high-speed economic growth in the period between the mid 1950s and the mid 1970s.[1] This type of policy is difficult to maintain unless, as in Japan during that period, the manufacturing sector is completely protected from international competition and is permitted freely to export to the world market. As antitrust policy, in contrast, we refer to a policy of controlling competition on a country's non-tradable sector. In most developed countries, this type of policy is incorporated by competition laws, as presented by the U.S. antitrust law. Although the U.S. law includes an extraterritorial application clause, it has been difficult for a single country directly to control the degree of competition in another country's non-tradable sector. We refer to this type of policy as antitrust policy in order to distinguish it from what we call industrial policy.

In order to construct a two-country game in which each country controls the degrees of competition in both its manufacturing and service sectors, we build a two-country partial equilibrium model in which one country is specialized in manufacturing a tradable middle product that is transformed into a final consumption good in each country. As in Yano and Honryo (2010, 2011a, b), it is assumed that the governments of the two countries play a game in which they

[1] For a general discussion on industrial policy, see Komiya et al. (1988).

control the degrees of competition so as to maximize their respective countries' welfare.

Our main finding is that in a Nash equilibrium the exporting country of a manufactured product suppresses competition in its manufacturing sector at the same time that the importing country retaliates against this policy by suppressing competition in its service sector. We demonstrate that this strategy of the importing country is purely retaliatory; so long as the exporting country maintains perfect competition in its manufacturing sector, there is no incentive for the importing country to adopt anti-competitive policy in its service sector.

These results cast a new light on the U.S.-Japan trade relationship since the end of the WWII. From the 1950s through the 1980s, on the one hand, Japan exported an enormous volume of manufactured products to the U.S., including textiles, TVs and other electronic products, and cars. During this period, anti-competitive actions were sometimes promoted explicitly by the government (voluntary export restraint on cars in the 1980s) and some other times accused to be promoted (see Matsushita Elec. Industrial Co. v. Zenith Radio, 475 U.S. 574 (1986)). In the 1980s, on the other hand, the U.S. started easing its antitrust law applications in its banking industry and, since then, has created huge financial institutions, covering both banking and securities business.

Our results provide a new explanation for the sequence of these phenomena, regarding the recent development of mega banks as triggered by the Japanese industrial policy during the post WWII period. We show that a country's imposition of a beggar-thy-neighbor policy on international market may meet the retaliatory action from other countries through policy impositions on their domestic markets. This is only possible by constructing a framework in which we can analyze the effects of a country's internal policies such as anti-competitive practices in banking industry, on international trade.

Our tradable/non-tradable sector model is a highly streamlined version of the general equilibrium trade model developed in the seminal work by Sanyal and Jones (1982). Their model has been shown to be particularly useful for the analysis of cross-border effects of competition policy. Yano (2001) transforms the model into a dynamic general equilibrium model and demonstrates that a trade-surplus country can use anti-competitive policy on its non-tradable service sector as a beggar-thy-neighbor policy just like a tariff policy. Yano and Dei (2003) and Yano and Honryo (2011b) examine a similar issue in a static general equilibrium model. See Yano and Dei (2004, 2007); Takahashi (2005); Ota (2006); Honryo and Yano (2006); Yano et al. (2006); Takahashi et al. (2008) and Ma (2009) for further studies.

In a broader context, the effects of competition policies are studied by Richardson (1999); Horn and Levinsohn (2001); Francois and Horn (2006) and De Stefano and Rysman (2010). Those studies, in general, demonstrate that an exporting country can become better off by restricting competition in its export sector. Yano and Honryo (2011b), in contrast, demonstrates that an importing country can become better off by restricting competition in its non-tradable service sector, which transforms tradable middle products into final consumption goods and sells them in the domestic market.

Since Brander and Spencer (1985), a large literature has developed on industrial policy in an imperfectly competitive market. A survey on that literature is beyond the scope of this study [see Feenstra (2004, Chap. 8)]. In that literature, industrial policy tool toward the export sector is export subsidy. By contrast, in this study, industrial policy controls the degree of competition in the export sector.

In what follows, we introduce a model and state our main result in Sect. 2. A proof for the result is given in the appendix.

2 Simple Sanyal-Jones Model

In this section, we introduce a partial equilibrium model in which the government of each country sets a degree of competition in its markets.

Our model follows Sanyal and Jones (1982), which highlight the interaction between the tradable middle product sector and the non-tradable final consumption good sector. The Sanyal-Jones model is built on a general equilibrium trade model. In their model, it is assumed that primary productive factors produce commodities (middle products) that can be traded on world markets but are never consumed directly as final products. The final consumption sector transforms middle products obtainable on the world market to produce final (non-traded) consumption goods. As Yano (2001) shows, this setting is highly useful to analyze the role of what we call antitrust policy in this study.

The suppression of competition takes in the form of restricting the number of firms. In that case, Cournot competition is assumed to take place. Otherwise, perfect competition takes place with infinitely many firms. The assumption that the middle product good is produced in one country is adopted so as to treat the effect of an industrial policy in the exporting country in the simplest manner; if the good is produced in both countries, the effect of a country's industrial policy cannot be captured under the assumption of Cournot competition.

We adopt a partial equilibrium model in which, in each country, the final consumption sector transforms a tradable middle product M into a non-tradable final consumption good X. The middle product is manufactured only in the home country. For the sake of simplicity, we assume that one unit of the middle product can be transformed into one unit of the final good without any cost.

In both middle product and final good markets, Cournot competition takes place. The marginal cost of an individual home middle product producer is increasing in its output, y. Let $c = c(y)$ be the total cost function; assume $c(0) > 0$; $c' > 0$ and $c'' > 0$.

The demand for the final non-traded consumption good, X, in the home and foreign countries are represented by linear inverse demand functions $p = -aX + b$ and $p^* = -a^*X^* + b$, respectively, where p and $p*$ are the prices of good X in the home and foreign countries.

The government of the home country controls the degrees of competition in its final consumption good sector and in the middle product sector by changing the number of firms in those sectors, m and n, respectively. If $m = \infty$ ($n = \infty$), the final consumption sector (the middle product sector) is perfectly competitive. The government of the foreign country controls the degree of competition in its final consumption good sector only, m^*; the foreign country does not, by assumption, produce the middle product.

The firms behave in the Cournot-Nash fashion. In the home country's final consumption good sector, the production plan of firm j, $j = 1, \ldots, m$, is described by the following maximization problem:

$$\max_{x_j} \left\{ -a\left(x_j + \sum_{i \neq j} x_i \right) + b \right\} x_j - q x_j$$

where q is the world price of the middle product. By the symmetry of an equilibrium, the first order condition for this problem is:

$$-amx + b - ax - q = 0. \tag{1}$$

In the foreign country, the first order condition is

$$-a^* m^* x^* + b - a^* x^* - q = 0. \tag{2}$$

The market clearing condition for good M is

$$mx + m^* x^* = Y \tag{3}$$

where Y is the aggregate output of the middle product.

Given the world supply of the middle product, Y, the equilibrium conditions in the final consumption good markets can be described by (1), (2), and (3). By solving these conditions for x, x^* and q, given Y, m and m^*, we obtain the derived demand function for the middle product, relating the middle product output, Y, to the middle product price, q. Denote the inverse derived demand function by $q = Q(Y; m, m^*)$. Then, in the (home) middle product sector, the production plan of firm $j, j = 1, \ldots, n$, is described by the following maximization problem

$$\max_{y_j} Q\left(y_j + \sum_{i \neq j}^{n} y_i; m, m^* \right) y_j - c(y_j).$$

Since the middle product producers are symmetric, the first order condition for optimization is

$$Q(ny; m, m^*) + Q'(ny; m, m^*)y - c'(y) = 0, \tag{4}$$

which determines an individual firm's output level, y. Our equilibrium is given by (4), with the inverse derived demand function, Q, that is determined endogenously by (1), (2), and (3).

3 Policy Game

We assume that the governments of the home and foreign countries play a game of competition and industrial policies. Each government's return in the game is the sum of consumer and producer surpluses. In order to describe the game explicitly, denote by $y(n,m,m^*), x(n,m,m^*)$, and $x^*(n,m,m^*)$ the middle product output, the home final good consumption, and the foreign final good consumption in market equilibrium for the case in which the home country sets the number of firms in the middle product market at n (industrial policy) and that in the final good market at m (antitrust policy) and in which the foreign country sets the number of firms in the final good market at m^* (antitrust policy). Moreover, let $p(n,m,m^*)$ and $q(n,m,m^*)$ be the corresponding equilibrium prices of good X and M. Finally, denote by $U = U(X)$ and $U^* = U^*(X^*)$ the total willingness to pay of home and foreign consumers, respectively.

Since we assume that one unit of the middle product can be transformed into one unit of the final good without any cost, the home government's return can be expressed as a function of n, m and m^* as follows:

$$
\begin{aligned}
W(n,m,m^*) = \int_0^{mx(n,m,m^*)} & U(X)dX - m[p(n,m,m^*)x(n,m,m^*)] \\
& + m[p(n,m,m^*)x(n,m,m^*) - q(n,m,m^*)x(n,m,m^*)] \\
& + n\left[q(n,m,m^*)y(n,m,m^*) - \int_0^{y(n,m,m^*)} c'(y)dy\right];
\end{aligned}
$$

the term on the first line on the right-hand side of this expression is the consumer surplus, that on the second line the producer surplus of the final consumption good sector, and that on the third line the producer surplus of the middle product sector. The foreign government's return can be expressed in a similar, but simpler, form:

$$
\begin{aligned}
W^*(n,m,m^*) = \int_0^{m^*x^*(n,m,m^*)} & U^*(X^*)dX^* - m^*[p^*(n,m,m^*)x^*(n,m,m^*)] \\
& + m^*[p^*(n,m,m^*)x^*(n,m,m^*) - q(n,m,m^*)x^*(n,m,m^*)].
\end{aligned}
$$

Our policy game is

$$
G = (W(n,m,m^*), W^*(n,m,m^*)),
$$

in which the home government strategically chooses n and m and in which the foreign government chooses m^*.

As is well known, in general, the equilibrium of a Cournot game converges to a perfectly competitive equilibrium as the number of firms becomes infinity. This holds in the present model as well. In the case in which the home country maintains perfect competition in the middle product sector, it holds that $Q(Y) = q = c'(0)$. Similarly, in the case in which the home country maintains perfect competition in the final consumption good sector, it holds that $p = q$. Finally, in

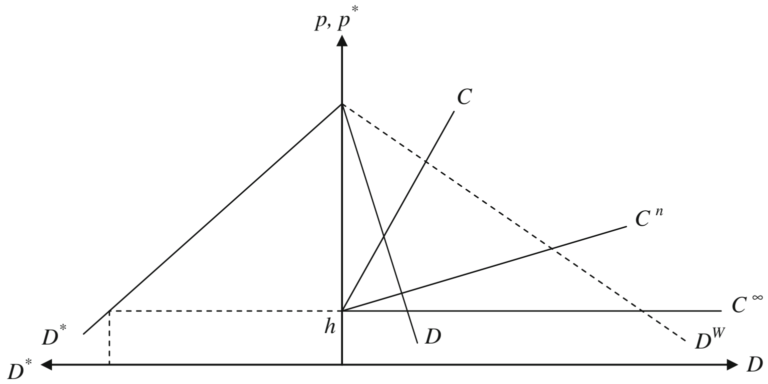


Fig. 1 Markets for middle product and final good

the case in which the foreign country maintains perfect competition in the final consumption good sector, it holds that $p^* = q$.

Let the home country's individual firm's marginal cost function be $c'(y) = gy + h$. In order to exclude a trivial case, we assume

$$b > h. \tag{5}$$

The next lemma implies that it is optimal for the home country (exporter of the middle product) to maintain perfect competition in its final consumption good sector. (See the Appendix for a proof.)

Lemma 1 $\partial W(n, m, m^*)/\partial m > 0$.

Lemma 1 shows that it is optimal for the exporting country always to maintain perfect competition in its final consumption good sector, $m = \infty$. This implies that n and m^* may be thought of as the strategies of game G.[2]

In order to analyze this game, in Fig. 1, curves D and D^* illustrate the home and foreign demand curves for the final consumption good. Curve C illustrates the marginal cost curve of an individual home middle product producer. Moreover, curve C^n relates p to ny, given $c'(y) = p$. This curve, C^n, may be thought of as the country-wide marginal cost curve, which relates aggregate output Y to marginal cost p.

Curve D^W relates price p to the total demand for the final consumption good, $D(p) + D^*(p)$ for the case of $p = p^*$. This demand curve shows the world demand for the final consumption good in the case in which both countries maintain perfect competition in their respective final consumption goods sectors. This is because we

[2] Yano and Honryo (2010, 2011a, b) show that in the game in which only competition policies are adopetd, an asymmetric Nash equilibrium tends to emerge in which $m = \infty$ and $m^* < \infty$. That result is known to be model specific; in other model specifications, it may hold that $m < \infty$ and $m^* < \infty$ in a Nash equilibrium (see Yano and Dei (2007)).

assume that one unit of the middle product can be transformed into one unit of the final consumption good in both countries; as a result, the price of the final consumption good in one country becomes equal to that of the other in the case in which both countries maintain perfect competition in their final consumption good sectors.

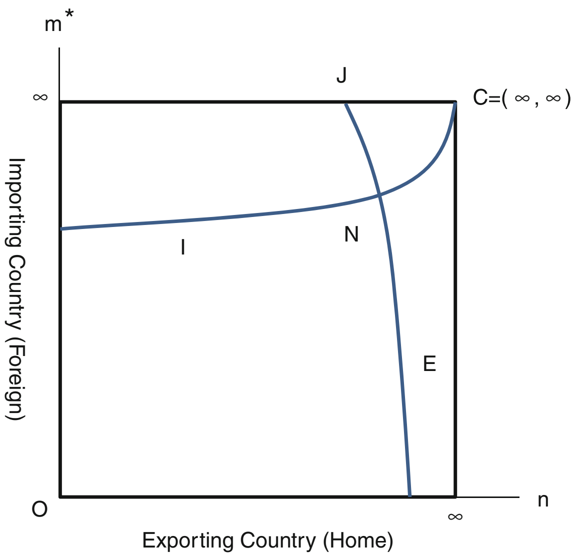
We will first examine the importing country's optimal policy, given the exporting country's policy, which is illustrated by curve I in Fig. 2. In this figure, the state of perfect competition $(n, m^*) = (\infty, \infty)$ is shown at the upper right-hand side corner, $C = (\infty, \infty)$. As this figure shows, the importing country's optimal policy is to maintain perfect competition in its final consumption good sector $(m^* = \infty)$ if the exporting country maintains perfect competition in its middle product sector $(n = \infty)$. This is due to the fact that if the exporting country maintains perfect competition in its middle product sector, due to the assumption of Cournot competition, the supply curve of the middle product in Fig. 1 becomes the horizontal line C^∞ through $h = c'(0)$. In this case, it is not optimal for the importing country to suppress competition in the final consumption good sector; it would not create any terms-of-trade effect and, as a result, would only reduce the country's surplus. In summary, the importing country's optimal policy curve goes through the point of perfect competition, $C = (\infty, \infty)$, in Fig. 2.

The next lemma demonstrates that if the exporting country suppresses competition in its middle product sector, it is optimal for the importing country to suppress competition in its final consumption good sector.

Lemma 2 $\partial W^*(n, \infty, \infty)/\partial m^* < 0$ *if* $n < \infty$.

This shows that the importing country's optimal policy curve, I, lies below the upper border of the box of the game, G, in Fig. 2. This result implies that so long as the exporting country restricts competition in the middle product sector, the

Fig. 2 Reaction curves



“supply” curve of the middle product good becomes upward-sloping. As a result, the importing country can always create a favorable terms of trade effect by shifting from perfect competition to imperfect competition.

On the other hand, if the middle product sector is perfectly competitive, the supply curve of the middle product becomes horizontal and hence the price of the middle product is determined independently from the countries’ domestic policies. In such a case, the foreign country does not have an incentive to intervene into its domestic market, because it cannot manipulate the terms-of-trade by doing so.

An interesting implication of this lemma is that there is no incentive for the importing country to take anti-competitive policy unless the exporting country does so.

Proposition 1 *Unless the exporting country suppresses competition in its middle product sector, the importing country has no incentive to take anti-competitive policy in its final consumption good sector.*

Finally, the next lemma demonstrates that if the importing country maintains perfect competition in its final consumption good sector, it is optimal for the exporting country to suppress competition in its middle product sector.

Lemma 3 $\partial W(\infty,\infty,\infty)/\partial n < 0$ *if*

$$a > \sqrt{\frac{\frac{g}{2}}{a^* + \frac{g}{2}}}a^* \tag{6}$$

This result implies that if the importing country maintains perfect competition in its final consumption good sector, given (6), the optimal policy curve of the exporting country, E, lies off the origin on the upper border, say, at point J. For the exporting country, the suppression of competition in the middle product sector induces a favorable terms-of-trade effect, or an increase in the international price of the middle product, which benefits the producers of the middle product but harms consumers. If the exporting country is small, the price increase becomes mostly a burden to the importing country’s consumers, and hence benefits the exporting country as a whole, which explains the condition (6). Lemmas 1, 2, and 3 readily imply our main result.

Proposition 2 *Suppose that the importing country’s demand is sufficiently large relative to that of the exporting country, i.e., a^* is small relative to a. In a Nash equilibrium of policy game G, the exporting country adopts an anti-competitive industrial policy while the importing country adopts an anti-competitive competition policy. If, instead, the exporting country’s demand is sufficiently large, in a Nash equilibrium, perfect competition is maintained in every sectors in both countries.*

Propositions 1 and 2 cast a new light on the U.S.–Japan trade relationship since the end of the WWII. From the 1950s through the 1980s, on the one hand, Japan exported an enormous volume of manufactured products to the U.S., including textiles, TVs and other electronic products, and cars. During this period, anti-competitive actions were sometimes promoted explicitly by the government (voluntary export restraint on cars in the 1980s) and some other times accused to be promoted (see Matsushita v. Zenith Radio, *op. cit.*). In the 1980s, on the other hand, the U.S. started easing its antitrust law applications in its banking industry and, since then, has created huge financial institutions, covering both banking and securities business.

Our results provide a new explanation for the sequence of these phenomena, regarding the recent development of mega banks as triggered by the Japanese industrial policy during the post WWII period. Condition for this interpretation is possible when the importing country's market is relatively large (a^*/a is small so that the importing country's demand curve is sufficiently flat to that of the exporting country). This coincides with the fact that the U.S. has a much larger final consumption market than Japan.

One important implication of the result is that in order to achieve the first best distortion-free outcome, a simple adoption of the standard principle of reciprocity may not be sufficient. This clearly differs from past experiences on the international harmonization of tariff policies, in which case, the principle of reciprocity under the GATT-WTO regime has highly been effective. In order to attain the first best outcome, it may be necessary that one country's reduction in the distortionary policy in a tradable sector should be met with reduction in different distortionary policy, perhaps in non-tradable domestic sector.

4 Appendix

Proof of Lemma 1

For mathematical simplicity, we introduce the following notations:

$$\lambda = 1/n, \delta = 1/m, \text{ and } \delta^* = 1/m^*.$$

Perfect competition policies in the three markets can be expressed as $\lambda = 0$, $\delta = 0$, and $\delta^* = 0$. Lemma 1 can be rewritten as $\partial \tilde{W}(\lambda, \delta, \delta^*)/\partial \delta < 0$ where $W = \tilde{W}(\lambda, \delta, \delta^*)$. From (1) and (2), we obtain

$$X = \frac{b - q}{a(1 + \delta)}, \tag{A.1}$$

and

$$X^* = \frac{b - q}{a^*(1 + \delta^*)}. \tag{A.2}$$

From these and (3), we have

$$q = -BY + b \tag{A.3}$$

where

$$\begin{aligned} B &= \frac{a(1+\delta)a^*(1+\delta^*)}{a(1+\delta)+a^*(1+\delta^*)} \\ &= B(\delta, \delta^*). \end{aligned} \tag{A.4}$$

Then this and (4) yield

$$Y = \frac{b-h}{B(1+\lambda)+g\lambda}. \tag{A.5}$$

Note that $y = \lambda Y$ and $c^{'}(y) = g\lambda Y + h$.

The total surpluses of the home country are

$$W = \frac{1}{2}(b-p)X + (p-q)X + Y\left[q - (\frac{1}{2}g\lambda Y + h)\right],$$

where $\frac{1}{2}g\lambda Y + h$ is the average variable cost of a manufacturing firm. A change in W is given by

$$\mathrm{d}W = (p-q)\mathrm{d}X + (Y-X)\mathrm{d}q + \left[q - c^{'}(\lambda Y)\right]\mathrm{d}Y, \tag{A.6}$$

because $\mathrm{d}p = -a\mathrm{d}X$ and $c^{'}(\lambda Y) = g\lambda Y + h$.

Consider first the term $\left[q - c^{'}(\lambda Y)\right]\mathrm{d}Y$ of (A.6) and show that $\left[q - c^{'}(\lambda Y)\right]\mathrm{d}Y \geq 0$ when $\mathrm{d}\delta < 0$. From (A.4) and (A.5), we have

$$B_\delta = \frac{aa^{*2}(1+\delta^*)^2}{[a(1+\delta)+a^*(1+\delta^*)]^2}. \tag{A.7}$$

and

$$Y_\delta = -\frac{(b-h)(1+\lambda)B_\delta}{[(1+\lambda)B+g\lambda]^2}. \tag{A.8}$$

Because $B_\delta > 0$, then $Y_\delta < 0$. This implies that $\mathrm{d}Y = Y_\delta d\delta > 0$ when $\mathrm{d}\delta < 0$. We know that $q - c^{'}(\lambda Y) \geq 0$ from (4), so that $\left[q - c^{'}(\lambda Y)\right]dY \geq 0$ when $\mathrm{d}\delta < 0$.

Next we consider the term $(Y-X)\mathrm{d}q$ of (A.6) and show that $(Y-X)\mathrm{d}q \geq 0$ when $\mathrm{d}\delta < 0$. Differentiate (A.3) totally and use (A.8) and (A.5) to have

$$\mathrm{d}q = -B_\delta \frac{(b-h)g\lambda}{[(1+\lambda)B+g\lambda]^2}\mathrm{d}\delta. \tag{A.9}$$

This implies that $\mathrm{d}q > 0$ if $\lambda > 0$ and $\mathrm{d}\delta < 0$. If $\lambda = 0$, $\mathrm{d}q = 0$ because q is fixed at h. Since the home country is an exporting country, $Y - X > 0$. Thus we have $(Y - X)\mathrm{d}q \geq 0$ when $\mathrm{d}\delta < 0$.

Finally consider the term $(p - q)\mathrm{d}X$ of (A.6). Differentiate (A.1) totally and use (A.3), (A.4), (A.5), (A.7) and (A.9) to have

$$\begin{aligned}\mathrm{d}X &= \frac{b-h}{a(1+\delta)^2[(1+\lambda)B + g\lambda]^2}\left\{g\lambda[(1+\delta)B_\delta - B] - B^2(1+\lambda)\right\}\mathrm{d}\delta \\ &= \frac{b-h}{a(1+\delta)^2[(1+\lambda)B + g\lambda]^2}\left\{g\lambda\left[-\frac{a(1+\delta)a^*(1+\delta^*)a(1+\delta)}{[a(1+\delta)+a^*(1+\delta^*)]^2}\right] - B^2(1+\lambda)\right\}\mathrm{d}\delta\end{aligned}$$

This shows that $\mathrm{d}X > 0$ when $\mathrm{d}\delta < 0$. Because we consider the case in which $\mathrm{d}\delta < 0$, we exclude the case in which $\delta = 0$, that is, $p - q = 0$. Thus $(p - q)\mathrm{d}X > 0$ when $\mathrm{d}\delta < 0$.

Since, in (A.6), the first term is positive and the second and third terms are nonnegative, we can show that $\mathrm{d}W > 0$ when $\mathrm{d}\delta < 0$. This proves Lemma 1.

Proof of Lemma 2

Lemma 2 can be rewritten as $\partial\tilde{W}^*(\lambda, 0, 0)/\partial\delta^* > 0$ if $\lambda > 0$ where $W^* = \tilde{W}^*(\lambda, \delta, \delta^*)$. The total surpluses of the foreign country are

$$W^* = \frac{1}{2}(b - p^*)X^* + (p^* - q)X^*.$$

A change in W^* is given by

$$\mathrm{d}W^* = -X^*\mathrm{d}q. \tag{A.10}$$

We have used $\mathrm{d}p^* = -X^*\mathrm{d}q$, and $p^* - q = 0$ because $\delta^* = 0$. In a similar fashion to (A.9), we have

$$\mathrm{d}q = -B_{\delta^*}\frac{(b-h)g\lambda}{[(1+\lambda)B + g\lambda]^2}\mathrm{d}\delta^*, \tag{A.11}$$

where $B_{\delta^*} = \frac{a^2a^*}{(a+a^*)^2} > 0$. From (A.10) and (A.11), we have

$$\mathrm{d}W^* = X^*B_{\delta^*}\frac{(b-h)g\lambda}{[(1+\lambda)B + g\lambda]^2}\mathrm{d}\delta^*,$$

which implies that if $\lambda > 0$, $\mathrm{d}W^* > 0$ when $\mathrm{d}\delta^* > 0$. This proves Lemma 2.

Proof of Lemma 3

Lemma 3 can be rewritten as $\partial W(0,0,0)/\partial\lambda > 0$. A change in W is given by

$$\begin{aligned}
\mathrm{d}W &= \frac{1}{2}[(b-p)\mathrm{d}X - X\mathrm{d}p] + (p-q)\mathrm{d}X + X(\mathrm{d}p - \mathrm{d}q) \\
&\quad + \left[q - (\frac{1}{2}g\lambda Y + h)\right]\mathrm{d}Y + Y\left[\mathrm{d}q - \mathrm{d}(\frac{1}{2}g\lambda Y + h)\right] \\
&= \left[\frac{1}{2}(b-p) + (p-q)\right]\mathrm{d}X + \frac{1}{2}X\mathrm{d}p + (Y-X)\mathrm{d}q \\
&\quad + \left[q - (\frac{1}{2}g\lambda Y + h)\right]\mathrm{d}Y - \frac{1}{2}gY(Y\mathrm{d}\lambda + \lambda\mathrm{d}Y) \\
&= \left[\frac{1}{2}(b-p) + (p-q)\right]\mathrm{d}X + \frac{1}{2}X\mathrm{d}p + (Y-X)\mathrm{d}q \\
&\quad + [q - (g\lambda Y + h)]\mathrm{d}Y - \frac{1}{2}gY^2\mathrm{d}\lambda \\
&= \left[\frac{1}{2}(b-p) + (p-q) - \frac{1}{2}aX\right]\mathrm{d}X + (Y-X)\mathrm{d}q + [q - (g\lambda Y + h)]\mathrm{d}Y - \frac{1}{2}gY^2\mathrm{d}\lambda \\
&= (p-q)\mathrm{d}X + (Y-X)\mathrm{d}q + [q - (g\lambda Y + h)]\mathrm{d}Y - \frac{1}{2}gY^2\mathrm{d}\lambda
\end{aligned}$$

The coefficient of $\mathrm{d}X$ is zero because $\delta = 0$. The coefficient of $\mathrm{d}Y$ is also zero because $\lambda = 0$. Then we have

$$\mathrm{d}W = (Y-X)\mathrm{d}q - \frac{1}{2}gY^2\mathrm{d}\lambda.$$

Next we consider the relation between $\mathrm{d}q$ and $\mathrm{d}\lambda$. Note that in (A.5), B is fixed when δ, δ^* are fixed at zero:

$$B = \frac{aa^*}{a + a^*}. \tag{A.12}$$

From (A.5), we have

$$Y_\lambda = -\frac{(b-h)(B+g)}{B^2},$$

when $\lambda = 0$. From this and $q = -BY + b$, we have

$$\mathrm{d}q = \frac{(b-h)(B+g)}{B}\mathrm{d}\lambda.$$

Noting that $Y = \frac{b-h}{B}$ with (A.12) and $X = \frac{b-q}{a}$ with $q = h$, we can rewrite the coefficient of $\mathrm{d}q$, $Y - X$, as

$$Y - X = \frac{b-h}{a^*}.$$

Therefore

$$\begin{aligned}
\mathrm{d}W &= \left\{ (Y-X)\frac{(b-h)(B+g)}{B} - \frac{1}{2}g\left(\frac{b-h}{B}\right)^2 \right\}\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{B}\left[\frac{B+g}{a^*} - \frac{g}{2B}\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{B}\left[\frac{B}{a^*} + \frac{g}{a^*} - \frac{g}{2B}\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{B}\left[\frac{a}{a+a^*} + \frac{g}{a^*} - \frac{g}{2B}\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{B}\left[\frac{a}{a+a^*} + \frac{g}{a^*} - \frac{g}{2}\frac{a+a^*}{aa^*}\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{B}\left[\frac{a^2a^* + ga(a+a^*) - \frac{g}{2}(a+a^*)^2}{aa^*(a+a^*)}\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{Baa^*(a+a^*)}\left[a^2a^* + ga(a+a^*) - \frac{g}{2}(a+a^*)^2\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{a^2a^{*2}}\left[a^2a^* + ga(a+a^*) - \frac{g}{2}\left(a^2 + 2aa^* + a^{*2}\right)\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{a^2a^{*2}}\left[a^2a^* + \frac{g}{2}a^2 - \frac{g}{2}a^{*2}\right]\mathrm{d}\lambda \\
&= \frac{(b-h)^2}{a^2a^{*2}}\left[(a^* + \frac{g}{2})a^2 - \frac{g}{2}a^{*2}\right]\mathrm{d}\lambda
\end{aligned}$$

Thus $\partial\tilde{W}(0,0,0)/\partial\lambda \;\substack{>\\=\\<}\; 0$ as

$$(a^* + \frac{g}{2})a^2 - \frac{g}{2}a^{*2} \;\substack{>\\=\\<}\; 0$$

$$(a^* + \frac{g}{2})a^2 \;\substack{>\\=\\<}\; \frac{g}{2}a^{*2}$$

$$a \begin{array}{c} > \\ = \\ < \end{array} \sqrt{\frac{\frac{g}{2}}{a^* + \frac{g}{2}}} a^*$$

Lemma 3 holds if and only if $a > \sqrt{\frac{\frac{g}{2}}{a^*+\frac{g}{2}}} a^*$.

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