The Incentives for Cooperation in International Copyright: Comparing Cooperative and Competitive Models

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Abstract

Copyright has been a source of international dispute and cooperation. We analyze the incentive for cooperation in international copyright by analyzing a cooperative model of international copyright policy-making and comparing it to a competitive model. Our analyses suggest that cooperation in copyright policy-making improves global welfare. However, cooperation does not always improve individual national welfare. For example, a country with a small market for information goods may prefer competition over cooperation, as competition may allow it to free-ride on the copyright protection provided by the country with a large market for information goods. Finally, among other things, the incentive for cooperation increases with consumer's preference for variety of information goods, decreases with prices elasticity, and increases with the difference between countries in economies of scale of their creative industries.

Keywords: international copyright policy, cooperative vs. competitive policy-making, national and global welfare analyses, mathematical modeling, numerical analysis

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Introduction

Copyright has been a source of disputes in international trade and diplomacy. Such disputes existed between Europe and the United States in 19th century (Kahn, 2005). They exist today between U.S. and other countries, especially, the emerging markets (IIPA, 2009).

There has also been growing international cooperation in copyright. Such cooperation can be seen from the international treaties in copyright: the Berne Convention of 1886, the World Intellectual Property Organization (WIPO) of 1967, the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs) of 1994, and the WIPO Copyright Treaty of 1996. Such cooperation may also be reflected in the growing harmonization of international copyright: the harmonization of copyright across European Union (EU) in the 1993, the harmonization of copyright between EU and the United States in 1998 through the U.S. 1998 Sonny Bono Copyright Term Extension Act, and the extension of copyright terms in many other countries since then to harmonize their copyright terms with that of the U.S.

This paper examines the incentive for cooperation in international copyright. It does so by analyzing a cooperative model of international copyright and comparing it with a competitive model. Specifically, it seeks to answer the following questions: A) does cooperation in international copyright policy-making yield higher collective global welfare than competition in such policy-making? B) Does cooperation lead to higher national welfare for individual countries? C) if not, what country, in terms of size of market for information goods and capability of its creative industry, etc., has the incentive to cooperate? D) How does such incentive change with characteristics of demand of consumers and technologies of creators of information goods in the countries?

There have been little theoretical studies of international copyright. Most theoretical studies of copyright, e.g., those in Novos (1984), Johnson (1985), Liebowitz (1985), Besen and Kirby (1989), Landes and Posner (1989), Yoon (2002), and Yuan (2005), assume a single copyright policy maker and a single market for information goods and do not incorporate international trade. One exception is Yuan (2009), which models how two countries trading in information products may differ in copyright policy due to their differences in size of market and capability of creation. Yuan (2009) assumes that trading nations set their copyright policies to maximize their respective national interests.

This paper develops and analyzes a cooperative model of international copyright. In the cooperative model, nations set their copyright policies to maximize the collective global welfare. The paper further compares the copyright policy and welfare of global and national information economies with those under the competitive model.

The main results of the paper are: cooperation pays in terms of global welfare, as the cooperative model yields higher collective global welfare. However, cooperation may not always be counted on, as the cooperative model does not always lead to higher national welfare for individual countries. In particular, a small country may prefer a competitive copyright policy, in which it can free ride on the copyright protection provided by the large country designed to provide incentive to creators to create information goods for its large market for information goods. Furthermore, the incentive for cooperation changes with parameters of the markets and the creative industries. For example, incentive for cooperation may be stronger when consumer's taste for variety of information goods becomes stronger, when consumers become less sensitive to prices of information goods, perhaps through increase in per capita national income, or if countries differ more in economies of scale of their creative industries.

The rest of paper is organized as follows. The next section describes the cooperative model. The third section presents its results, in comparison with that of the competitive model. Then the paper concludes. The mathematical procedures used to solve the cooperative model are given in the Appendix.

The Cooperative Model

The Behavior of Consumers and Creators

Consumers and creators have the same behavior as those described in (Yuan, 2009). A simple world information economy composes of two countries. Each has a sector of creators and a market for information goods. A creator in either country develops original information products and sells copies of its products on the domestic and foreign markets.

The copyright of a country may be set up according to either the cooperative model or the competitive model described below. The policy adopted by a country applies to both domestic products and foreign products on the market of the country. If prices of the same products differ

on the two markets or copyright protection on one market expires before on the other, effective ban on parallel importation will be assumed.

Assume the following notations:

i, j: indices of creators of country 1 or 2;
n_1: number of creators of country 1;
n_2: number of creators of country 2;
s_{1i}: number of first copy products of creator i of country 1;
s_{2i}: number of first copy products of creator i of country 2;
S: total number of first copy products $S=n_1*s_1+n_2*s_{2;}$
$c_{1i}(s_{1i})$: creative cost of creator i of country 1;
$c_{2i}(s_{2i})$: creative cost of creator i of country 2;
b: reproduction cost per copy of creators of both country 1 and 2;
p_{11it}: price per copy of products of creator i of country 1 in country 1 at time t;
p_{12it}: price per copy of products of creator i of country 1 in country 2 at time t;
p_{21it}: price per copy of products of creator i of country 2 in country 1 at time t;
p_{22it}: price per copy of products of creator i of country 2 in country 2 at time t;
$p_{11\text{-}it}$: vector of prices of products of all creators, other than i of country 1, in country 1 at time t;
$p_{12\text{-}it}$: vector of prices of products of all creators, other than i of country 1, in country 2 at time t;
$p_{21\text{-}it}$: vector of prices of products of all creators, other than i of country 2, in country 1 at time t;
$p_{22\text{-}it}$: vector of prices of products of all creators, other than i of country 2, in country 2 at time t;
$d_{11it}(s_{1i}, s_{1\text{-}i}, s_{2i}, p_{11i}, p_{11\text{-}i}, t)$: rate of demand for products of i of country 1 in country 1 at time t;
$d_{12it}(s_{1i}, s_{1\text{-}i}, s_{2i}, p_{12i}, p_{12\text{-}i}, t)$: rate of demand for products of i of country 1 in country 2 at time t;
$d_{21it}(s_{1i}, s_{2\text{-}i}, s_{2i}, p_{21i}, p_{21\text{-}i}, t)$: rate of demand for products of i of country 2 in country 1 at time t;
$d_{22it}(s_{1i}, s_{2\text{-}i}, s_{2i}, p_{22i}, p_{22\text{-}i}, t)$: rate of demand for products of i of country 2 in country 2 at time t;
cs_1: consumer surplus of country 1;
cs_2: consumer surplus of country 2;
γ: social discount rate for consumers and creators in both countries.
T_1: copyright duration of country 1;
T_2: copyright duration of country 2;

For the cooperative model, $T_1=T_2\equiv T$ will be assumed for reasons discussed later.

The profit of creator i of country one is:

$$\pi_{1i} = \int_0^{T_1}(d_{11it}(p_{11it} - b)e^{-\gamma t}dt + \int_0^{T_2}(d_{12it}(p_{12it} - b)e^{-\gamma t}dt - c_{1i}(s_{1i}) \qquad (1)$$

The first term is the quasi rent from selling its products on the market of country one during copyright duration of that country from time 0 to time T_1; the second term is the quasi rent from

selling on the market of country two during copyright duration from time 0 to time T_2. The third term is the total creative cost of creator i creating s_{1i} first-copy products.

Similarly, the profit of creator i of country two is:

$$\pi_{2i} = \int_0^{T_1}(d_{21it}(p_{21it} - b)e^{-\gamma t}dt + \int_0^{T_2}(d_{22it}(p_{22it} - b)e^{-\gamma t}dt - c_{2i}(s_{2i}) \qquad (2)$$

A creator chooses prices and number of first-copy products to maximize profit. The first-order conditions are:

$$\frac{\partial \pi_{1i}}{\partial p_{11it}} = 0 \qquad (3)$$

$$\frac{\partial \pi_{1i}}{\partial p_{12it}} = 0 \qquad (4)$$

$$\frac{\partial \pi_{1i}}{\partial s_{1i}} = 0 \qquad (5)$$

$$\frac{\partial \pi_{2i}}{\partial p_{21it}} = 0 \qquad (6)$$

$$\frac{\partial \pi_{2i}}{\partial p_{22it}} = 0 \qquad (7)$$

$$\frac{\partial \pi_{2i}}{\partial s_{2i}} = 0 \qquad (8)$$

A creator also decides whether to enter or stay on the market. The information goods industries are assumed to be open. Therefore, the marginal creator makes zero economic profits. If all creators in a country have the same technology, they will all make zero profit. That is:

$$\pi_{1i} = 0 \qquad (9)$$

$$\pi_{2j} = 0 \qquad 10)$$

The consumer surplus of country one is:

$$cs_1 = \sum_{i=1}^{n_1}\int_0^{\infty}\left(\int_b^{\infty} d_{11i}dp_{11it}\right)e^{-\gamma t}dt + \sum_{i=1}^{n_2}\int_0^{\infty}\left(\int_b^{\infty} d_{21i}dp_{21it}\right)e^{-\gamma t}dt$$

$$-\sum_{i=1}^{n_1}\int_0^{T_1}\left(\int_b^{p^*_{11it}} d_{11i}dp_{11it}\right)e^{-\gamma t}dt-\sum_{i=1}^{n_2}\int_0^{T_1}\left(\int_b^{p^*_{21it}} d_{21i}dp_{21it}\right)e^{-\gamma t}dt \quad (11)$$

Where p^*_{11it} and p^*_{21it} are prices chosen by creator i of country one and creator i of country two, respectively, on the market of country one during copyright protection. The first term is country one's consumer surplus from all products of creators of country one, if the products were priced at marginal reproduction cost b from the moment they are created; the second term is the surplus from products of creators of country two, if the products were priced at reproduction cost b from the moment they are created; the third term is the loss of consumer surplus from products of creators of country one due to copyright protection, which lasts from time 0 to T_1; the fourth term is the loss of consumer surplus from products of creators of country two due to the same copyright protection.

Similarly, the consumer surplus of country two is:

$$cs_2=\sum_{i=1}^{n_1}\int_0^{\infty}\left(\int_b^{\infty} d_{12i}dp_{12it}\right)e^{-\gamma t}dt+\sum_{i=1}^{n_2}\int_0^{\infty}\left(\int_b^{\infty} d_{22i}dp_{22it}\right)e^{-\gamma t}dt$$

$$-\sum_{i=1}^{n_1}\int_0^{T_2}\left(\int_b^{p^*_{12it}} d_{12i}dp_{12it}\right)e^{-\gamma t}dt-\sum_{i=1}^{n_2}\int_0^{T_2}\left(\int_b^{p^*_{22it}} d_{22i}dp_{22it}\right)e^{-\gamma t}dt \quad (12)$$

Where p^*_{12it} and p^*_{22it} are prices chosen by creator i of country one and creator i of country two, respectively, on the market of country two during copyright protection. Here the demands are from the market of country two; and copyright duration lasts from time 0 to T_2.

Assume all creators in a country have the same technology. They all make zero economic profit. Social welfare is then the same as consumer surplus.

The Cooperative Model

In the cooperative model, T_1 and T_2 may theoretically be different. However, it turns out that such a general model may be indeterminate, as one country's shorter copyright protection may be compensated by the other country's longer protection, without affecting the collective global welfare. Therefore, $T_1=T_2\equiv T$ will be imposed for the cooperative model.

Then, the problem of the cooperative model is for Country one and country two to come together to set a common copyright duration to maximize their collective global welfare, subject to the

behavior of the consumers and creators as described in (3) to (10). As the creators of both countries make zero profit, collective global welfare is the same as the collective global consumer surplus, cs_1+cs_2. Therefore, one has:

$$\max_T cs_1 + cs_2 \tag{13}$$

S.t. (3)-(10) and T_1=T_2≡T

The Competitive Model

The competitive model is re-written here for the reader's convenience. In the competitive model, the problem of the copyright authority of country one is to set duration T_1 to maximize the social welfare cs_1, given the behavior of creators of the two countries as described in (3)-(10) and the duration T_2 set by country two as described below, i.e.:

$$\max_{T_1} cs_1 \tag{14}$$

S.t. (3)-(10) and T_2 satisfying (15)

The problem of the copyright authority of country two is to set duration T_2 to maximize the social welfare cs_2, given creator behavior in (3)-(10) and T_1 set by country one as describe in (14), i.e.:

$$\max_{T_2} cs_2 \tag{15}$$

S.t. (3)-(10) and T_1 satisfying (14)

The Results

To solve the cooperative and competitive models, one needs to further specify the markets and creative industries of the two countries.

Specification of Demand and Cost Functions

As in the (Yuan, 2009), assume the following demand and cost functions:

$$d_{11it} = D_1 s_{1i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{j=1}^{n_2} s_{2j}\right)^{\alpha-1} p_{11it}{}^{-\delta} \prod_{j\neq i} p_{11jt}{}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_2} p_{21jt}{}^{\frac{\beta}{n_1+n_2-1}} g_1(t) \tag{16}$$

$$d_{12it} = D_2 s_{1i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{j=1}^{n_2} s_{2j}\right)^{\alpha-1} p_{12it}^{-\delta} \prod_{j\neq i} p_{12jt}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_2} p_{22jt}^{\frac{\beta}{n_1+n_2-1}} g_2(t) \quad (17)$$

$$d_{21it} = D_1 s_{2i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{j=1}^{n_2} s_{2j}\right)^{\alpha-1} p_{21it}^{-\delta} \prod_{j\neq i} p_{21jt}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_1} p_{11jt}^{\frac{\beta}{n_1+n_2-1}} g_1(t) \quad (18)$$

$$d_{22it} = D_2 s_{2i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{j=1}^{n_2} s_{2j}\right)^{\alpha-1} p_{22it}^{-\delta} \prod_{j\neq i} p_{22jt}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_1} p_{12jt}^{\frac{\beta}{n_1+n_2-1}} g_2(t) \quad (19)$$

and

$$g_1(t) = \begin{cases} 1 - \dfrac{t}{T_{01}} & if \quad t < T_{01}(1-\theta_1) \\ \theta_1 & otherwise \end{cases} \quad (20)$$

$$g_2(t) = \begin{cases} 1 - \dfrac{t}{T_{02}} & if \quad t < T_{02}(1-\theta_2) \\ \theta_2 & otherwise \end{cases} \quad (21)$$

and

$$c_{1i}(s_{1i}) = c_{01} + a_1 {s_{1i}}^{\rho_1} \qquad \forall \text{ i of country 1} \quad (22)$$

$$c_{2i}(s_{2i}) = c_{02} + a_2 {s_{2i}}^{\rho_2} \qquad \forall \text{ i of country 2} \quad (23)$$

where $0<\alpha<1$, $\delta>1$, $\beta>0$, $0\leq \theta_1 <1$, $0\leq \theta_2 <1$, $\rho_1>1$, $\rho_2>1$, and D_1, D_2, T_{01}, T_{02}, c_{01}, c_{02} and a_1 and a_2 are positive constants.

Given the multiplicativity of the factors affecting the demand, the common price elasticity, and the common reproductive cost of b for all products, it is easy to derive that creators set prices which are uniform for all products, all creators, at all moments of time:

$$p_{11it} = p_{12it} = p_{21j} = p_{22j} = p \equiv \frac{\delta}{\delta-1} b \quad (23)$$

Given the identical cost functions within one country, it can be derived that creators of one country all create the same number of first-copy products: $s_{1i} = s_{1j} \equiv s_1$ and $s_{2i} = s_{2j} \equiv s_2$.

In order to obtain consumer surpluses cs_1 and cs_2 and price p, sizes of creators, s_1 and s_2, total number of first-copy products S, duration of copyright T (and T_1 and T_2 for the competitive model), it is necessary to use both analytical and numerical procedures, given values of the parameters in the demand and cost functions.

Baseline Solution

Assume the following parameter values:

$$[D_1, D_2, \alpha, \delta, \beta, b, T_{01}, T_{02}, \theta_1, \theta_2, \gamma, c_{01}, c_{02}, a_1, a_2, \rho_1, \rho_2] =$$

$$[7*10^6 \ \ 7*10^6 \ 0.3 \ \ 2 \ \ 0.5 \ \ 5 \ \ 100 \ 100 \ \ 0.001 \ 0.001 \ 0.05 \ 3*10^5 \ 3*10^5 \ 10^4 \ \ 10^4 \ 1.2 \ 1.2 \ ]$$

The following numerical solution is computed for the cooperative model, as compared to the competitive model:

Table 1. Result of Cooperative Model as Compared to the Competitive Model

	T_1	T_2	s_1	s_2	S	cs_1 ($B)	cs_2 ($B)
Cooperative	14	14	64	64	13281	0.86	0.86
Competitive	7	7	63	63	6224	0.80	0.80

Under the above parameter values, creators of two countries have the same technologies and consumers the same preferences. Given the above parameters, the common copyright duration for the two countries by the cooperative model is 14, compared to the 7 years according to the competitive model; creators in both countries each create 64 original products in the cooperative model, compared to the 63 number under the competitive model; the total number of first-copy products is 13,281 under the cooperative model, compared to the number of 6,224 under the competitive model; and consumer surpluses for both countries are $0.86 billion under the cooperative model, higher than that of $0.80 billion by the competitive model.

The optimality of the solutions of the two models for each creator and for each country is shown in Figure 1-7. If a creator deviates from the optimal size of 64 in the cooperative model or 63 for

the competitive model, the creator will incur a loss, given that both countries adopt the optimal duration of copyright of 14 years in the cooperative model or 7 years in the competitive model and other creators stay at their respective optimal sizes 64 or 63 under the respective models.

Similarly, if the countries deviate from their optimal duration, 14 years for the cooperative model or 7 years for the competitive model, the welfare of the countries will be lower than the maximum of $0.86 billion or $0.80 billion of the respective models, given that the other country in the case of the competitive model maintains the optimal duration and the creators behave as described by the respective models.

Under the above parameter values, cooperative international copyright leads to higher social welfare for both countries.

Does Cooperation Always Lead to Higher Collective Welfare?

Whether cooperation always leads higher collective global welfare is an important question. A higher collective global welfare is the basis for international copyright cooperation. If the collective global welfare is not increased by cooperation, there is no reason for cooperation. If the collective global welfare is increased by cooperation, even if the welfare of individual countries are not, cooperation is still desirable, thought it might require certain means, such as welfare transfer, to bring about such cooperation.

To answer the question, change the values of each parameter in the model, and keep the other parameters at their baseline values. Take values for each parameter from a corresponding interval of the parameter. The intervals are chosen to cover wide ranges of "reasonable values" for those parameters. Solve the models and compute global welfare and the percent difference of global welfare of the cooperative model from that of the cooperative model. The ranges of the percent differences in global welfare are listed in Table 2 with the ranges of change of the parameter values, for which solutions are found for the two models in the corresponding intervals.

For all the parameter changes, global welfare under cooperative model is higher than that of the competitive model. For those changes in the parameters values, the global welfare under cooperative model is 0.03% to 19.54% higher than that of the competitive model.

Table 2. Difference in Global Welfare of Cooperative Model from Competitive Model

Parameter	Interval of Parameter Value	% Difference of Global Welfare
D_1	10^6~10^8	0.13~6.70
D_2	10^6~10^8	0.13~6.70
α	0.1~0.48	2.00~11.86
δ	1.2~4	5.42~6.70
β	0.101~0.9	6.69~6.70
b	1~50	6.68~6.70
T_{01}	1~1000	0.03~6.70
T_{02}	1~1000	0.03~6.70
θ_1	0.0001~0.3	6.70~6.70
θ_2	0.0001~0.3	6.70~6.70
Γ	0.0002~0.3	6.64~6.70
c_{01}	$2.94*10^4$~10^7	6.70~19.54
c_{02}	$2.94*10^4$~10^7	6.70~19.54
a_1	6700~10^4	6.70~14.32
a_2	6040~10^4	6.70~16.28
ρ_1	1.152~1.253	6.70~10.78
ρ_2	1.152~1.253	6.70~10.78

To check the sensitivity of the result, draw random values for the 17 parameters from the above 17 dimensional space, compute the model. Repeat the process. The range of the percent difference of collective welfare of the cooperative model from that of the competitive model is 0.13%-31.20% for 74 sets of random parameter values for which solutions are found for both models at the time of this writing.

However, the results show that copyright durations in both countries are not always longer under cooperative than under the competitive model but not always. Figure 60 and 61 show that when the economic life of information products in a country is short, the copyright duration of that country is short under the competitive model. In response, the duration of the other country under competitive model has to be long, longer than that under the cooperative model. In other cases, copyright durations under cooperative model in both countries are longer than under competitive model for the above parameter values.

The above intervals and area for the parameter values cover a wide range of "reasonable" value for those parameters. The result suggests that the cooperative model leads to higher global welfare relative to the competitive model. Therefore, there is a need for international cooperation in setting copyright policy.

It should be noted that as the some of the parameters in the model, such as D_1, D_2, δ, β, b, T_{01}, T_{02}, c_{01}, c_{02}, a_1, a_2, ρ_1, and ρ_2 can change within infinitely wide intervals and not coverable by numerical computation. Therefore, the above result through simulation may not be conclusive.

Do Individual Countries Always Prefer Cooperation over Competition?

Higher collective global welfare under the cooperative model means that cooperation is worthwhile for all countries as a whole. However, that does not necessarily mean that cooperation will be considered worthwhile for all individual countries. Whether each country has the incentive to cooperate depends on whether each country achieves higher national welfare under the cooperative model than under the competitive model. In the baseline case, both individual countries have higher welfare in the cooperative model than under the competitive model. So both countries have incentive to cooperate. The question is whether this is always true. To answer this question, look at the percent gains of welfare of the individual countries from the cooperative model relative to that of the competitive model at different parameter values as chosen above. The results are shown in Table 3 and figures 9-59.

Table 3. Percent Gain of National Welfare from Cooperative Model over Competitive Model

Parameter	Interval of Parameter Value	Country One Welfare	Country Two Welfare
D_1	10^6~10^8	-25.89~25.32	-27.94~25.09
D_2	10^6 ~10^8	-27.94~25.09	-25.89~25.32
α	0.1~0.48	2.00~11.86	2.00~11.86
δ	1.2~4	5.42~ 6.70	5.42~ 6.70
β	0.101~0.9	6.69~ 6.70	6.69~ 6.70
b	1~50	6.68~ 6.70	6.68~ 6.70
T_{01}	1~1000	-48.34~20.48	-7.08~31.23
T_{02}	1~1000	-7.08~31.23	-48.34~20.48
θ_1	0.0001~0.3	6.70~ 7.15	6.26~ 6.70
θ_2	0.0001~0.3	6.26~ 6.70	6.70~ 7.15
γ	0.0002~0.3	6.64~ 6.70	6.64~ 6.70
c_{01}	$2.94*10^4$~10^7	6.68~45.39	1.50~25.99
c_{02}	$2.94*10^4$~10^7	1.50~25.99	6.68~45.39
a_1	6700~10^4	6.70~ 6.70	6.70~23.12
a_2	6040~10^4	6.70~27.76	6.70~ 6.70
ρ_1	1.152~1.254	6.70~14.92	6.70~15.17
ρ_2	1.152~1.254	6.70~15.17	6.70~14.92

Table 3 shows that individual national welfare is not always higher under the cooperative model than under the competitive model. As the values of four parameters, D_1, D_2, T_{01}, and T_{02} change,

the welfare of country one or country two can be higher under the competitive model than under the cooperative model.

Figures 28, 30, 40, 31, 29, and 43 show details of the above cases in which individual national welfare is higher under the competitive model. Figure 28, 30 and 40 show, respectively, that when demand level of country one becomes small relative to the demand level of country two, or demand level in country two becomes big relative to that of country one, or the economic life of information products in country one become short, the welfare of country one becomes smaller under the cooperative model than under the competitive model. Similarly, figures 31, 29, and 43 show, respectively, that when demand level in country two become small, or demand level in country one becomes big, or economic life of information products in country two become short, country two may achieve higher national welfare under the competitive model than under cooperative model.

In summary, when a country has small market or the economic life of information products in the country is short, the country can be better off under the competitive model than under cooperative model.

To understand this result, one may consider the following result of the competitive model. When the demand level of a country becomes small or the economic life of information goods in the market of the country becomes short, the country is better off to provide minimal or no copyright protection. Such minimal copyright protection lets the country free ride on the creative incentive brought about by the copyright protection provided by the larger country and allows consumers of the small country to avoid paying monopolistic price, enjoy information products at marginal reproductive cost, and achieve maximal surplus. While the other country has no choice but to provide copyright protection to give incentive for creators to create original information goods to satisfy its large or longer demand for information goods by the consumers in the country. Otherwise, it stands to lose big. Thus, the small country may be better off to free ride, rather than to follow a common copyright policy, which achieves optimal collective global welfare.

In conclusion, individual countries sometimes do not have the incentive to cooperate. In such cases, to achieve optimal global welfare possible under the cooperative model, extra incentives may need to be given to countries which have lower national welfare under the cooperative

model. One way to give such incentives is to transfer some of the higher national welfare achieved in the other countries under the cooperative model to countries which have lower national welfare than under competitive model. Since collective global welfare is always higher under the cooperative model, such as transfer, in principle, can make all countries better off under the cooperative model and induce them to cooperate.

Note, in cases where both countries have higher national welfare under the cooperative model than under the competitive model, it is still possible for either country to achieve higher national welfare by adopting the copyright duration of the competitive model, if the other country adopts the copyright duration of the cooperative model. The choices of the two countries between cooperative copyright or competitive copyright may constitute a Prisoner's Dilemma. In the baseline case, the choice and payoff matrix is as follows:

Table 4. National Welfare ($B) and Copyright Policy Choice

(Country 1 welfare, country 2 welfare)		Country 2	
		Competitive duration (7 years)	Cooperative Duration (14 years)
Country 1	Competitive duration (7 years)	(0.80, 0.80)	(0.91, 0.78)
	Cooperative Duration (14 years)	(0.78, 0.91)	(0.86,0. 86)

Thus, to achieve the higher global and national welfare of the cooperative model in such cases, strategic behavior in the forms of monitoring, threat, and retaliation, is still needed. Fortunately, such strategic behavior is feasible, as international copyright is not a one-shot Prisoner's Dilemma game but a repeated game of the Prisoner's Dilemma.

How Does Incentive for Cooperation Change with Market Parameters?

Another interesting question is how such incentive changes with characteristics of the markets and creative technologies in the two countries. The incentive for cooperation of a country can be measured by the percent gain of national welfare of the country from the cooperative model relative to the competitive model. Figures 28-59 show the change of such relative gains of each country with parameters of markets and creative industries.

Figure 32-33 show that the percent gain in national welfare of both countries from the cooperative model relative to the competitive model increase with α. When α increases from 0.1 to 0.48, the percent welfare gain of either country increases from 2.00% to 11.86%. The parameter α represents the preference of consumers for variety in information goods. When consumers' preference for variety is stronger, so will be the incentive for cooperation.

Figure 34 and 35 show that the percent welfare gain of both countries from the cooperative model relative to the competitive model decreases with δ. When δ decreases from 4 to 1.2, the percent gain in welfare of either country increases from 5.42% to 6.70%. The parameter δ is the price elasticity of information goods in the two markets. The less elastic is the demand, the stronger is the incentive for cooperation.

Figure 36-37 show that the percent gain of national welfare from cooperation relative to competition increases marginally with cross-price elasticity. When cross-price elasticity increases from 0.101 to 0.9, the percent gain increases from 6.69% to 6.70% for both countries. Cross-price elasticity may reflect both strength of demand and taste for variety. The stronger is cross-price elasticity, the weaker may be the demand or stronger the preference for variety. The two effects on welfare through weaker demand and stronger taste for variety are in the opposite directions and may cancel each other. And the net effect is rather marginal.

Figure 38-39 show that the percent gain of national welfare from cooperation relative to competition increases marginally as copying cost decreases. The result shows that the under-protection of copyright under the competitive model becomes severer as copying cost decreases. When copying cost decreases, the optimal copying protection in both countries under both models decreases slightly, as new creative incentive and severer deadweight from lower copying cost out-weight higher desirability of information goods. However, copyright duration decreases faster under the competitive model, which is at 0.59% in both countries, than under cooperative model, which is at 0.18%, making the loss from the competitive model a little severer.

Figure 44-47 show that percent welfare gain from cooperation for a country increases with the residual demand in this country and decreases with residual demand in the other country. This is consistent with effect of the parameters of demand level and economic life of information goods. Increase in residual demand in a country represents increase in general demand in the country,

which makes the incentive for cooperation in this country stronger but the incentive for cooperation in the other country weaker.

Figure 48-49 show that the incentive for cooperation decreases with social discount rate. Higher social discount rate means lower total net present value of information products, therefore, smaller loss from the competitive model.

Figure 50-57 show that when the fixed creative cost or per-product creative cost decrease in a country, the incentive for cooperation in the country decreases but the incentive for cooperation in the other country increases. For example, as c_{01} decreases from 10^7 to 29,400, the gain of national welfare from cooperation by country one decreases from 45.39% to 6.68% and that of country two increases from 1.50% to 25.99%. As a_1 decreases from 10,000 to 6,700, the gain of national welfare from cooperation by country one decreases marginally from 6.703% to 6.698% and that of country two increases from 6.79% to 23.12%. When the fixed or per-product creative cost in a country improves, the country is more inclined to compete and other country is more inclined to cooperate, even though both still prefer cooperation.

Finally, figure 58 and 59 show that when diseconomies of scale in creation in a country become more different from that of the other country, the incentive for cooperation in both countries become stronger. For example, the incentive for cooperation in this country becomes stronger marginally and that in the other country becomes much stronger when the economies of scale of this country become better relative to the other country. In figure 58 and 59, the percent welfare gain of both countries from cooperation relative to competition are the lowest when ρ_1 equals ρ_2 at 1.2. When ρ_1 decreases from 1.20 to 1.15, the percent gain of national welfare from cooperation by country one increases from 6.70% to 6.72% and that by country two increases from 6.70% to 15.17%. Conversely, if the economies of creative scale of creators in a country deteriorate relative to that of the other country, the incentive for this country to cooperative increases significantly; that for the other country increases slightly.

Why does improvement in fixed or per-product creative cost in a country decrease the incentive to cooperate in this country, while that in the economies of creative scale increase it? Improvements in fixed or per-product creative cost and in the economies of creative scale all increase incentive to create. However, improvement in fixed or per-product creative cost may

incentivize all creative decisions, while that in the economies of creative scale may incentivize marginal creative decisions more. Therefore, improvement in fixed or per-product creative cost may increase incentive for creation more, reduces more of the loss from the competitive model, than that in the economies of creative scale. Thus, the former may reduce the incentive for cooperation, the latter increases.

Conclusion

We developed and analyzed a cooperative model of international copyright policy-making and compared it to a competitive model. Our analyses suggest that cooperation in international copyright policy-making improves global welfare. However, it does not always improve individual national welfare. Therefore, international copyright cooperation is desirable in general but may require "extraordinary" mechanism to be achieved.

Furthermore, the incentive for individual nations to cooperate depends on the characteristics of the markets and the creative industries. For example, the incentive increases with consumers' preference for variety, decreases with price elasticity, and increases with the gap in creative economies of scales between countries. As the characteristics of the markets and creative industries change over time with the developments in the economy and technologies, the incentives for nations to cooperate in copyright can be expected to change. Empirical verification of the results is left to future studies.

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Figure 1-4: Optimality of Baseline Solutions of the Cooperative Model

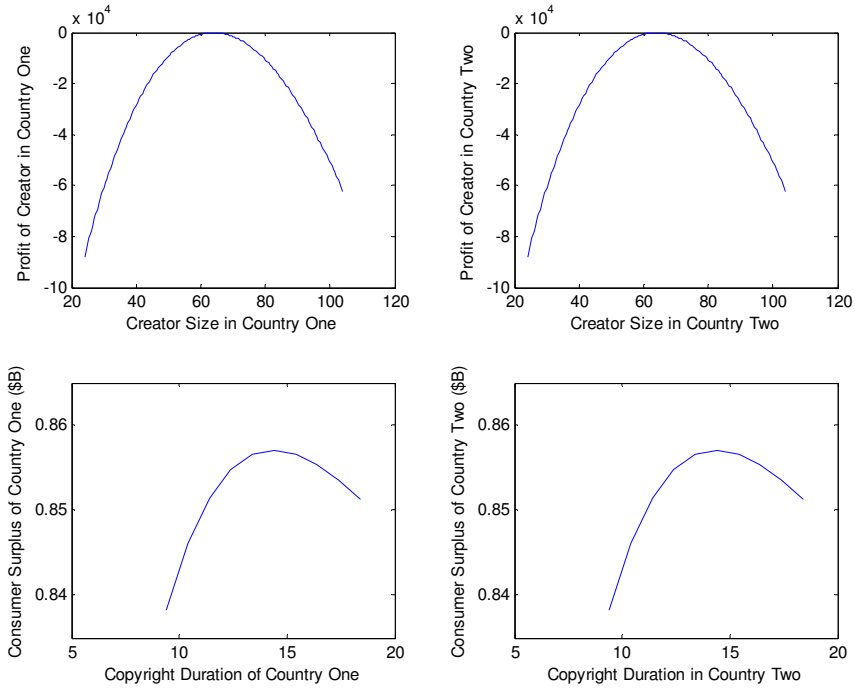


Figure 5-7: Optimality of Baseline Solutions of the Competitive Model

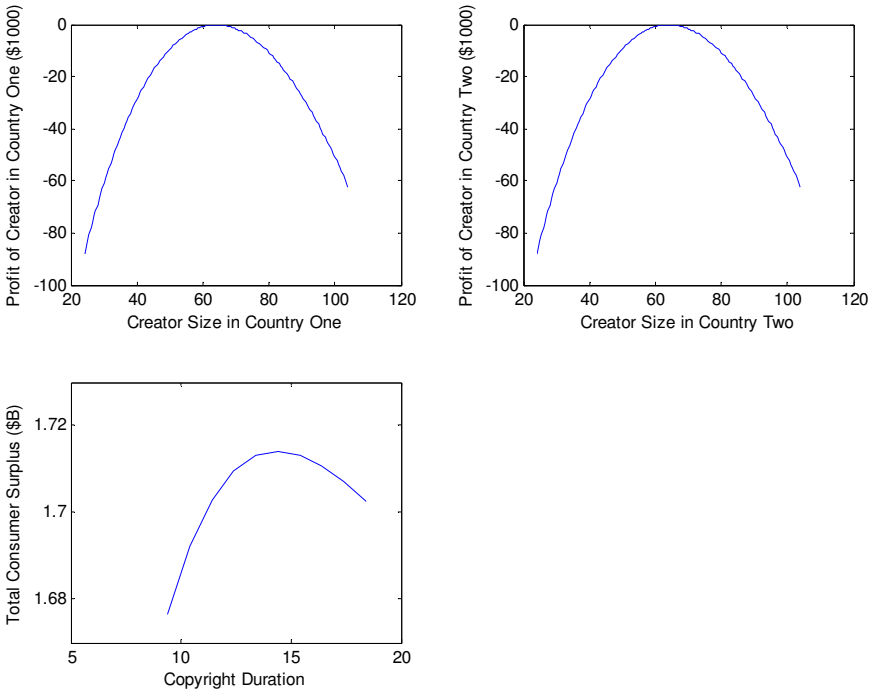


Figure 8-11. Difference in Global Welfare of Cooperative Model from Competitive Model

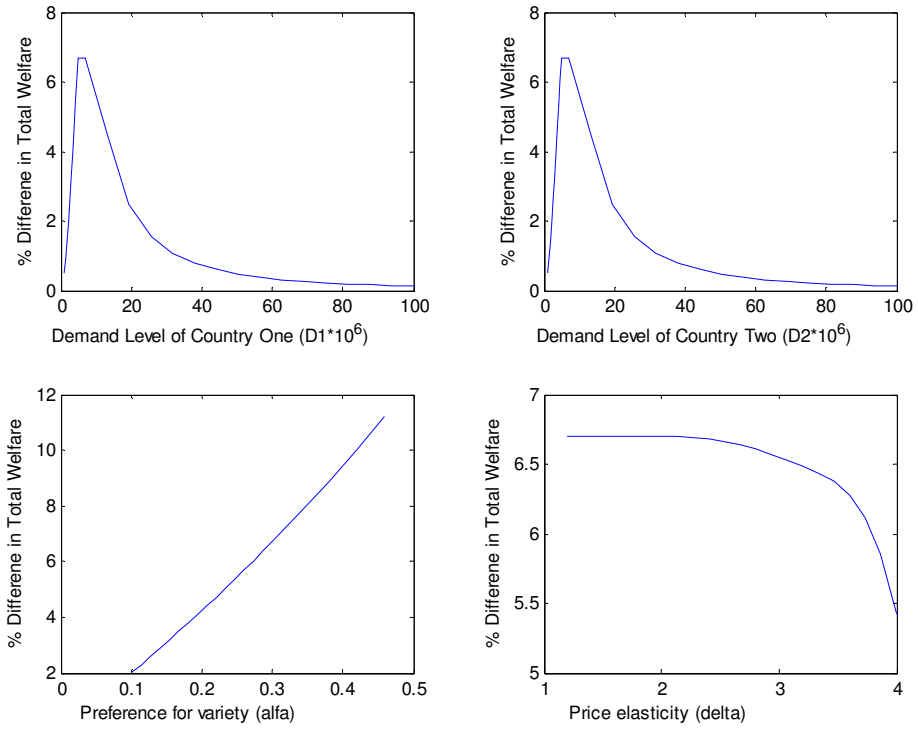


Figure 12-15. Difference in Global Welfare of Cooperative Model from Competitive Model

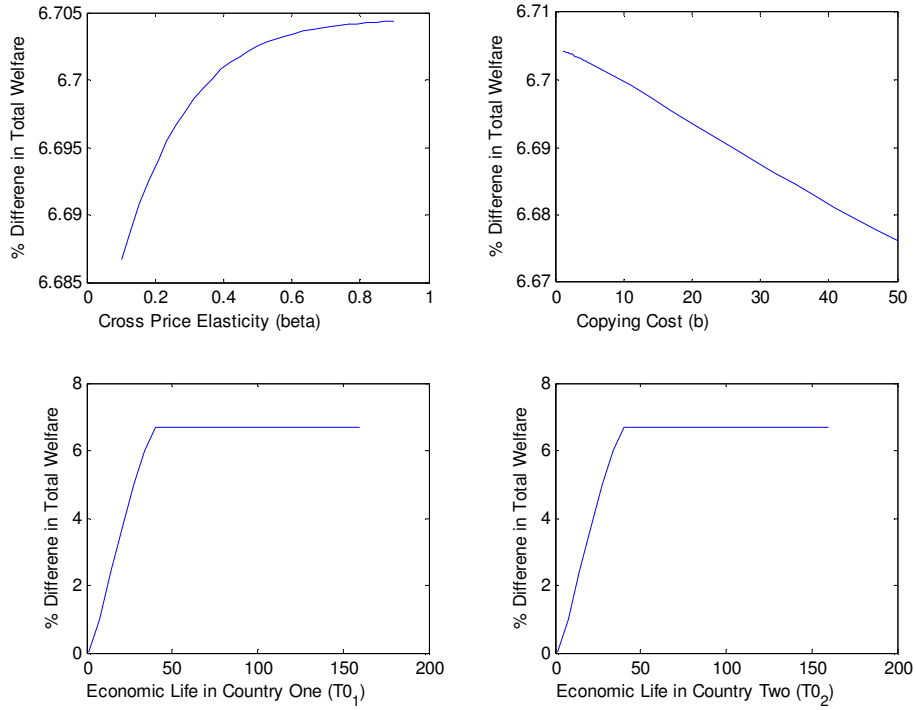


Figure 16-19. Difference in Global Welfare of Cooperative Model from Competitive Model

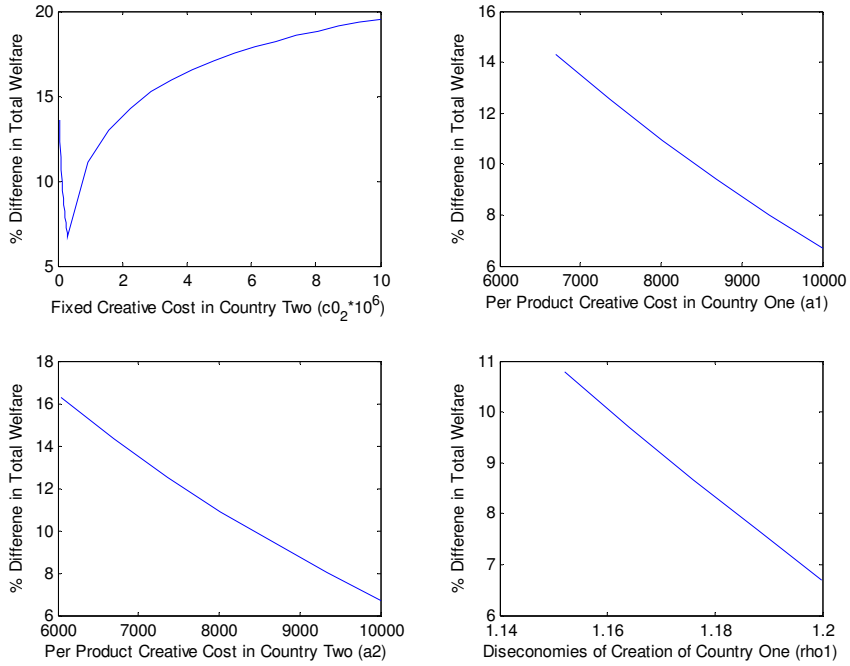


Figure 20-23. Difference in Global Welfare of Cooperative Model from Competitive Model

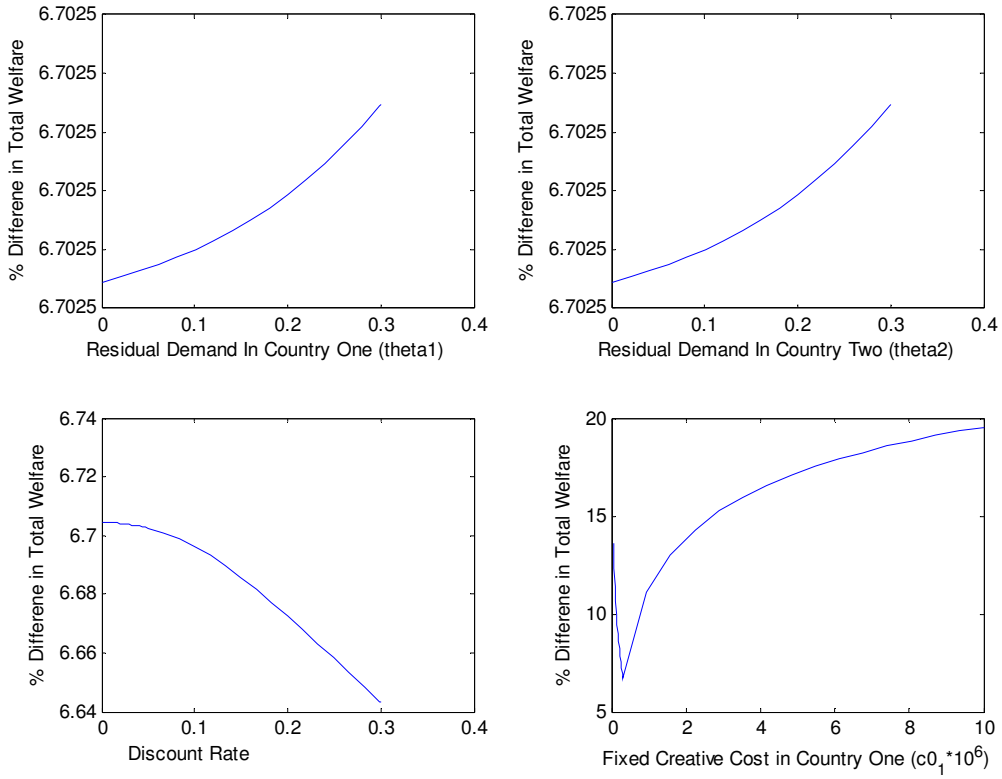


Figure 24-27. Difference in Global Welfare of Cooperative Model from Competitive Model

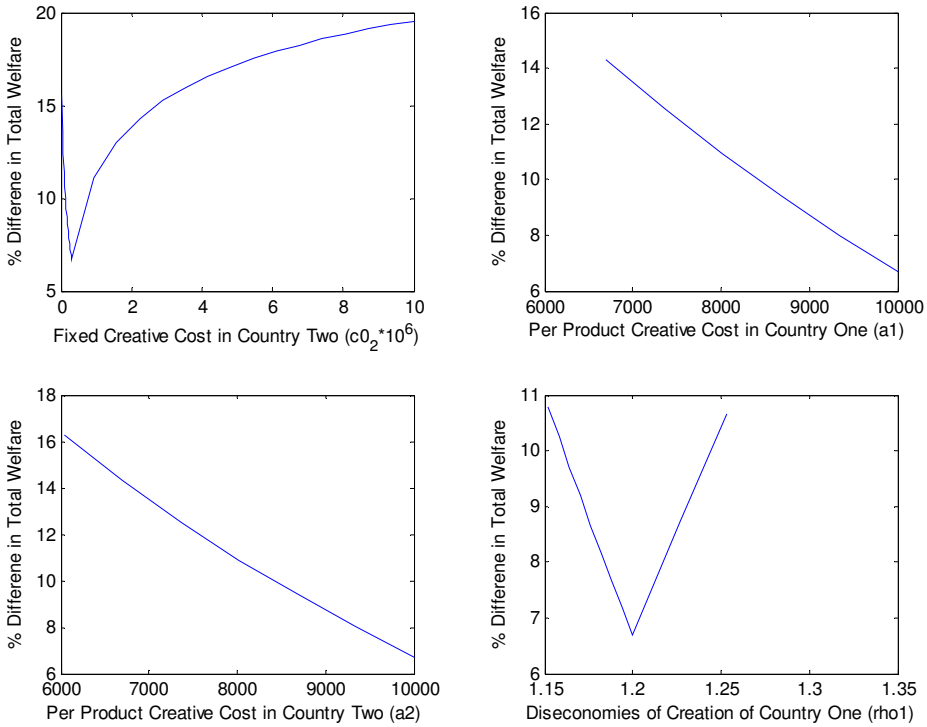


Figure 28-31. Difference in National Welfare of Cooperative Model from Competitive Model

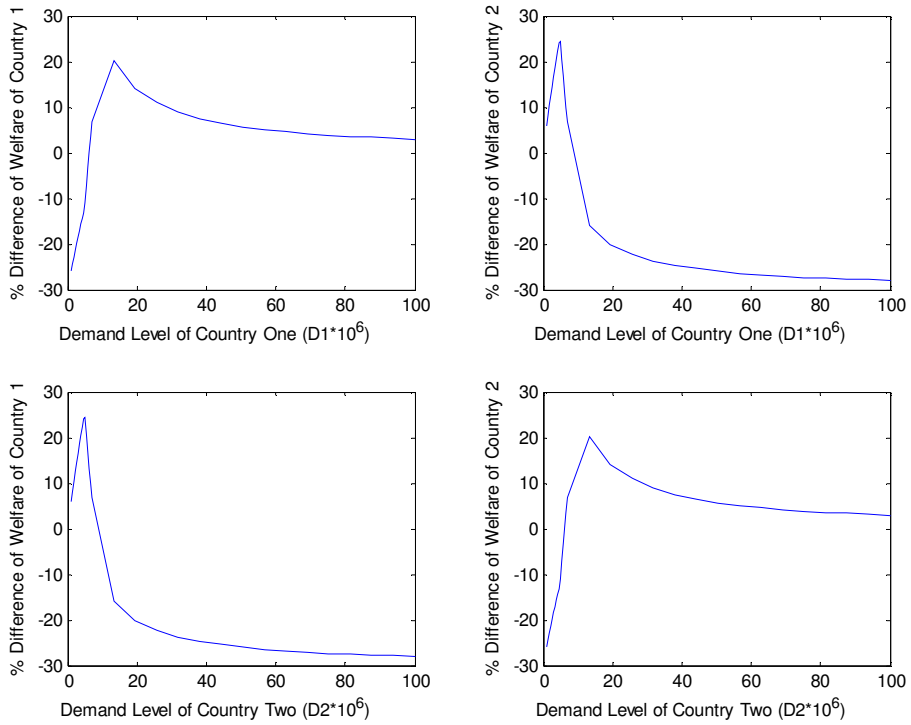


Figure 32-35. Difference in National Welfare of Cooperative Model from Competitive Model

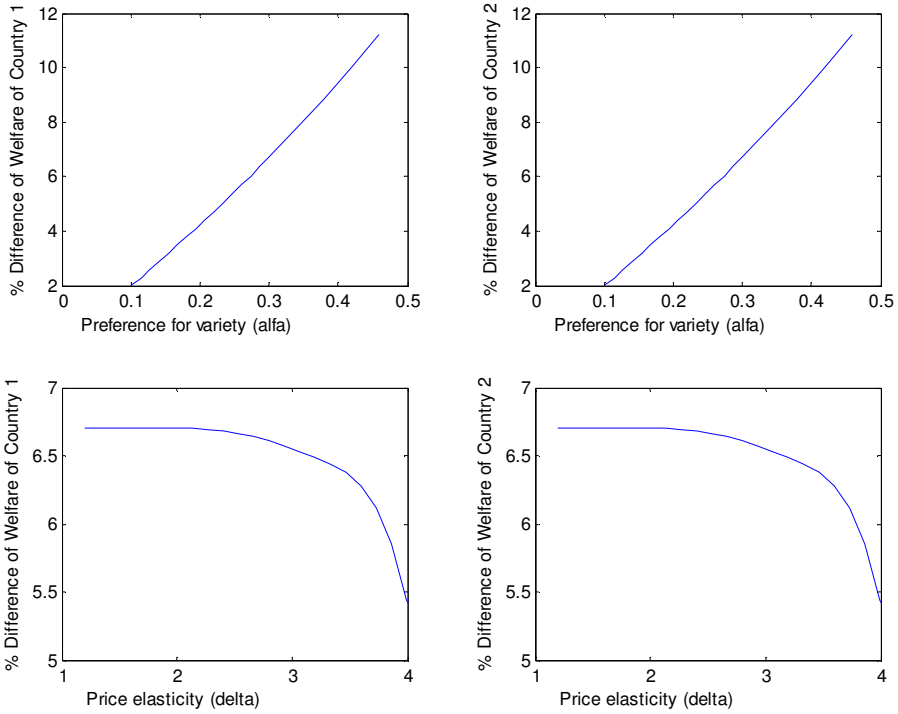


Figure 36-39. Difference in National Welfare of Cooperative Model from Competitive Model

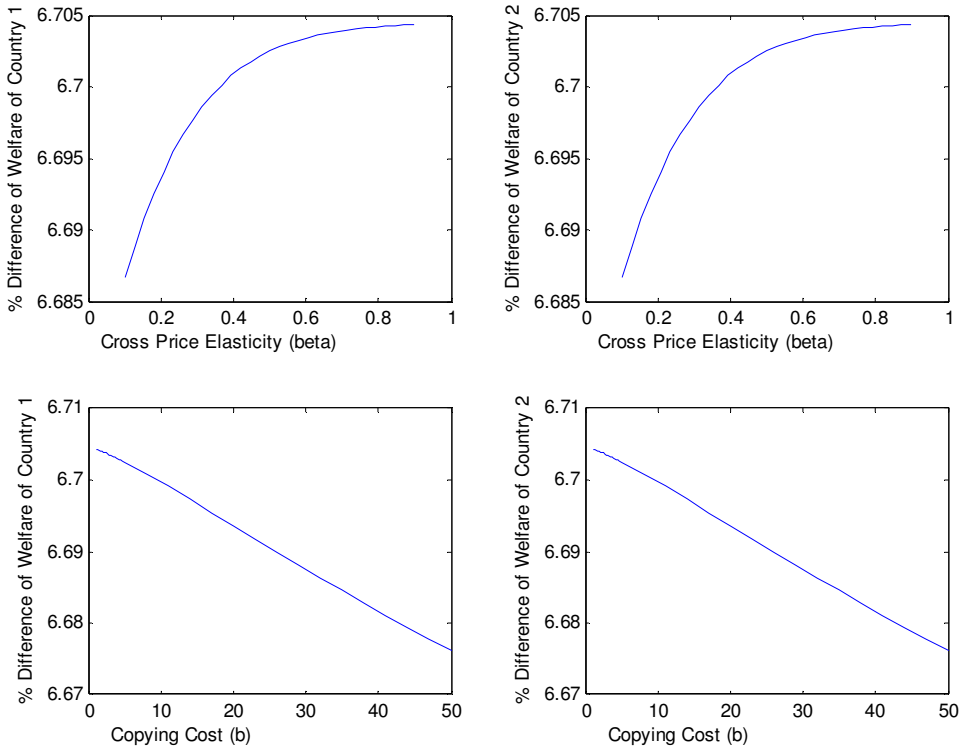


Figure 40-43. Difference in National Welfare of Cooperative Model from Competitive Model

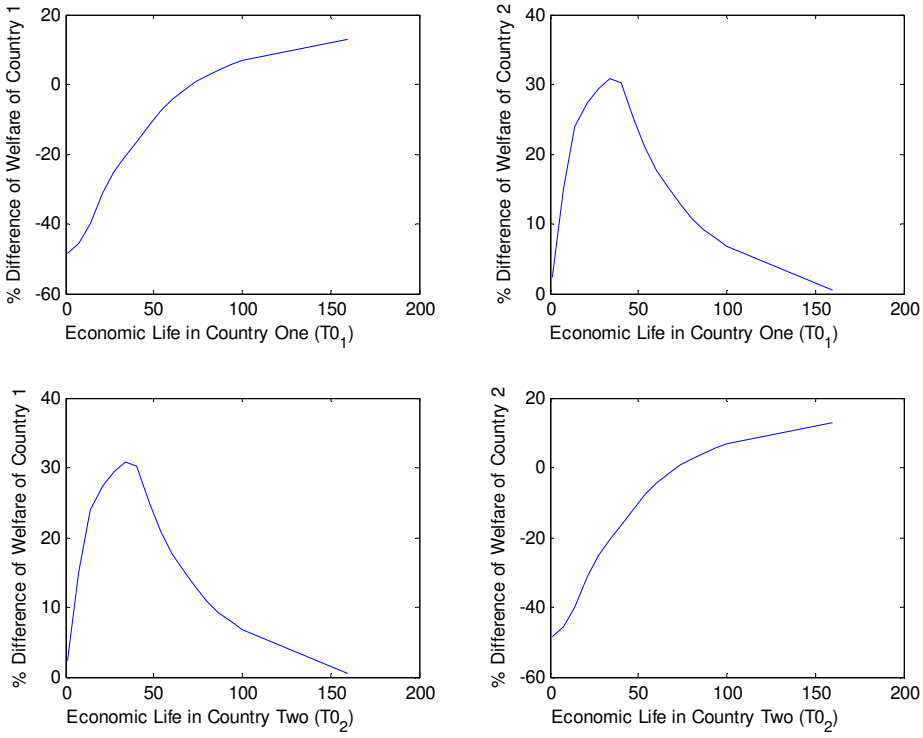


Figure 44-47. Difference in National Welfare of Cooperative Model from Competitive Model

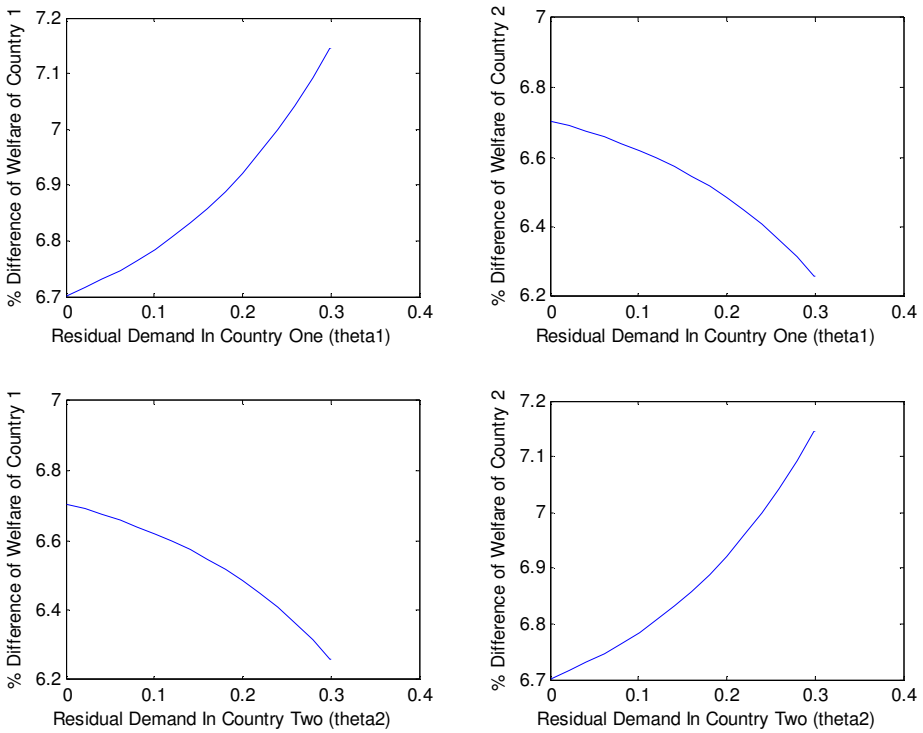


Figure 48-51. Difference in National Welfare of Cooperative Model from Competitive Model

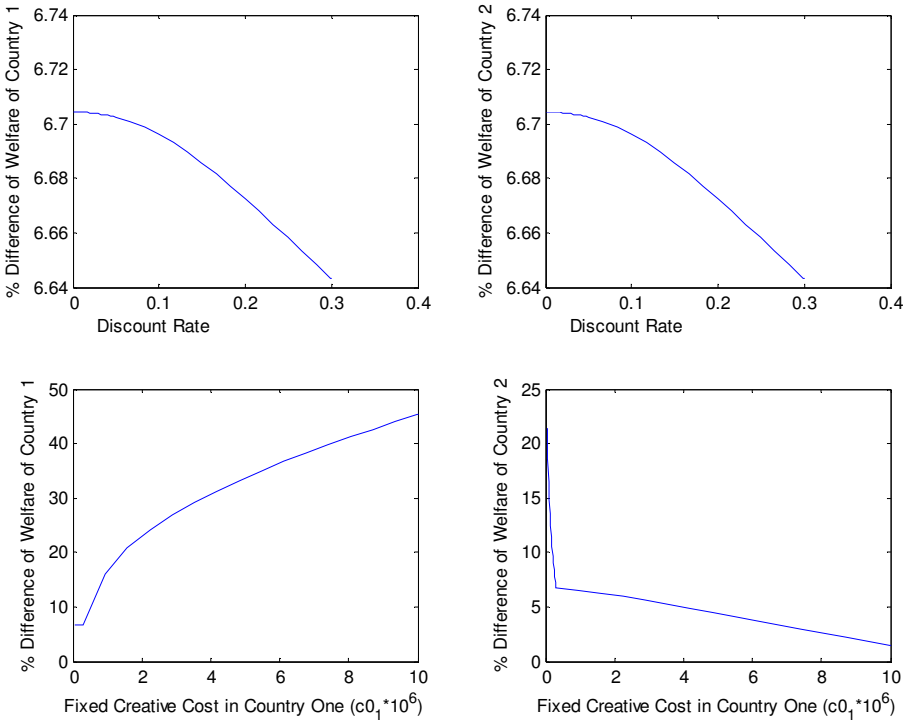


Figure 52-55. Difference in National Welfare of Cooperative Model from Competitive Model

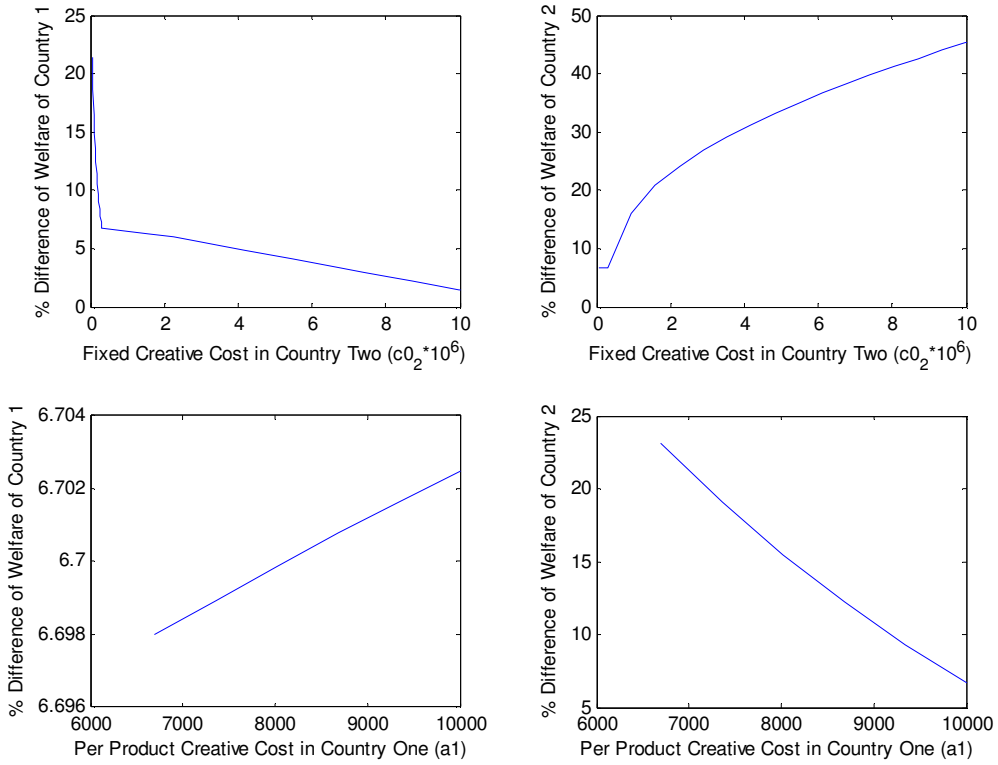


Figure 56-59. Difference in National Welfare of Cooperative Model from Competitive Model

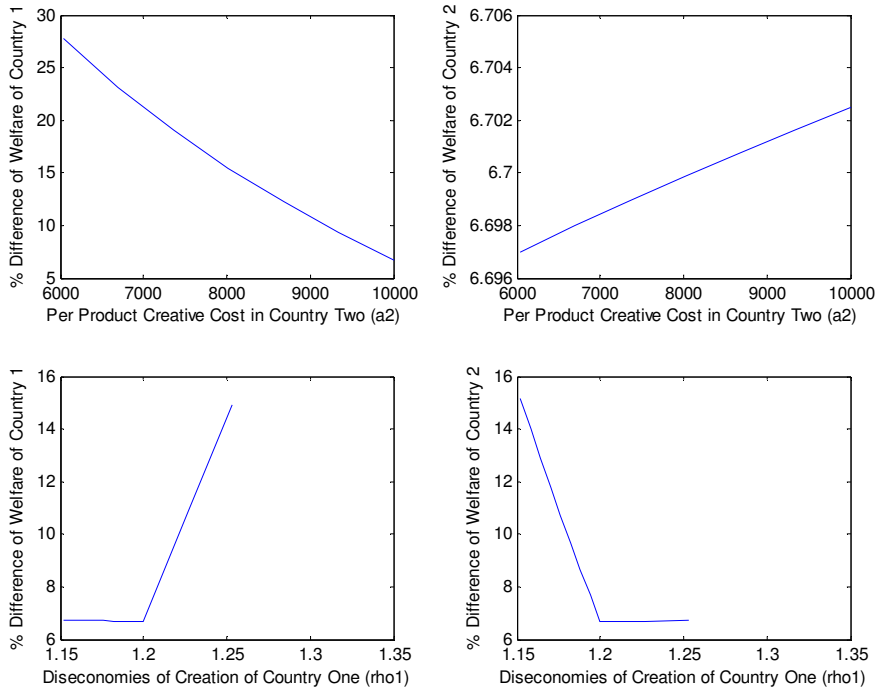
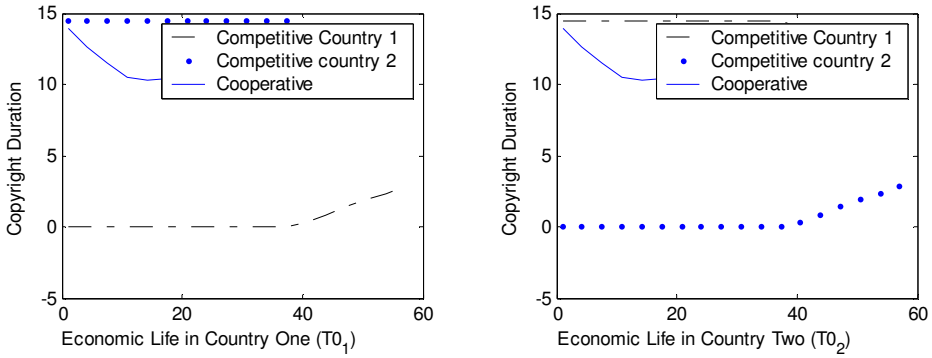


Figure 60-61. Difference in Copyright Duration



Appendix A: Mathematical Procedures to Solve the Cooperative Model

Copy (16)-(19):

$$d_{11i} = D_1 s_{1i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} {p_{1i}}^{-\delta} \prod_{j\neq i} {p_{1j}}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_2} {p_{2j}}^{\frac{\beta}{n_1+n_2-1}} g_1(t) \quad \text{(A.1)}$$

$$d_{12i} = D_2 s_{1i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} {p_{1i}}^{-\delta} \prod_{j\neq i} {p_{1j}}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_2} {p_{2j}}^{\frac{\beta}{n_1+n_2-1}} g_2(t) \quad \text{(A.2)}$$

$$d_{21i} = D_1 s_{2i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} {p_{2i}}^{-\delta} \prod_{j\neq i} {p_{2j}}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_1} {p_{1j}}^{\frac{\beta}{n_1+n_2-1}} g_1(t) \quad \text{(A.3)}$$

$$d_{22i} = D_2 s_{2i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} {p_{2i}}^{-\delta} \prod_{j\neq i} {p_{2j}}^{\frac{\beta}{n_1+n_2-1}} \prod_{j=1}^{n_1} {p_{1j}}^{\frac{\beta}{n_1+n_2-1}} g_2(t) \quad \text{(A.4)}$$

The demand for a creator's product depends on the price of the products of the creators in the same ways regardless of the specific creators and country of origin and country of market. Markets only differ in level and in how demands change over time.

From $\frac{\partial \pi_{1i}}{\partial p_{11i}} = 0$, $\frac{\partial \pi_{1i}}{\partial p_{12i}} = 0$, $\frac{\partial \pi_{2i}}{\partial p_{21i}} = 0$, and $\frac{\partial \pi_{2i}}{\partial p_{22i}} = 0$ and the above demand function, one has:

$$p_{11i} = p_{12i} = p_{21j} = p_{22j} = p \equiv \frac{\delta}{\delta-1} b \quad \text{(A.5)}$$

Plug it into (A.1)-(A4),

$$d_{11i} = D_1 s_{1i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} p^{\beta-\delta} g_1(t) \quad \text{(A.6)}$$

$$d_{12i} = D_2 s_{1i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} p^{\beta-\delta} g_2(t) \quad \text{(A.7)}$$

$$d_{21i} = D_1 s_{2i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} p^{\beta-\delta} g_1(t) \quad \text{(A.8)}$$

$$d_{22i} = D_2 s_{2i}\left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} p^{\beta-\delta} g_2(t) \quad \text{(A.9)}$$

Plug it into profit function (1) and (2),

$$\pi_{1i} = [D_1 G_1(T) + D_2 G_2(T)] s_{1i} \left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} p^{\beta-\delta}(p-b) - c_1(s_{1i}) = 0 \qquad \text{(A.10)}$$

$$\pi_{2i} = [D_1 G_1(T) + D_2 G_2(T)] s_{2i} \left(\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}\right)^{\alpha-1} p^{\beta-\delta}(p-b) - c_2(s_{2i}) = 0 \qquad \text{(A.11)}$$

Where

$$G_1(T) = \int_0^T g_1(t)\, e^{-\gamma t} dt$$

And

$$G_2(T) = \int_0^T g_2(t)\, e^{-\gamma t} dt$$

From $\frac{\partial \pi_{1i}}{\partial s_{1i}} = 0$, $\pi_{1i} = 0$, $\frac{\partial \pi_{2i}}{\partial s_{2i}} = 0$, and $\pi_{2i} = 0$, one has:

$$\frac{c_1(s_{1i})}{s_{1i}} + (\alpha - 1)\frac{c_1(s_{1i})}{\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}} = c_1{}'(s_{1i}) \qquad \text{(A.12)}$$

$$\frac{c_2(s_{2i})}{s_{2i}} + (\alpha - 1)\frac{c_2(s_{2i})}{\sum_{j=1}^{n_1} s_{1j} + \sum_{i=1}^{n_2} s_{2j}} = c_2{}'(s_{2i}) \qquad \text{(A.13)}$$

Assuming all creators of country one have the same cost function and so do creators of country two. Then, by symmetry, $s_{1i} = s_{1j} \equiv s_1$ and $s_{2i} = s_{2j} \equiv s_2$. Therefore,

$$\frac{c_1(s_1)}{s_1} + (\alpha - 1)\frac{c_1(s_1)}{n_1 s_1 + n_2 s_2} = c_1{}'(s_1) \qquad \text{(A.14)}$$

$$\frac{c_2(s_2)}{s_2} + (\alpha - 1)\frac{c_2(s_2)}{n_1 s_1 + n_2 s_2} = c_2{}'(s_2) \qquad \text{(A.15)}$$

That is,

$$\frac{1}{s_1} + \frac{\alpha - 1}{n_1 s_1 + n_2 s_2} = \frac{c_1{}'(s_1)}{c_1(s_1)} \qquad \text{(A.16)}$$

$$\frac{1}{s_2} + \frac{\alpha - 1}{n_1 s_1 + n_2 s_2} = \frac{c_2{}'(s_2)}{c_2(s_2)} \qquad \text{(A.17)}$$

From (A.16) an (A.17):

$$n_1 s_1 + n_2 s_2 = \frac{\alpha - 1}{\frac{c_1'(s_1)}{c_1(s_1)} - \frac{1}{s_1}} = \frac{\alpha - 1}{\frac{c_2'(s_2)}{c_2(s_2)} - \frac{1}{s_2}} \tag{A.18}$$

Marginal profit conditions (A.10) and (A.11) become:

$$[D_1 G_1(T_1) + D_2 G_2(T_2)] s_1 (n_1 s_1 + n_2 s_2)^{\alpha - 1} p^{\beta - \delta}(p - b) - c_1(s_1) = 0 \tag{A.19}$$

$$[D_1 G_1(T_1) + D_2 G_2(T_2)] s_2 (n_1 s_1 + n_2 s_2)^{\alpha - 1} p^{\beta - \delta}(p - b) - c_2(s_2) = 0 \tag{A.20}$$

Demand functions (A.6) –(A.9) become:

$$d_{11i} = D_1 s_1 (n_1 s_1 + n_2 s_2)^{\alpha - 1} {p_{1i}}^{-\delta} p^{\beta} g_1(t) \tag{A.21}$$

$$d_{12i} = D_2 s_1 (n_1 s_1 + n_2 s_2)^{\alpha - 1} {p_{1i}}^{-\delta} p^{\beta} g_2(t) \tag{A.22}$$

$$d_{21i} = D_1 s_2 (n_1 s_1 + n_2 s_2)^{\alpha - 1} {p_{2i}}^{-\delta} p^{\beta} g_1(t) \tag{A.23}$$

$$d_{22i} = D_2 s_2 (n_1 s_1 + n_2 s_2)^{\alpha - 1} {p_{2i}}^{-\delta} p^{\beta} g_2(t) \tag{A.24}$$

Consumer surplus (11 an (12) become:

$$cs_1 = D_1 (n_1 s_1 + n_2 s_2)^{\alpha} \frac{b^{-\delta+1}}{\delta - 1} p^{\beta} G_1(\infty) - D_1 (n_1 s_1 + n_2 s_2)^{\alpha} \frac{b^{-\delta+1} - p^{-\delta+1}}{\delta - 1} p^{\beta} G_1(T) \tag{A.25}$$

$$cs_2 = D_2 (n_1 s_1 + n_2 s_2)^{\alpha} \frac{b^{-\delta+1}}{\delta - 1} p^{\beta} G_2(\infty) - D_2 (n_1 s_1 + n_2 s_2)^{\alpha} \frac{b^{-\delta+1} - p^{-\delta+1}}{\delta - 1} p^{\beta} G_2(T) \tag{A.26}$$

Zero profit conditions become:

$$[D_1 G_1(T) + D_2 G_2(T)] s_1 \left(\frac{\alpha - 1}{\frac{c_1'(s_1)}{c_1(s_1)} - \frac{1}{s_1}} \right)^{\alpha - 1} p^{\beta - \delta}(p - b) - c_1(s_1) = 0 \tag{A.27}$$

$$[D_1 G_1(T_1) + D_2 G_2(T_2)] s_2 \left(\frac{\alpha - 1}{\frac{c_2'(s_2)}{c_2(s_2)} - \frac{1}{s_2}} \right)^{\alpha - 1} p^{\beta - \delta}(p - b) - c_2(s_2) = 0 \tag{A.28}$$

From (A.27), (A.28) and (A.18), one has

$$\frac{c_1(s_1)}{s_1} = \frac{c_2(s_2)}{s_2} \tag{A.29}$$

Average costs of creators of the two countries must be the same.

Consumer surplus become:

$$cs_1 = D_1\left(\frac{\alpha-1}{\frac{c_1'(s_1)}{c_1(s_1)}-\frac{1}{s_1}}\right)^{\alpha}\frac{b^{-\delta+1}}{\delta-1}p^{\beta}G_1(\infty) - D_1\left(\frac{\alpha-1}{\frac{c_1'(s_1)}{c_1(s_1)}-\frac{1}{s_1}}\right)^{\alpha}\frac{b^{-\delta+1}-p^{-\delta+1}}{\delta-1}p^{\beta}G_1(T) \tag{A.30}$$

$$cs_2 = D_2\left(\frac{\alpha-1}{\frac{c_2'(s_2)}{c_2(s_2)}-\frac{1}{s_2}}\right)^{\alpha}\frac{b^{-\delta+1}}{\delta-1}p^{\beta}G_2(\infty) - D_2\left(\frac{\alpha-1}{\frac{c_2'(s_2)}{c_2(s_2)}-\frac{1}{s_2}}\right)^{\alpha}\frac{b^{-\delta+1}-p^{-\delta+1}}{\delta-1}p^{\beta}G_2(T) \tag{A.31}$$

Let

$$W \equiv cs_1 + cs_2$$

Then,

$$W = [D_1G_1(\infty) + D_2G_2(\infty)]\left(\frac{\alpha-1}{\frac{c_1'}{c_1}-\frac{1}{s_1}}\right)^{\alpha}\frac{b^{-\delta+1}}{\delta-1}p^{\beta} - [D_1G_1(T) + D_2G_2(T)]\left(\frac{\alpha-1}{\frac{c_1'}{c_1}-\frac{1}{s_1}}\right)^{\alpha}\frac{b^{-\delta+1}-p^{-\delta+1}}{\delta-1}p^{\beta} \tag{A.32}$$

Note the global welfare W is a function of only T and s_1. Similarly, W can also be written as a function of T and s_2. When creators in country one has significant cost disadvantage and are competed out of the market, one has to use the form of W as function of T and s_2. All the following procedures are written for the W as function of T and s_1. They can be written in parallel for the W as function of T and s_2.

First order condition of the cooperative model is:

$$\frac{dW}{dT} = [D_1G_1(\infty) + D_2G_2(\infty)]\frac{b^{-\delta+1}}{\delta-1}p^{\beta}(\alpha-1)^{\alpha}(-\alpha)\left(\frac{c_1'}{c_1}-\frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{c_1''c_1 - c_1'^2}{c_1^2}+\frac{1}{s_1^2}\right)\frac{\partial s_1}{\partial T}$$

$$-[D_1G_1(T) + D_2G_2(T)]\frac{b^{-\delta+1}-p^{-\delta+1}}{\delta-1}p^{\beta}(\alpha-1)^{\alpha}(-\alpha)\left(\frac{c_1'}{c_1}-\frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{c_1''c_1 - c_1'^2}{c_1^2}+\frac{1}{s_1^2}\right)\frac{\partial s_1}{\partial T}$$

$$-\left(\frac{\alpha-1}{\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}}\right)^{\alpha}\frac{b^{-\delta+1}-p^{-\delta+1}}{\delta-1}p^{\beta}[D_1g_1(T)e^{-\gamma T}+D_2g_2(T)e^{-\gamma T}]=0 \tag{A.33}$$

We need derivative of s_1 to T.

Take derivate to T on both sides of (A.27):

$$[D_1g_1(T)+D_2g_2(T)]e^{-\gamma T}s_1\left(\frac{\alpha-1}{\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}}\right)^{\alpha-1}p^{\beta-\delta}(p-b)$$

$$+[D_1G(T)+D_2G(T)]p^{\beta-\delta}(p-b)(\alpha-1)^{\alpha-1}\left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{1-\alpha}+s_1(1\right.$$

$$\left.-\alpha)\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{-\alpha}\left(\frac{c_1{}''(s_1)c_1(s_1)-c_1{}'^2}{c_1{}^2(s_1)}+\frac{1}{s_1{}^2}\right)\right]\frac{\partial s_1}{\partial T}-c_1{}'(s_1)\frac{\partial s_1}{\partial T}=0$$

Thus,

$$\frac{\partial s_1}{\partial T}=\frac{-[D_1g_1(T)+D_2g_2(T)]e^{-\gamma T}s_1\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{1-\alpha}A}{[D_1G_1(T)+D_2G_2(T)]A\left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{1-\alpha}+s_1(1-\alpha)\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{-\alpha}\left(\frac{c_1{}''c_1-c_1{}'^2}{c_1{}^2(s_1)}+\frac{1}{s_1{}^2}\right)\right]-c_1{}'(s_1)} \tag{A.34}$$

where

$$A\equiv p^{\beta-\delta}(p-b)(\alpha-1)^{\alpha-1} \tag{A.35}$$

Equations (A.27) and (A.33) are only functions of T and s_1. Collect equations:

$$f_1=A[D_1G_1(T)+D_2G_2(T)]s_1\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{1-\alpha}-c_1(s_1)=0 \tag{A.36}$$

$$f_2=E(-\alpha)\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{c_1{}''(s_1)c_1(s_1)-c_1{}'^2}{c_1{}^2(s_1)}+\frac{1}{s_1{}^2}\right)\frac{\partial s_1}{\partial T}$$

$$-[F_1G_1(T)+F_2G_2(T)](-\alpha)\left(\frac{c_1{}'(s_1)}{c_1(s_1)}-\frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{c_1{}''(s_1)c_1(s_1)-c_1{}'^2}{c_1{}^2(s_1)}+\frac{1}{s_1{}^2}\right)\frac{\partial s_1}{\partial T}$$

$$-[F_1 g_1(T) + F_2 g_2(T)] \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha} e^{-\gamma T} = 0 \quad \text{(A.37)}$$

Where

$$A \equiv p^{\beta-\delta}(p-b)(\alpha-1)^{\alpha-1} \quad \text{(A.38)}$$

$$E_1 \equiv D_1 \frac{b^{-\delta+1}}{\delta-1} p^{\beta} G_1(\infty)(\alpha-1)^{\alpha} \quad \text{(A.39)}$$

$$E_2 \equiv D_2 \frac{b^{-\delta+1}}{\delta-1} p^{\beta} G_2(\infty)(\alpha-1)^{\alpha} \quad \text{(A.40)}$$

$$E \equiv E_1 + E_2 \quad \text{(A.41)}$$

$$F_1 \equiv D_1 \frac{b^{-\delta+1} - p^{-\delta+1}}{\delta-1} p^{\beta}(\alpha-1)^{\alpha} \quad \text{(A.42)}$$

$$F_2 \equiv D_2 \frac{b^{-\delta+1} - p^{-\delta+1}}{\delta-1} p^{\beta}(\alpha-1)^{\alpha} \quad \text{(A.43)}$$

And

$$\frac{\partial s_1}{\partial T} = \frac{-[D_1 g_1(T) + D_2 g_2(T)] e^{-\gamma T} s_1 \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{1-\alpha} A}{[D_1 G_1(T) + D_2 G_2(T)] A \left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{1-\alpha} + s_1(1-\alpha)\left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha}\left(\frac{c_1{}''c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2}\right)\right] - c_1{}'(s_1)} \quad \text{(A.44)}$$

Equations f_1 and f_2 only depend on s_1 and T. Newton's Method requires derivatives of f_1 and f_2 to s_1 and T.

$$\frac{\partial f_1}{\partial s_1} = A[D_1 G_1(T_1) + D_2 G_2(T)] \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{1-\alpha}$$

$$+A[D_1 G_1(T) + D_2 G_2(T)](1-\alpha) s_1 \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha} \left(\frac{c_1{}''(s_1) c_1(s_1) - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2}\right) - c_1{}'(s_1) \quad \text{(A.45)}$$

$$\frac{\partial f_1}{\partial T} = A[D_1 g_1(T) + D_2 g_2(T)] e^{-\gamma T} s_1 \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{1-\alpha} \quad \text{(A.46)}$$

$$\frac{\partial f_2}{\partial s_1} = E(-\alpha)(-\alpha-1)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-2}\left(\frac{{c_1}''(s_1)c_1(s_1) - {c_1}'^2}{{c_1}^2(s_1)} + \frac{1}{{s_1}^2}\right)^2 \frac{\partial s_1}{\partial T}$$

$$+E(-\alpha)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}'''c_1 + {c_1}''{c_1}' - 2{c_1}'{c_1}''}{{c_1}^2(s_1)} - 2{c_1}'\frac{{c_1}''c_1 - {c_1}'^2}{{c_1}^3(s_1)} - \frac{2}{{s_1}^3}\right)\frac{\partial s_1}{\partial T}$$

$$+E(-\alpha)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}''(s_1)c_1(s_1) - {c_1}'^2}{{c_1}^2(s_1)} + \frac{1}{{s_1}^2}\right)\frac{\partial^2 s_1}{\partial T \partial s_1}$$

$$-[F_1G_1(T) + F_2G_2(T)](-\alpha)(-\alpha-1)\left(\frac{{c_1}'}{c_1} - \frac{1}{s_1}\right)^{-\alpha-2}\left(\frac{{c_1}''c_1 - {c_1}'^2}{{c_1}^2} + \frac{1}{{s_1}^2}\right)^2 \frac{\partial s_1}{\partial T}$$

$$-[F_1G_1(T) + F_2G_2(T)](-\alpha)\left(\frac{{c_1}'}{c_1} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}'''c_1 + {c_1}''{c_1}' - 2{c_1}'{c_1}''}{{c_1}^2(s_1)} - 2{c_1}'\frac{{c_1}''c_1 - {c_1}'^2}{{c_1}^3(s_1)} - \frac{2}{{s_1}^3}\right)\frac{\partial s_1}{\partial T_1}$$

$$-[F_1G_1(T) + F_2G_2(T)](-\alpha)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}''(s_1)c_1(s_1) - {c_1}'^2}{{c_1}^2(s_1)} + \frac{1}{{s_1}^2}\right)\frac{\partial^2 s_1}{\partial T \partial s_1}$$

$$-[F_1g_1(T) + F_2g_2(T)](-\alpha)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}''c_1 - {c_1}'^2}{{c_1}^2} + \frac{1}{{s_1}^2}\right)e^{-\gamma T_1} \qquad \text{(A.47)}$$

$$\frac{\partial f_2}{\partial T} = +E(-\alpha)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}''(s_1)c_1(s_1) - {c_1}'^2}{{c_1}^2(s_1)} + \frac{1}{{s_1}^2}\right)\frac{\partial^2 s_1}{\partial T^2}$$

$$-[F_1G_1 + F_2G_2](-\alpha)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}''(s_1)c_1(s_1) - {c_1}'^2}{{c_1}^2(s_1)} + \frac{1}{{s_1}^2}\right)\frac{\partial^2 s_1}{\partial T^2}$$

$$-[F_1g_1(T) + F_2g_2(T)](-\alpha)\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha-1}\left(\frac{{c_1}''(s_1)c_1(s_1) - {c_1}'^2}{{c_1}^2(s_1)} + \frac{1}{{s_1}^2}\right)\frac{\partial s_1}{\partial T_1}e^{-\gamma T_1}$$

$$-\left(\frac{{c_1}'(s_1)}{c_1(s_1)} - \frac{1}{s_1}\right)^{-\alpha}\{F_1[{g_1}'(T)e^{-\gamma T} - \gamma g_1(T)e^{-\gamma T}] + F_2[{g_2}'(T)e^{-\gamma T} - \gamma g_2(T)e^{-\gamma T}]\} \qquad \text{(A.48)}$$

We need second order derivatives of s_1 to s_1 and T.

$$\frac{\partial^2 s_1}{\partial T \partial s_1} =$$

$$\frac{-[D_1 g_1(T) + D_2 g_2(T)] e^{-\gamma T} A \left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} + s_1(1-\alpha) \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2} \right) \right]}{[D_1 G_1(T) + D_2 G_2(T)] A \left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} + s_1(1-\alpha) \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2} \right) \right] - c_1{}'(s_1)}$$

$$- \frac{-[D_1 g_1(T) + D_2 g_2(T)] e^{-\gamma T} s_1 \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} A}{\left\{ [D_1 G_1(T) + D_2 G_2(T)] A \left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} + s_1(1-\alpha) \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2} \right) \right] - c_1{}'(s_1) \right\}^2}$$

$$\times \left\{ [D_1 G_1(T) + D_2 G_2(T)] A[H] - c_1{}''(s_1) \right\} \qquad \text{(A.49)}$$

$$\frac{\partial^2 s_1}{\partial T^2} =$$

$$+ \frac{-[D_1(g_1{}'(T) - \gamma g_1(T)) + D_2(g_2{}'(T) - \gamma g_2(T))] e^{-\gamma T} s_1 \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} A}{[D_1 G_1(T) + D_2 G_2(T)] A \left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} + s_1(1-\alpha) \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2} \right) \right] - c_1{}'(s_1)}$$

$$- \frac{-[D_1 g_1(T) + D_2 g_2(T)] e^{-\gamma T} s_1 \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} A}{\left\{ [D_1 G_1(T) + D_2 G_2(T)] A \left[\left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{1-\alpha} + s_1(1-\alpha) \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2} \right) \right] - c_1{}'(s_1) \right\}^2}$$

$$\times \left\{ [D_1 g_1(T) + D_2 g_2(T)] e^{-\gamma T} A \left[\left(\frac{c_1{}'}{c_1} - \frac{1}{s_1} \right)^{1-\alpha} + s_1(1-\alpha) \left(\frac{c_1{}'}{c_1} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2} + \frac{1}{s_1{}^2} \right) \right] \right\} \qquad \text{(A.50)}$$

Where

$$H \equiv 2(1-\alpha) \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2} \right)$$

$$+ (1-\alpha)(-\alpha) s_1 \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha-1} \left(\frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^2(s_1)} + \frac{1}{s_1{}^2} \right)^2$$

$$+ s_1(1-\alpha) \left(\frac{c_1{}'(s_1)}{c_1(s_1)} - \frac{1}{s_1} \right)^{-\alpha} \left(\frac{c_1{}''' c_1 + c_1{}'' c_1{}' - 2 c_1{}' c_1{}''}{c_1{}^2(s_1)} - 2 c_1{}' \frac{c_1{}'' c_1 - c_1{}'^2}{c_1{}^3(s_1)} - \frac{2}{s_1{}^3} \right) \qquad \text{(A.51)}$$

And

$$A \equiv p^{\beta-\delta}(p-b)(\alpha-1)^{\alpha-1}$$

Finally, copy (20) and (21)

$$g_1(t) = \begin{cases} 1 - \dfrac{t}{T^0{}_1} & if \quad t < T^0{}_1(1-\theta_1) \\ \theta_1 & otherwise \end{cases} \tag{A.52}$$

$$g_2(t) = \begin{cases} 1 - \dfrac{t}{T^0{}_2} & if \quad t < T^0{}_2(1-\theta_2) \\ \theta_2 & otherwise \end{cases} \tag{A.53}$$

Now Newton's Method can be used to compute T and s_1 (or T and s_2 if creators of country one has cost disadvantage and are competed out of the market). With s_1, one can use (A.29) to compute s_2 (or vice versa). Then, one can compute total number of first-copy products by (A.18) and cs_1 and cs_2 from (A.25) and (A.26).