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Illegal Extractions of Renewable Resources and International Trade with Costly Enforcement of Property Rights*

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Abstract

Illegal extractions of renewable resources threaten sustainable use of those resources. The world community has recently paid increasing attention to the issue of illegal logging. This paper tries to explain why it is important to exclude illegally logged timber from the international market by using a stylized model in the literature of trade and renewable resources. It is shown that a fall in the price of timber may cause a switch of management regime from enforced property rights to open-access, expanding the supply of timber and reducing forest stock. When several countries export timber, an increase in illegal logging in one country due to a regime switch may also increase illegal logging in other countries. While conflicting with the GATT/WTO rules for reasons of discrimination by process and production methods (PPMs), import restrictions only on illegally logged timber will be effective to prevent the international diffusion of illegal logging.

Keywords: renewable resources; illegal logging; property rights; open access; enforcement; process and production methods (PPMs).

JEL classification: F10, Q20.

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1. Introduction

Illegal extractions of renewable resources are a dangerous threat to the sustainability of these resources. For example, in the case of forests, illegal logging is a major cause of deforestation. The average annual change in forest area during 1990–2000 was –9.4 million hectares worldwide and –2.27 million hectares in Southeast Asia. Indonesia alone recorded an average annual deforestation of 1.31 million hectares during the period (FAO, 2005). On the other hand, Seneca Creek Associates and Wood Resources International (2004) report that about 8% (131.0 million m^3) of the world's roundwood production, 6% (25.9 million m^3) of lumber production, and 17% (10.0 million m^3) of plywood production are from suspicious sources and likely illegal. Moreover, based on various reports from NGOs, 70%–80% of timber production in Indonesia, 20%–50% of production in Russia, and 20%–90% of production in Brazil is suspected of being illegal. Substantial amounts of illegal extractions are also reported for fishery and wildlife.

Illegal extractions of resources are a serious problem not only because they are "illegal" but also, and more importantly, because they cause overexploitation of resources. Those who illegally extract renewable resources are typically myopic and would not consider the sustainable use of the resources. Therefore, they try to maximize the current period profits without taking the resource dynamics into account. Consequently, if the owner of the resource does not enforce the property rights at all, illegal extractors will harvest the resource, which will result in the well-known "open-access" situation.

From the perspective of sustainable use of renewable natural resources, the world community addresses the issue of illegal harvests for various resources. For example, the world community has recently paid increasing attention to the issue of illegal logging. This issue began to attract international attention when the G8 Action Program on Forests was initiated in 1998. The leaders of G8 countries also discussed this issue at the Kyushu-Okinawa G8 summit in July 2000, which triggered international attention. At the World Summit on Sustainable Development (WSSD) in Johannesburg in September 2002, Japan launched the Asia Forest Partnership (AFP) in cooperation with Indonesia, intergovernmental organizations, and NGOs. The AFP is aimed at promoting sustainable forest management in Asia through controlling illegal logging as well as controlling forest fires and reforesting degraded lands.[1]

Measures that have been implemented or considered to control illegal logging include (i) restrictions on public procurement of wood and wood products by the domestic public procurement policy and (ii) restrictions on trade of wood and wood products by bilateral agreements between importing and exporting countries of these products. For example, the European Union (EU) requires

[1] AFP held six meetings as of September 2006. For details, see the AFP's website (http://www.asiaforests.org/).

environmental considerations in the public procurement procedure.[2] The Commission of the European Communities (2004) explains how environmental aspects can be incorporated in the public procurement procedure. Moreover, the United Kingdom (UK) announced the "UK Government Timber Procurement Policy: Timber Procurement Advice Note" in January 2004 (DEFRA, 2004), which provides new guidelines on the way of procuring wood and wood products by the public sector in the UK. The Japanese Government also restricts public procurement to legal and sustainable wood and wood products. At the G8 Gleneagles Summit held in the UK in July 2005, Japan announced that it would restrict public procurement of wood and wood products only to those verifying legality and sustainability by utilizing the Law on Promoting Green Purchasing.[3] The Japanese Government published new guidelines for public procurement of wood and wood products (Forestry Agency of Japan, 2006) in February 2006, which require certification of legality and sustainability to suppliers of wood and wood products to the public sector in Japan.

With regard to the restrictions on trade of wood and wood products by bilateral agreements, the EU's Forest Law Enforcement, Governance and Trade (FLEGT), which requires certification of legality for imports of timber on the basis of voluntary bilateral agreements with exporting countries, is under preparation (Commission of the European Communities, 2003). This action plan includes support from the EU to timber-producing countries for development of verification systems, capacity building, and policy reform. Under the FLEGT, trade between the signatories of the bilateral agreements is restricted to legally and sustainably harvested timber in exchange for this support.

These actions to exclude illegally harvested resources from the international market would be effective in controlling illegal extractions of resources in individual countries. The effects of these actions may well be beyond that. The reason is as follows. Illegal extractions of renewable resources in one country may not just be a threat to the conservation of the resources in that country. They may also be a threat to resources in other countries. The intuition is rather simple. Since a larger amount of the resource good is supplied under illegal extraction than under enforced property rights, the world price of the resource good faces a downward pressure. A lower price of the resource good reduces incentive for the owners of resources in other countries to enforce property rights when the enforcement of the property rights is costly, while a lower price also reduces the incentive for illegal extractions. If the former effect dominates the latter, illegal extractions of the resources would increase in these countries. Actions to exclude illegally harvested resources from the international market may

[2] Parliament and Council of the European Communities (2004), Directive 2004/17/EC of the European Parliament and of the Council of 31 March 2004, coordinating the procurement procedure of entities operating in the water, energy, transport and postal services sectors. Parliament and Council of the European Communities (2004), Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004, on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts.

[3] The formal name is the "Law Concerning the Promotion of Procurement of Eco-Friendly Goods and Services by the State

be effective in preventing this international diffusion of illegal harvests.

However, trade restrictions only on illegally harvested resources (or resources harvested in an unsustainable manner) will not be allowed under the current GATT/WTO rules. A principle of the GATT/WTO rules is non-discrimination for the goods that are judged to be "like products." Traditionally, discriminatory treatments based on *process and production methods* (PPMs) have not been allowed under the GATT/WTO rules.[4] Physical characteristics of illegally harvested resource goods (or resource goods harvested in an unsustainable manner) are not different from those of legally harvested ones (or the ones harvested in a sustainable manner). Thus, the issue of legality (or sustainability) corresponds to *non-product-related process and production methods* (NPR-PPMs), which implies that trade restrictions only on illegally harvested resources will be judged as violating the current GATT/WTO rules. It is said that the EU and some countries try to restrict trade of illegally harvested wood and wood products by bilateral agreements in order to avoid potential challenges from other countries at the WTO. Since the trade restrictions against illegally harvested wood and wood products are directly related to the issue of NPR-PPMs, the responses to this issue could be important not just for the forestry sector but for a wide range of industries in which NPR-PPMs matter.

The main purpose of this paper is to examine the issue of illegal extractions of renewable resources, including the possibility of international diffusion of illegal extractions, in a formal model. In order to accomplish the task, I use a stylized model in the literature of trade and renewable resources (Brander and Taylor, 1997a, b, 1998). Since the model is highly stylized, the implications from its analysis will be applicable to a wide range of renewable resources, including fish, forests, and wildlife. The model is a Ricardian type of general equilibrium model with renewable resources. A key is that enforcement of property rights over renewable resources is endogenously chosen. A fixed cost of enforcement is assumed, which may make a resource owner choose not to enforce property rights if the cost is high. If property rights are not enforced, the resource becomes subject to open-access. Since the cost of enforcement is fixed, the decision of a resource owner is binary: either to enforce the property rights perfectly by paying the fixed cost or not to enforce the property rights at all. While it would be more realistic to allow variable costs and intermediate levels of enforcement, the assumption of the fixed enforcement cost is very useful to simplify the analysis and to illustrate the results clearly.

Since the resource is renewable, illegal extractions characterized by open-access introduce two types of distortion into the economy. The first is a static or *intra-temporal* distortion; namely, rent dissipation due to excess entry to the resource sector. This corresponds to the well-known phenomenon of the "tragedy of the commons." The second distortion is a dynamic or *inter-temporal* one, which is a resource stock reduction due to myopic actions by illegal harvesters. The results in the

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and Other Entities." For details, see http://www.env.go.jp/en/lar/green/index.html (Ministry of the Environment).

[4] For detailed discussion on the issue of PPMs and on the treatments of this issue in recent GATT/WTO trade dispute cases, see Isaac and Kerr (2003), Quick and Lau (2003), Engel (2004), and Read (2004).

case of open-access are owing to either or both of these distortions.

In this paper, the cases of small open economy and large countries exporting the resource good are both examined. The starting point of the analysis is at a free-trade steady-state equilibrium in which property rights are enforced. Then, I analyze how this initial steady state would be disturbed by an exogenous shock, such as a fall in the international price of the resource good. Moreover, I investigate how import restrictions could affect the equilibrium.

The main results are as follows. First, in the case of a small open economy, a reduction in the price of the resource good may lead its higher output with lower resource stock in a steady state. This counterintuitive result owes to the regime switch from enforced property rights to open-access. Since the long-run supply curve of the resource good is typically backward bending under open-access (Copes, 1970; Clark, 1990), a similar result could be obtained without regime switch. However, without regime switch a larger supply due to a reduction in price must be accompanied by an *increase* in the resource stock. The result of a larger supply with lower resource stock caused by a reduction in price is hence specific to the case of regime switch. Note that a fall in the price of the resource good also decreases the incentive for illegal harvests. Thus, in order to obtain the result that a fall in the price is followed by an increase in the output and a decrease in the stock, the effect of the regulatory regime switch must dominate the effect of the lower incentive for illegal harvests. Second, in the case of several large exporting countries of the resource good, an increase in the enforcement cost of property rights in one country may not only cause a regime switch from enforced property rights to open-access in that country but also cause a regime switch in some other countries. This result can be viewed as the international diffusion of illegal harvests of renewable resources. Third, when an import restriction is imposed on imports of the resource good in general, international diffusion of illegal harvests may be reinforced. This is because an inward shift in the world demand for the resource good will further decrease the good's world price. When an import restriction is imposed only on imports of an illegally harvested resource good, by contrast, international diffusion of illegal harvests may be prevented. This is because such an import restriction will increase the world price of the legally harvested resource good, increasing the incentive for the owners of the resource to enforce property rights.

The analysis in this paper is in line with the studies in the field of trade and renewable resources. The basic model in this paper is based on the one developed by Brander and Taylor (1997a, b, 1998). In their papers, the regime of renewable resource management (either private property rights or open-access) is given exogenously. They ignore the cost of enforcing property rights. Thus, the possibility of regime switch is not considered in their papers. The resource management regime is also exogenous in Chichilnisky (1993, 1994) and Jinji (2007). Francis (2005) endogenizes the enforcement of property rights in the Brander and Taylor model, as this paper does. Like this paper, he considers a fixed cost of enforcing property rights. However, his focus is on the welfare effects of the possible

regime switch and does not analyze the possibility of the international diffusion of illegal harvests.

Hotte, Long, and Tian (2000) also endogenize the enforcement of property rights in a more sophisticated way and examine the impact of trade liberalization on property rights regimes and welfare. In their model, the cost of enforcing property rights is increasing in the level of enforcement and the level of enforcement can change continuously from perfect enforcement to perfect open-access. An important result in their paper is that for any positive level of enforcement, the owner of the resource always chooses the entry-deterrence level of legal harvests of the resource, which totally removes an incentive for illegal harvests. Their result implies that even if the possibility of intermediate level of property rights enforcement is allowed, the legally harvested resource good and the illegally harvested resource good will not be supplied at the same time as long as the sites of the resources are symmetric.

Moreover, Jinji (2006) extends the Brander and Taylor model by endogenizing the carrying capacity of the resource. He explicitly models the dependence of the carrying capacity on the "base resource" such as land. Unlike the original Brander and Taylor model, under open-access a fall in the price of the resource good may result in a lower level of the resource stock in Jinji (2006) because a lower price of the resource good takes away not only labor inputs but also inputs of land from the resource sector. One may think that this result seems to be similar to that in this paper. However, a lower stock level due to a fall in the price is not followed by a higher harvest, which differs from the result in this paper.

Although the open-access regime is assumed, Copeland and Taylor (2006) demonstrate the possibility of sequential resource depletion in exporting countries of the resource good, which is similar to the international diffusion of illegal harvests in this paper. The main difference is that in their paper the "domino effect" of the resource depletion is driven by a high demand for the resource good and that the price of the resource good *rises* in the process of the sequential resource depletion.

The rest of the paper is organized in the following way. Section 2 sets up the basic framework of the model. Section 3 analyzes the case of a small open economy. Section 4 extends the analysis to the case of large exporting countries of resource goods. Section 5 discusses policy implications of the analysis. Section 6 provides some concluding remarks.

2. The Basic Setup

In this section, I describe the basic setup of the model.

2.1. Supply and demand

The model is a Ricardian type of general equilibrium model with renewable resources developed by Brander and Taylor (1997a, b, 1998). Let $S(t)$ denote the size of the renewable resource stock at time t.

The net change in the resource stock at time t is given by

$$dS/dt = G(S(t)) - H(t), \tag{1}$$

where $G(S(t))$ denotes the natural growth rate and $H(t)$ is the harvest rate. I omit the time argument hereafter. As is usual in the previous studies, I use a specific functional form for $G(S)$, which is given by

$$G(S) = rS(1 - S/K), \tag{2}$$

where r is the intrinsic growth rate and K is the maximum possible size or "carrying capacity" for the resource stock. A typical resource dynamics is depicted in Figure 1. In this figure, the resource stock size, S, is measured along the horizontal axis and the growth rate and the harvest rate are measured along the vertical axis. The inverted U shaped curve in the figure represents the growth function $G(S)$. Since the growth rate is positive for $S < K$ and negative for $S > K$, $S = K$ is a unique stable steady state without human harvests. The highest harvest is obtained in steady states when $S = K/2$, which is called the "maximum sustainable yield" (MSY).

For concreteness, I refer to the renewable resource as "forest" and the resource extraction activity as "logging." However, the implications of the analysis are applicable to a wide range of renewable resources not merely specific to forests.

There are two goods: the harvest of the renewable resource or "timber," H, and some other good or "manufactures," M. Good M is treated as a numeraire whose price is normalized to one. Labor, L, is the only primary factor of production, besides the resource stock. Good M is produced with constant returns to scale technology using only labor. By choice of units, one unit of good M is simply produced by one unit of labor:

$$M = L_M, \tag{3}$$

where L_M denotes the amount of labor employed in manufacturing. The harvest of timber is, on the other hand, carried out by the Schaefer production function:

$$H = \alpha S L_H, \tag{4}$$

where α is a positive constant and L_H is amount of labor used in the forestry sector, which may be legitimately employed labor or illegal extractors. Let L_E be legitimately employed labor and L_P be illegal extractors or "poachers." Then, $L_H = L_E + L_P$ holds. In Figure 1, the harvest function is depicted as an upward-sloping line. In this figure, a line that corresponds to the case of all labor being legitimately employed and a line that corresponds to the case of all labor being illegal are illustrated.

The full employment condition is given by

$$L = L_E + L_P + L_M. \tag{5}$$

Substitute (3) and (4) into (5) to yield the Ricardian production possibility frontier:

$$H = \alpha S(L - M). \tag{6}$$

A steady state emerges when $dS/dt = 0$, or $G(S) = H$. Equate $G(S)$ with H as given by (4) and solve for S to yield $S = 0$ or $S_{ss} = K(1 - \alpha L_H / r)$. The harvest of good H in a steady state with positive resource stock is given by substituting S_{ss} into (4), yielding

$$H_{ss} = rS_{ss}(1 - S_{ss}/K). \tag{7}$$

Substitute (7) and S_{ss} into (6) to obtain production of manufactures in a steady state:

$$M_{ss} = L - (r/\alpha)(1 - S_{ss}/K). \tag{8}$$

A representative household is endowed with one unit of labor and forest and is assumed to have instantaneous utility given by $u = h^{\beta} m^{1-\beta}$, where h and m are consumption levels of goods H and M, respectively. Let p denote the price of good H. The instantaneous budget constraint is given by $ph + m = I$, where I is the household's total income, which includes wage income w and rents from forestry, π^H, if any. Aggregate demands for goods H and M are given by

$$H^D = \beta IL/p, \qquad M^D = (1 - \beta)IL, \tag{9}$$

where the superscript D indicates variables in the demand side.

2.2. Endogenous enforcement of property rights

Each forest owner tries to maximize the steady-state rents from forestry, given the price of timber and wages.[5] For simplicity, I assume that all of the forests are identical and focus on symmetric equilibria, i.e., each forest owner takes the same action in equilibrium.

Each forest owner decides whether or not to enforce property rights. The enforcement of property rights is costly. Following Francis (2005) and Jinji (2006), I assume that the property rights can be perfectly enforced by hiring a fixed number of workers, L_R, to restrict access to the forest. Rents in the forestry sector, π^H, are given by

$$\pi^H = pH - wL_E - L_R. \tag{10}$$

The owner of the forest maximizes (10) subject to (4) and $S_{ss} = K(1 - \alpha L_E / r)$. Assuming an interior solution, the first-order condition yields the optimal employment L_E^R and the optimal steady-state level of S in the enforced property right regime for a given p as

$$L_E^R = (r/2\alpha)(1 - w/\alpha Kp), \tag{11}$$

$$S_{ss}^R(p) = K/2 + w/2\alpha p, \tag{12}$$

[5] This assumption would be more relevant in the forestry sector, because forest owners make decisions on planting and cutting trees by taking into account future profits several decades later.

respectively, where the superscript R indicates variables under enforced property rights.[6] Eq. (12) implies that under the enforced property rights the resource stock in steady states never goes below $K/2$. Substitute (11) and (12) into (4) to yield the steady-state supply of timber under enforced property rights:

$$H_{ss}^{R}(p) = (r/\alpha p)(\alpha Kp + w)(\alpha Kp - w)/4\alpha Kp. \tag{13}$$

A typical steady-state supply curve of timber under enforced property rights is illustrated as H_{ss}^{R} in Figure 2.

Moreover, substitute (11) and (12) into (10) to obtain the maximized rents in the forestry sector in steady states:[7]

$$\pi^{H*} = (r/\alpha)(\alpha Kp - w)/4\alpha Kp - L_R. \tag{14}$$

Note that an interior solution requires $L_E^R < L - L_R$, or

$$(r/2\alpha)(1 - 1/\alpha Kp) < L - L_R. \tag{15}$$

Throughout the paper, I assume that condition (15) is satisfied so that when the property rights are enforced, an interior solution prevails. It is easy to see that under condition (15) the economy is always diversified whenever the property rights are enforced. This implies that $w = 1$ always holds when the property rights is enforced.

The following comparative statics results are obtained:

Lemma 1. *Assuming an interior solution, (i)* $d\pi^{H*}/dp > 0$, *(ii)* $d\pi^{H*}/dr > 0$, *and (iii)* $d\pi^{H*}/dL_R < 0$.

(Proofs of Lemmas and Propositions are presented in the Appendix.)

Lemma 1 shows that an increase in p raises the incentive to enforce property rights. Similarly, the incentive to enforce property rights is higher as the resource grows faster. Moreover, a higher cost of enforcement reduces the incentive to enforce property rights.

When the owner of the forest decides not to enforce the property rights, on the other hand, the forest is subject to illegal logging and hence the usual open-access condition holds. Under the open-access, the harvest of timber is determined by profit maximization under free-entry conditions, which requires current-period profits for the representative harvester to be zero. The current-period zero-profit condition yields

$$p = w/\alpha S. \tag{16}$$

[6] Note they are essentially equivalent to those in the case of the "conservationist country" in Brander and Taylor (1997b).

[7] This is the same as what Francis (2005) shows, while he assumes that the government acts to maximize the rents at the aggregate level.

Thus, the steady-state level of *S* under open-access for a given *p* is given by

$$S_{ss}^{O}(p) = w/\alpha p, \tag{17}$$

where the superscript *O* indicates variables under open-access. Noting that as shown above, the steady-state stock level is given by $S_{ss} = K(1-\alpha L_H/r)$, the number of illegal extractors in steady states is given by $L_P = (r/\alpha)(1-S/K)$. Substitute this and (17) into (4) to obtain the steady-state supply of timber under open-access:

$$H_{ss}^{O}(p) = (rw/\alpha p)(1-w/\alpha Kp). \tag{18}$$

As is well known (Copes, 1970; Clark, 1990), the steady-state supply curve of a renewable resource under open-access is backward bending, as illustrated as H_{ss}^{O} in Figure 2.

Since the enforcement of the property rights is costly, the forest owners may optimally choose not to enforce the property rights.

Throughout the paper I assume that $L > r/\alpha$ holds so that the economy cannot specialize in good *H* in steady states.

Define p^x implicitly by $H_{ss}^{R}(p^x) = H_{ss}^{O}(p^x)$, as depicted in Figure 2. H_{ss}^{R} and H_{ss}^{O} are given by (13) and (18), respectively. Thus, equating (13) and (18) yields $p^x = (2w+1)/\alpha K$, where *w* is the wage rate under open-access in steady state. If the economy is diversified under open-access in steady state, $w = 1$ and hence $p^x = 3/\alpha K$.

Define also $\overline{p}$ implicitly by $\pi^{H*}(\overline{p}) = 0$, i.e., the price at which the owner of the forest is indifferent between enforcing property rights and not doing so. Then, Lemma 1 (i) implies that for $p > \overline{p}$ the owner of the resource enforces property rights and that for $p < \overline{p}$ he does not. Then, I call the case in which $\overline{p} < p^x$ the "low enforcement cost" case and the case in which $\overline{p} > p^x$ the "high enforcement cost" case.

Taking the endogenous enforcement of property rights into account, typical examples of the supply curve of timber in the low enforcement cost and high enforcement cost cases are illustrated in Figure 3 (a) and (b), respectively. As seen in Figure 3, the main difference between the two cases is that at the threshold price there is a downward jump in the supply in the low-enforcement cost case, while there is an upward jump in the high-enforcement cost case.

3. A Small Open Economy

In this section, I examine the case of a small open economy that exports timber. The world price is exogenously given to this economy. I consider the case in which sufficient time has already passed and the small open economy is in a trading steady state. I call this an "initial steady state." I assume

that the property rights are enforced in the small open economy in the initial steady state, which implies that this economy is diversified in this state.

The focus in this section is on the effects of exogenous price change on this small open economy. Let p^w be the (exogenous) world price of timber in the initial steady state. Since the property rights are initially enforced in the small open economy, $p^w > \overline{p}$ must hold. Then, there exists a price p^c such that $H_{ss}^R(p^w) = H_{ss}^O(p^c)$ with $S_{ss}^O(p^c) > K/2$. In words, p^c is the price at which the steady-state timber harvest and the steady-state stock level under open-access are the same as those under enforced property rights at p^w, respectively. It yields that

$$p^c = 2p^w/(\alpha K p^w + 1). \tag{19}$$

A change in *p* affects both an incentive for the forest owners to enforce the property rights and the incentive for workers to engage in illegal logging. When the world price decreases from p^w to p^c, the incentive for the forest owners to enforce the property rights is reduced so that the decision of the forest owners changes from the enforced property rights to no enforcement. However, the number of workers who engage in illegal logging is also reduced due to the fall in *p*. When the price changes from p^w to p^c, the effects due to the reductions in the incentives for enforcement and illegal logging just offset each other, so that the harvest and the forest stock in steady states remain the same before and after the change. For price $p < p^c$, the latter effect dominates the former effect and hence a lower steady-state harvest and a higher steady-state stock are obtained. For price $p \in (p^c, \overline{p})$, the former incentive dominates the latter effect and hence a lower steady-state stock follows. The effect on the steady-state harvest depends on the case. In the low enforcement cost case, a higher steady-state harvest must follow for price $p \in (p^c, \overline{p})$. In the high enforcement cost case, a higher steady-state harvest follows only for price $p \in (p^c, p^d)$, where p^d is defined below.

When $p^w > p^x$ holds, there may exist a price p^d such that $H_{ss}^R(p^w) = H_{ss}^O(p^d)$ with $S_{ss}^O(p^c) < K/2$, which yields

$$p^d = 2wp^w/(\alpha K p^w - 1). \tag{20}$$

When the price changes from p^w to p^d, the steady-state harvest does not change. However, unlike the case of p^c, the steady-state stock level is lower at p^d than p^w.

Then, I consider a price change such that p^w suddenly falls until $p^w < \overline{p}$ holds. Although it is outside of the model, a decrease in the world price occurs because the world demand for timber may be weakened. I analyze the effects of this price fall separately in two cases. I first examine the case of low enforcement cost and then analyze the case of high enforcement cost. These two cases are

depicted in Figures 4 and 5, respectively.

3.1. Low enforcement cost case

Consider first the case of low enforcement cost. Since p^w suddenly falls until $p^w < \overline{p}$ holds, then the owners of forests stop enforcing property rights and hence the economy shifts to the open-access regime. Then, the resource dynamics gradually leads the economy to a new steady state. Under certain conditions, this regime switch results in a larger supply of timber throughout the transition and in a new steady state, compared with the initial trading steady state. However, forest stock is lower in the new steady state. A formal result is presented in the following proposition:

Proposition 1. *In the low-enforcement cost case, suppose that a small open economy is initially in a trading steady state in which property rights are enforced. Let* p^w *and* $p^{w'}$ *be the (exogenous) world prices of timber in the initial trading steady state and after the price change, respectively, where* $p^w > \overline{p} > p^{w'}$ *holds so that the regulatory regime of forests switches from enforced property rights to open-access after the change. Then, due to the price change in this small open economy (i) the output of good H is temporally larger if* $p^{w'} > p^c$ *and (ii) the forest stock is smaller and the output of good H is larger along the transition to a new steady state and in the new steady state for* $p^{w'} > p^c$ *unless* $p^w > p^x$ *and* $\overline{p} > p^d$.

Since *p* decreases below the threshold of enforcing property rights, the owners of forest in this economy decide not to enforce the property rights. Then, illegal harvesters enter the forestry sector and hence the production of timber temporally increases. However, harvest of timber is higher than the natural growth of forests, which sets off a shrinkage in forest stock. The forest stock and the harvest of timber gradually decrease along with the transition to a new steady state. This situation is illustrated in Figure 6. In this figure, PPFs are depicted on the *M*–*H* plane. Since the model is Ricardian, a PPF is given by a downward-sloping line. The initial PPF under enforced property rights has a horizontal intercept at $L - L_R$ and a vertical intercept at $\alpha S^R(L - L_R)$. The initial production point is at A. The initial consumption point is given by the tangency between the indifference curve and the budget line that goes through point A and has the slope of $-1/p^w$ at B. When the world price falls to $p^{w'}$, the forest owner decides not to enforce property rights. Due to the regime switch, the PPF shifts out because workers who were employed for enforcing property rights are now available to the production of either good *M* or good *H* including illegal logging. The value of marginal product of labor in the forestry sector (VMP_{L_H}) at the new world price $p^{w'}$ is temporally given by $p^{w'}\alpha S^R$, which is

higher than the wage in the manufacturing sector, $w = 1$. As a result, all workers engage in illegal logging and this economy temporally specializes in good *H*. The production point is temporally at C. The consumption point is temporally at D. Since the PPF shifts out, this economy can temporally be better off despite the terms-of-trade deterioration. However, since the harvest is higher than the natural growth rate, the forest stock begins to shrink, causing the PPF to shift down. When the forest stock reaches a new steady-state level under open-access, the shift of the PPF stops. The vertical intercept of the PPF at this situation is given by $\alpha S^O RL$. In Figure 6, the case in which the economy becomes diversified at $S = S^O$ is illustrated. The production point and the consumption point in the new steady state is at E and F, respectively. Because of the Cobb-Douglas utility function, point F lies on the same ray from the origin as point D. As is depicted in the figure, welfare in the new steady state could be lower than that in the initial steady state.

Proposition 1 shows that a reduction in *p* results in a lower forest stock and larger timber production in steady state unless the gap in price before and after the change is too large.

The condition for (iii) in Proposition 1 excludes the case in which p^w and $\overline{p}$ are too high.

3.2. High enforcement cost case

I now turn to the case of high enforcement cost. Similar to the previous case, I consider a price change such that $p^w > \overline{p} > p^{w\prime}$ holds, where p^w and $p^{w\prime}$ are the (exogenous) world prices of good *H* before and after the price change. As depicted in Figure 3, there is an upward jump at the threshold price $\overline{p}$. Thus, unlike the previous case, if p^w and $p^{w\prime}$ are sufficiently close to $\overline{p}$, the price change yields a *lower* steady state supply of good *H*, despite the regime switch from enforced property rights to open-access. Similar to the previous case, however, after the price change the supply of good *H* temporally expands.

There are three possible cases: (a) $p^{w\prime}$ is high (i.e., $p^{w\prime} > p^d$), (b) $p^{w\prime}$ is medium (i.e., $p^c < p^{w\prime} < p^d$), and (c) $p^{w\prime}$ is low (i.e., $p^{w\prime} < p^c$). Timber production in a new steady state becomes larger only in case (b), while the forest stock in a new steady state becomes lower in cases (a) and (b).

The effects of a reduction in *p* in the case of high enforcement cost are formally presented in the following proposition:

Proposition 2. *In the high-enforcement cost case, suppose that a small open economy is initially in a trading steady state in which property rights are enforced. Consider a price change such that the regulatory regime of forests switches from enforced property rights to open-access after the change. Then, due to the price change in this small open economy (i) the output of good H is temporally larger*

if $p^{w'} > p^c$ *and (ii) the forest stock in a new steady state is lower if* $p^{w'} > p^c$ *and the output of good H in a new steady state is larger if* $p^c < p^{w'} < p^d$.

As p^w is higher, the case in which a reduction in *p* yields a larger supply of good *H* is less likely to hold. This is because p^c and p^d become close to each other as *p* is higher, which is seen in Figure 5.

4. Large Exporting Countries of Timber

In this section, I extend the analysis to the case of a large country. Suppose that there are *n* large exporting countries of timber. The rest of the world imports timber and exports manufactures to these *n* countries. For simplicity, I assume that the rest of the world is not endowed with forest.

I also assume that these *n* countries are identical except for L_R, the cost of enforcing the property rights. Let L_{Ri} be the cost of enforcing the property rights in country *i* ($i = 1, 2, \ldots, n$). Order the countries so that

$$L_{R1} > L_{R2} > \ldots > L_{Rn}. \tag{21}$$

Since the costs of enforcing the property rights differ among countries, the threshold price for separating the low enforcement and high enforcement cost cases also differs among countries. Let $\overline{p}_i$ be the price at which the owner of the resource in country *i* ($i = 1, 2, \ldots, n$) is indifferent between enforcing property rights and not doing so. Then, condition (21) implies that $\overline{p}_1 > \overline{p}_2 > \ldots > \overline{p}_n$.

Suppose that initially property rights are enforced in all countries in the trading steady state. That is, $p^w > \overline{p}_1$ holds, where p^w is the world price of timber in the initial trading steady state. This implies that all exporters of timber are diversified in the initial steady state.

4.1. The international diffusion of illegal extractions in the low enforcement cost case

As is shown in the previous section, the case in which a reduction in *p* results in a larger production of timber is less likely to hold under the condition of high enforcement cost. Thus, in this section I focus on the case of low enforcement cost. More precisely, I consider the case in which $p^x > \overline{p}_1$ holds, which means that the condition for the case of low enforcement cost holds for all timber-exporting countries.

I first demonstrate that the world supply curve of timber is discontinuous at $\overline{p}_i, i = 1, 2, \ldots, n$ and that there may be multiple equilibria in steady states, depending on the world demand for timber.

Lemma 2. *Suppose that* $p^x > \overline{p}_1$ *holds. Then, the world supply curve of timber in steady states,* $H_{ss}^W(p)$*, is discontinuous at* $\overline{p}_i, i = 1, 2, \ldots, n$*. Depending on the world demand for timber, there may be multiple equilibria in steady states.*

The situation in an example of $n = 2$ is illustrated in Figure 7. In this figure, the world supply of timber in steady states is illustrated by thick curves denoted as H_{ss}^W, which is discontinuous at $\overline{p}_1$ and $\overline{p}_2$. This world supply curve of timber can be constructed by combining relevant parts of the steady-state supply curves of timber in each country. In the figure, the original steady-state supply curves of timber under enforced property rights and open-access are depicted by thin curves. For the price below $\overline{p}_2$ property rights are not enforced in either country. Thus, the world supply curve of timber at this part is constructed by summing horizontally two supply curves under open-access. For the price between $\overline{p}_2$ and $\overline{p}_1$ property rights are enforced in country 2 but not in country 1. Thus, the world supply curve at this part is given by adding horizontally the supply curve under enforced property rights and that under open-access. Finally, for the price above $\overline{p}_1$ property rights are enforced in both countries. Thus, the world supply curve at this part is obtained by summing horizontally two supply curves under enforced property rights.

The world demand for timber, $H^{WD}(p)$, on the other hand, is denoted as D in Figure 7. Four examples of the world demand for timber are depicted as D, D', D'', and D'''. If the world demand is D, the steady-state equilibrium point is point a, where both exporting countries adopt the enforced property rights regime. If the world demand is D' or D'', there are multiple equilibria, as is seen in the figure. Both countries may adopt the enforced property rights regime (like points b or e), or only country 2 adopts the enforced property rights regime while country 1 allows open-access (like point c), or neither country may adopt the enforced property rights regime (like points d or f). If the world demand is D''', the steady-state equilibrium is unique at point g, where both countries allow open-access.

Now, suppose that the enforcement cost has increased in country 1, which causes $\overline{p}_1$ to become higher than p^w, the world price of timber in the initial trading steady state.[8] Let $\overline{p}_1'$ be the enforcement cost in country 1 after the change, where $\overline{p}_1' > p^w$. Then, Proposition 1 implies that this change will result in a regime switch from enforced property rights to open-access in country 1. Moreover, this change in the enforcement cost in country 1 may also trigger a regime switch from enforced property rights to open-access in other countries. A formal result is presented in the

[8] An increase in the enforcement cost may occur because a new improved logging or transport instrument became available to illegal harvesters, which makes illegal logging easier.

following proposition:

Proposition 3. *Suppose that* $p^x > \overline{p}_1$ *holds. Suppose also that in an initial trading steady state all exporting countries of timber adopt the enforced property right regime. Then, consider an increase in* L_{R1} *in country 1 so that* $\overline{p}_1' > p^w$ *holds, where* $\overline{p}_1'$ *is the threshold price in country 1 after the change and* p^w *is the world price of timber in the initial trading steady state. Due to this change, (i) the regulatory regime of forests switches from enforced property rights to open-access in country 1 and (ii) the regulatory regime of forests may also switch from enforced property rights to open-access in countries 2 to k if at* $p^* < \overline{p}_k$ *it holds that* $H^{WD}(p^*) = H_{ss}^W(p^*)$.

Figure 8 illustrates the possible effects of a change in L_{R1} in an example of two countries. For example, suppose that the world demand curve for timber is given by D'' and that the initial steady state equilibrium is at point e, where the world price is p^w. Then, consider that for some reason L_{R1} has increased in country 1, which causes $\overline{p}_1$ to rise to $\overline{p}_1'$, where $\overline{p}_1' > p^w$ holds. Since the threshold price for country 1 is now higher than the world price of timber, the forest owner in country 1 switches the regulatory regime from enforced property rights to open-access. Consequently, part of the long-run world supply curve of timber changes. More precisely, the long-run world supply curve of timber between $\overline{p}_1$ and $\overline{p}_1'$ jumps to the right. In Figure 8, the dotted part of H_{ss}^W is no longer included as part of the supply curve after the change, which implies that point e can no longer be an equilibrium point. It turns out that after the change the unique steady-state equilibrium point is point f, where country 2 as well as country 1 switches its management regime from enforced property rights to open-access.

If the world demand curve for timber is given by D', on the other hand, there are still two steady state equilibria, points c and d in Figure 8. At point c the regime switch occurs only in country 1, while at point d the regime switch occurs in both countries. Thus, in such a case, the change in one country does not necessarily trigger the regime switch in another.

4.2. Import restrictions by importing countries

It would be interesting to see how import restrictions by importing countries can affect the management regime choice in the exporting countries. In particular, as I explain in the introduction, major importing countries of timber try to exclude illegally harvested timber from international transactions by signing bilateral agreements with exporting countries of timber. I will demonstrate that this action may not only reduce illegal logging in the country that signed the bilateral agreement but reduce illegal logging in other countries as well.

For simplicity, I assume that there is no problem of asymmetric information in the sense that legally harvested timber and illegally harvested timber can be perfectly distinguished without any additional costs. However, for consumers these two types of timber are perfect substitutes.

Then, the effects of permanent import restrictions are demonstrated in the following proposition.

Proposition 4. *A permanent import restriction on timber in general may reinforce the international diffusion of illegal harvests. By contrast, a permanent import restriction only on illegally harvested timber can prevent the international diffusion of illegal harvests.*

The intuition is rather simple. When an import restriction is imposed on timber in general without distinguishing between legally harvested timber and illegally harvested timber, the world demand for timber simply shifts to the left in Figure 8. This may cause more countries to switch the management regime from enforced property rights to open-access. For example, suppose that the world demand for timber is initially given by D' in Figure 8. In this case, an increase in L_{R1} will result in a change in equilibrium from point b to either point c or point d. If the new steady-state equilibrium is at point c, then the regime switch occurs only in country 1. If an import restriction is imposed on timber in general, the demand curve could shift to D''. If that is the case, then an increase in L_{R1} will result in a shift of equilibrium to point f, where neither country enforces property rights. In this way, an import restriction on timber in general may facilitate the international diffusion of illegal logging, which is against the intension of the import restriction.

When an import restriction is imposed only on illegally harvested timber, two different prices are assigned to legally harvested timber and illegally harvested timber. Thus, the import restriction only suppresses the demand for illegally harvested timber. In Figure 8, an import restriction only on illegally harvested timber does not shift the demand curve for legally harvested timber. Thus, the problem of shifting the equilibrium point discussed above may not occur in this case.

5. Policy Implications

In this section, I discuss what policy implications could be obtained from the paper's theoretical analysis.

The results in this paper imply that the current efforts by the world community to exclude illegally harvested wood and wood products (or wood and wood products harvested in an unsustainable manner) from the international market will be effective in preventing the international diffusion of illegal harvests. Thus, when trade of illegal timber is restricted by bilateral agreements, illegal logging in some third countries that are not involved in the agreements may be reduced, in addition to a reduction in illegal logging among the partners of the agreements. This positive external effect could potentially further justify the current efforts by the world community.

However, the result in the previous section also implies that it may be crucial to discriminate goods by their NPR-PPMs. Although illegally harvested timber is not different from legally harvested timber in its physical characteristics, it will be important to distinguish between these two products in order for trade policy to be effective. As I discussed in the introduction, however, discriminatory treatment based on the NPR-PPMs will not be allowed under the current GATT/WTO rules. Thus, it might be the second-best way to address the issue of illegal logging by bilateral agreements between exporting and importing countries. The potential effects of relaxing the GATT/WTO rules so that goods with different NPR-PPMs are judged not to be “like products" should be extensively investigated.

The current efforts to address the issue of illegally logged timber will not be generalized to the cases of NPR-PPMs for a number of reasons. First, in the case of illegal logging, the number of exporting countries to be involved is relatively small. Thus, it is easier to solve the problem by bilateral agreements. In the cases of NPR-PPMs, by contrast, a quite large number of countries could potentially become exporters and it is rather difficult to identify which countries will be involved. Consequently, it will be very hard to solve the problem by bilateral agreements. Second, a fundamental difference between the cases of illegal logging and NPR-PPMs is that exporting countries recognize the problem with illegal logging, while exporting countries do not consider that it is a real problem with NPR-PPMs in general. These differences affect the way of solving the problem.

6. Concluding Remarks

In this paper, I examined how illegal extractions of renewable resources in one country could affect harvest and conservation of the renewable resources in other countries through a change in the world price of the resources. Since the enforcement of property rights over the resources is costly, the resource owner decides whether or not to enforce these rights. If the owner chooses not to enforce the property rights, illegal extractors harvest the resource under open-access condition. In order to illustrate the results clearly, I assumed a fixed cost of enforcement so that the decision of the resource owner is binary: either to enforce or not to enforce the property rights.

I demonstrated that in the case of small open economy an exogenous reduction in the world price of the resource good may lead to its higher output with lower level of the resource stock in steady states. This could happen due to a switch in the regulatory regime from enforced property rights to open-access triggered by a fall in price. Moreover, I extended the analysis to the case of several large countries exporting the resource good. I assumed that these countries are identical except for the (fixed) enforcement cost. In this framework, I showed that when the enforcement cost rises in one country so that the regulatory regime in that country changes from enforced property rights to open-access, the regulatory regime in some other countries may also change from enforced property rights to open-access. This is because the regulatory regime switch in one country expands the world

supply of the resource good, placing a downward pressure on the world price of the resource good.

A major implication of the analysis in this paper is that the current efforts by the world community to exclude illegally logged timber from the international market by signing bilateral agreements will be effective in not only controlling illegal logging in countries that sign the agreements but also preventing international diffusion of illegal logging through a change in the world price of timber.

Several extensions and generalizations of the analysis in this paper can be considered. First, I used a specific functional form for the natural growth function of the resource stock. Although the functional form that I used in this paper is quite standard in the literature, some other functional forms may be more appropriate to some types of renewable resources. A well-known example of another type of the growth function is the one that is said to exhibit *critical depensation*, that is, a function with growth rates becoming negative when population drops below a critical level (Clark, 1990). For resources with critical depensation, the depletion of resources along with the transition to steady states is more likely to occur under the open-access regime. Consequently, the effects of illegal harvests are more serious.

Second, the harvest function can also be generalized. I used the standard Schaefer production function. If the sensitivity of harvest costs to the stock size is taken into account, the harvest function looks like $H = \alpha S^{\beta} L_H$, where $\beta \in [0,1]$. A decrease in β compresses the steady-state supply curve under open-access. However, as long as β is positive, the results in this paper do not qualitatively change.

Third, although I assumed a fixed enforcement cost and a binary regime choice (enforced property rights or open-access), it will be more general to allow intermediate levels of enforcement of property rights and a variable cost of enforcement, as in Hotte, Long, and Tian (2000). In such a case, both legally and illegally harvested resource goods may be supplied in one country in equilibrium, which is more realistic. Some additional results may be obtained. However, Hotte, Long, and Tian (2000) show that the owner of the resource will choose to deter completely the entry of illegal harvesters and that a mixed supply of legally and illegally harvested resource goods will not happen in one country as long as all the sites of the resources are symmetric. Moreover, when intermediate levels of enforcement are allowed, the results may become less clear. However, the main finding in this paper, that a fall in price may possibly cause a higher supply with lower resource stock, will generally hold as long as the effect of the price fall on the incentive for enforcement overrides the effect on the incentive for illegal harvests.

Fourth, I ignored discounting of future utility for analytical simplification. However, as Brander and Taylor (1997b) argue, this approach can be defensible from inter-temporal equity considerations. Brander and Taylor (1997b, pp. 290–291) provide a more detailed discussion of this issue.

Finally, I did not analyze the effects of a change in price of the resource good on harvests and the resource stock in importing countries. Since import restrictions of the resource goods by importing

countries might possibly be motivated by protecting the domestic resource sector in these countries, it would be important to attempt such an analysis.

Appendix: Proofs of Lemmas and Propositions

Proof of Lemma 1

Differentiate π^{H*}, which is given by (14), with respect to *p*, *r*, and L_R to yield

$$d\pi^{H*}/dp = rw/4\alpha^2 Kp^2 > 0,$$

$$d\pi^{H*}/dr = (\alpha Kp - w)/4\alpha^2 Kp > 0,$$

$$d\pi^{H*}/dL_R = -1 < 0,$$

respectively. ■

Proof of Proposition 1

(i) The temporary VMP_{L_H} after the price change is given by $p^{w'}\alpha S^R$. Since this economy becomes diversified in the new steady state that corresponds to $p^{w'}$, it holds that $S^O = 1/\alpha p^{w'}$, which implies that $\text{VMP}_{L_H}(p^{w'}, S^R) > 1$ if $S^R > S^O$. This inequality holds for $p^{w'} > p^c$. Thus, under this condition all the workers temporally engage in illegal logging. Since *S* is the same and L_H is higher, the output of good *H* must be temporally larger.

(ii) Along the transition to a new steady state, all the workers continue to engage in illegal logging until $p^{w'}\alpha S = 1$ holds. When $p^{w'}\alpha S = 1$ holds, a worker is indifferent between being employed in the *M* sector and engaging in illegal logging. Then, for $p^{w'} > p^c$ the steady-state forest stock under open-access $S_{ss}^O = 1/\alpha p^{w'}$ is smaller than the stock in the initial steady state. The same is true for the transition. With regard to the output, if $p^w < p^x$, then $H_{ss}^R(p^w) = H_{ss}^O(p)$ holds only at $p = p^c$. Thus, $H_{ss}^R(p^w) < H_{ss}^O(p)$ holds for any $p \in (p^c, \overline{p})$. Moreover, if $\overline{p} < p^d$, then property rights are enforced at $p = p^d$, which implies that $H_{ss}^R(p^w) < H_{ss}^O(p)$ holds for any $p \in (p^c, \overline{p})$. ■

Proof of Proposition 2

(i) The proof for Proposition 1 (i) can be used to prove this part.

(ii) The result for the forest stock can be proved in the same way as Proposition 1 (ii). Since $\overline{p} > p^x$, it holds that $H_{ss}^R(p^w) = H_{ss}^O(p)$ for $p = p^c$ and $p = p^d$. Given the shape of *G*(*S*), $H_{ss}^O(p)$ is larger for *p* between p^c and p^d. Thus, the output in the new steady state is larger if

$p^{w'} \in (p^c, p^d)$. ■

Proof of Lemma 2

The world supply function of good *H* in steady states is given by summing the supply functions of countries 1 to *n*. Each country's supply function of good *H* in steady states are given by a combination of $H_{ss}^R(p)$, which is given by (13) and $H_{ss}^O(p)$, which is given by (18). Since countries differ only in L_R, the same $H_{ss}^R(p)$ and $H_{ss}^O(p)$ apply to all countries. It is shown that $H_{ss}^R(p) = H_{ss}^O(p)$ holds only for $p = 1/\alpha K$ and $p = p^x$. Country *i*'s steady-state supply function is given by $H_{ss}^O(p)$ for $p < \overline{p}_i$ and $H_{ss}^R(p)$ for $p \geq \overline{p}_i$. By assumption $p^x > \overline{p}_1$ holds. Thus, the steady-state supply function is discontinuous at $\overline{p}_i$ for all countries, which also makes the world steady-state supply function discontinuous at $\overline{p}_i$.

Moreover, since $p^x > \overline{p}_1$, the steady-state output of good *H* in country *i* discontinuously decreases when the price rises from $\overline{p}_i - \varepsilon$ to $\overline{p}_i$, where $\varepsilon > 0$ is small. The steady-state outputs of good *H* in countries other than *i* change continuously for only a small amount. Thus, the world supply of good *H* discontinuously decreases by this price change. Since $H_{ss}^W(p) < H_{ss}^W(p')$ can hold for some *p* and p' with $p > p'$, it follows that $H_{ss}^W(p) = H^{WD}(p)$ and $H_{ss}^W(p') = H^{WD}(p')$ can also hold for $H^{WD}(p)$ such that $dH^{WD}(p)/dp < 0$. ■

Proof of Proposition 3

By construction, $H_{ss}^W(p^w) = H^{WD}(p^w)$ holds. When L_{R1} rises so that $\overline{p}_1' > p^w$ holds, the supply of country 1 changes from $H_{ss}^R(p)$ to $H_{ss}^O(p)$ for the price $p \in [\overline{p}_1, \overline{p}_1')$. Consequently, $H_{ss}^W(p)$ discontinuously expands for the price $p \in [\overline{p}_1, \overline{p}_1')$. Since $p^w \in (\overline{p}_1, \overline{p}_1')$, it may hold that $H_{ss}^W(p^w) > H^{WD}(p^w)$ after the change. From Lemma 2, there may exist multiple equilibria. If $H^{WD}(p^*) = H_{ss}^W(p^*)$ holds at $p^* < \overline{p}_k$, the disappearance of the initial steady-state equilibrium may result in a jump of the equilibrium to $p = p^*$. At this price, since $p^* < \overline{p}_k$, the regime switch occurs in all countries from country 1 up to country *k*. ■

Proof of Proposition 4

An import restriction by the importing country is modeled as a reduction in the world demand for good *H*. Consider first a permanent import restriction on good *H* in general. Let $H_{ir}^{WD}(p)$ be the

world demand for good H under the import restriction, where the subscript *ir* stands for "import restriction." Then, $H_{ir}^{WD}(p) < H^{WD}(p)$ holds for all relevant p. While $H^{WD}(p^w) = H_{ss}^{W}(p^w)$ initially holds for $p^w > \overline{p}_j$, there may be no p in the range of $p > \overline{p}_j$ such that $H_{ir}^{WD}(p) = H_{ss}^{W}(p)$. As a result, the steady-state equilibrium will shift to $p^{w\prime}$ such that $\overline{p}_k < p^{w\prime} < \overline{p}_j$ at which $H_{ir}^{WD}(p^{w\prime}) = H_{ss}^{W}(p^{w\prime})$ holds. This implies that the regulatory regime switches from enforced property rights to open-access in countries from country 1 to country $k-1$.

Consider next a permanent import restriction only on illegally harvested good H. In this case, the demand shift occurs only for good H produced under open-access. The world demand remains the same for good H produced under enforced property rights. Thus, when $H^{WD}(p^w) = H_{ss}^{W}(p^w)$ initially holds for $p^w > \overline{p}_j$, the import restriction will not disturb this equilibrium. Moreover, consider a change described in Proposition 3. Under the import restriction only on illegally harvested good H, legally harvested good H is distinguished from illegally harvested good H. Due to an increase in $\overline{p}_1$, $H_{ss}^{W}(p)$ discontinuously expands for the price $p \in [\overline{p}_1, \overline{p}_1{}')$, as proved in Proposition 3. However, $H_{ss}^{W}(p)$ is divided into H_R^W and H_O^W, which are the world supplies of good H under enforced property rights and under open-access, respectively. Then, due to an increase in $\overline{p}_1$, H_R^W is reduced and hence it may still hold that $H_R^W(p^{w\prime}) = H_R^{WD}(p^{w\prime})$ at $p^{w'} \in [\overline{p}_1, \overline{p}_1{}')$ after the change, where H_R^{WD} is the world demand for legally harvested good H. If that is the case, the world price of (legally harvested) good H remains above $\overline{p}_2$ and hence the regime switch occurs only in country 1.

■

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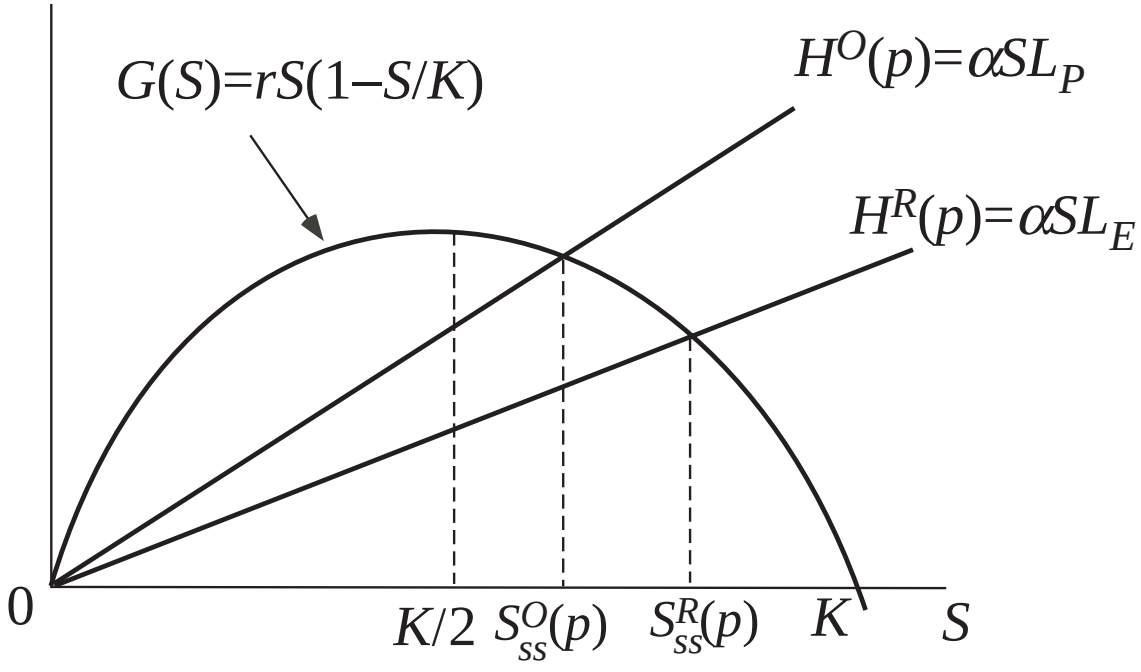


Figure 1. Resource dynamics

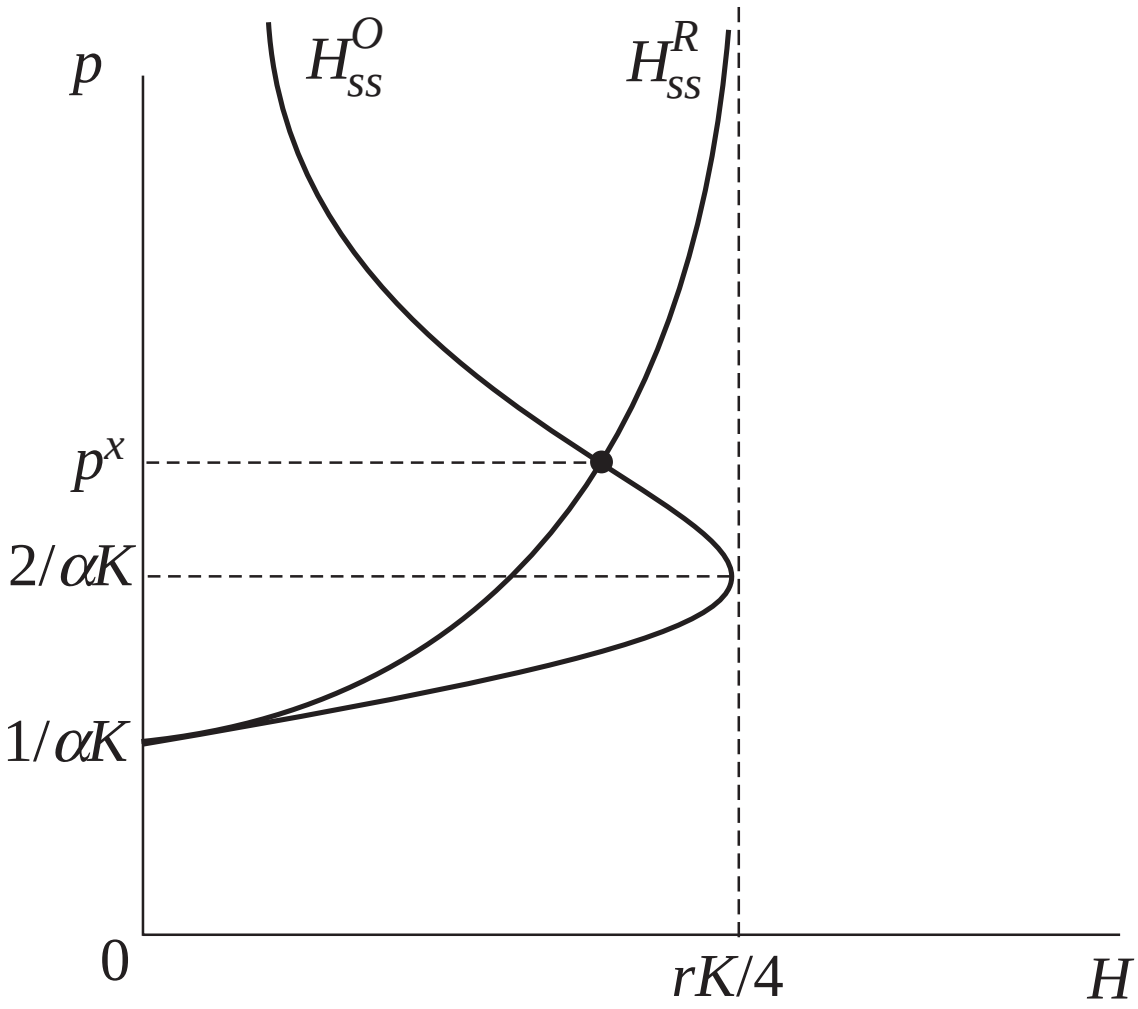
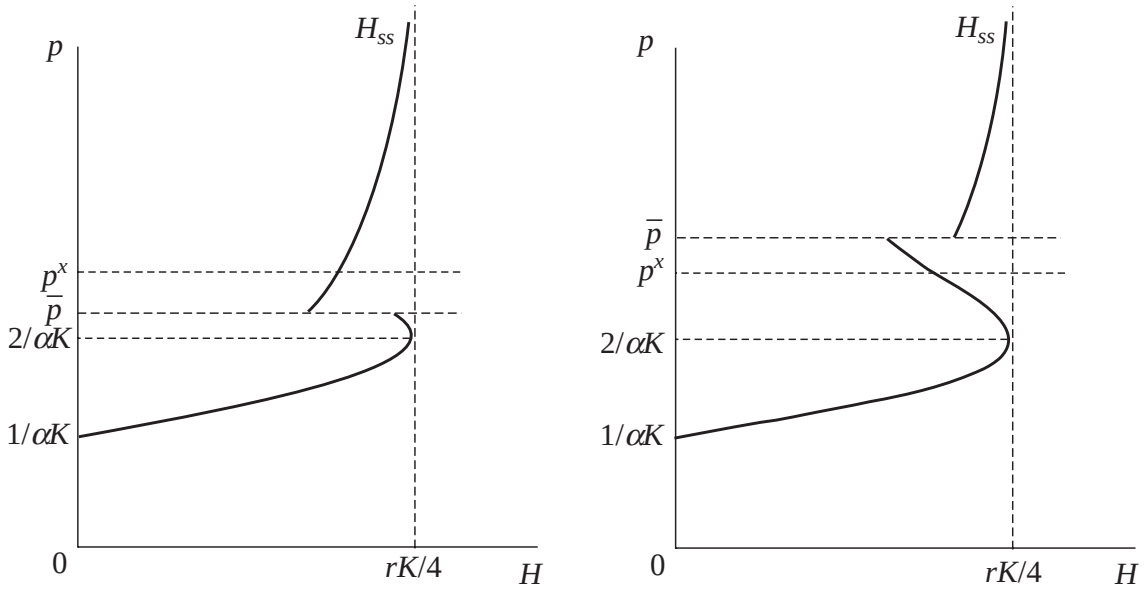


Figure 2. The steady-state supply curves of timber under two regimes



(a) Low enforcement cost

(b) High enforcement cost

Figure 3. The steady-state supply of timber in two cases

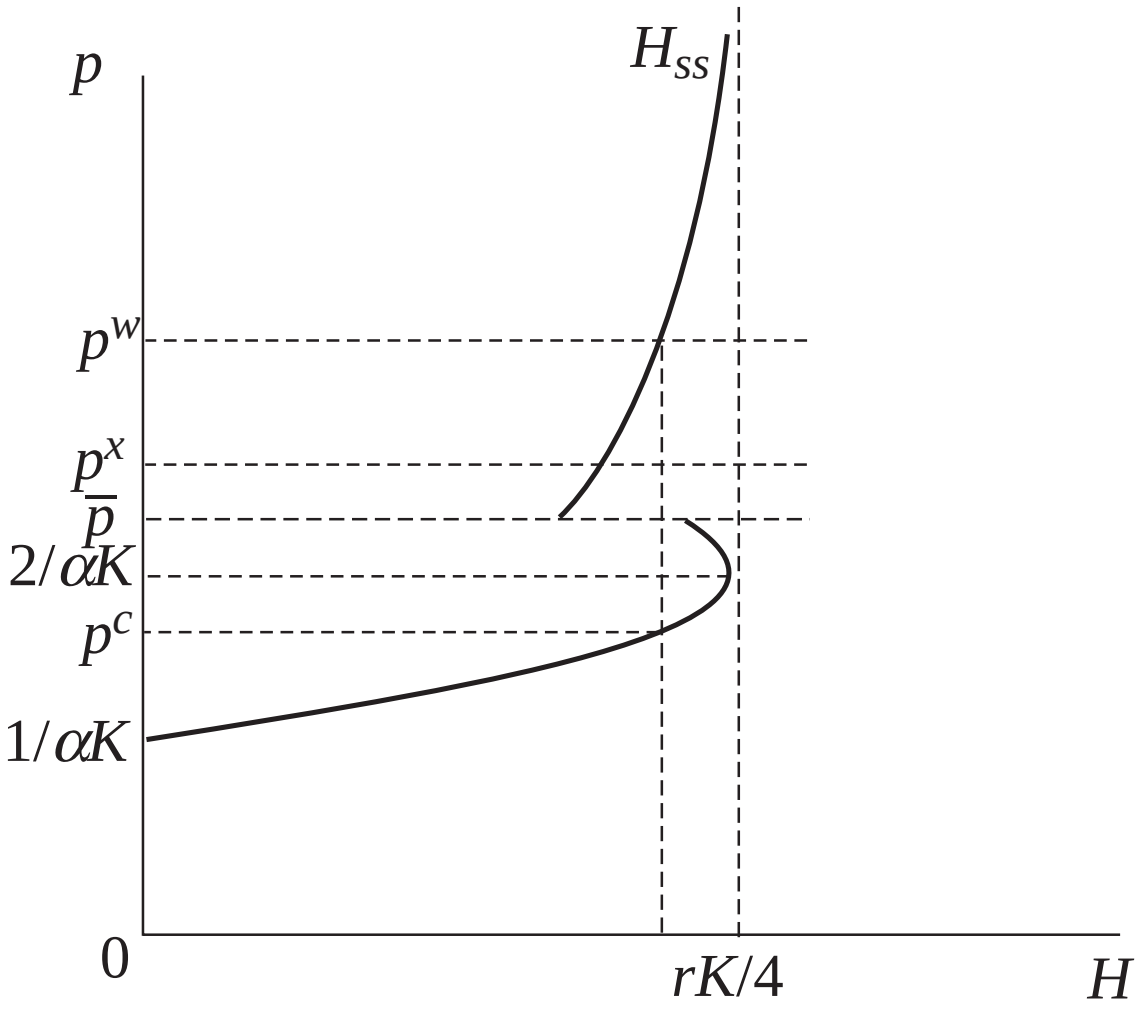


Figure 4. The steady-state supply of timber in the low-enforcement cost case

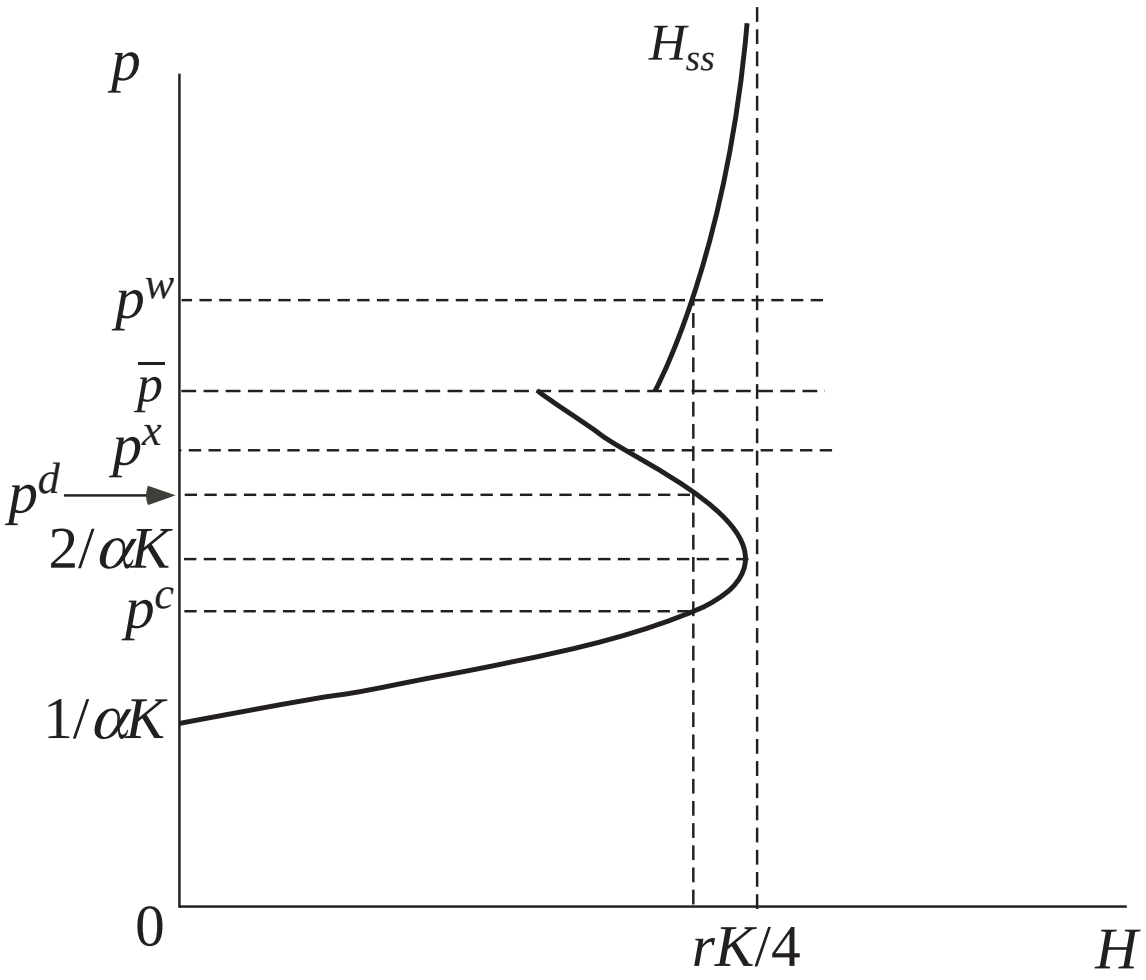


Figure 5. The steady-state supply of timber in the high-enforcement cost case

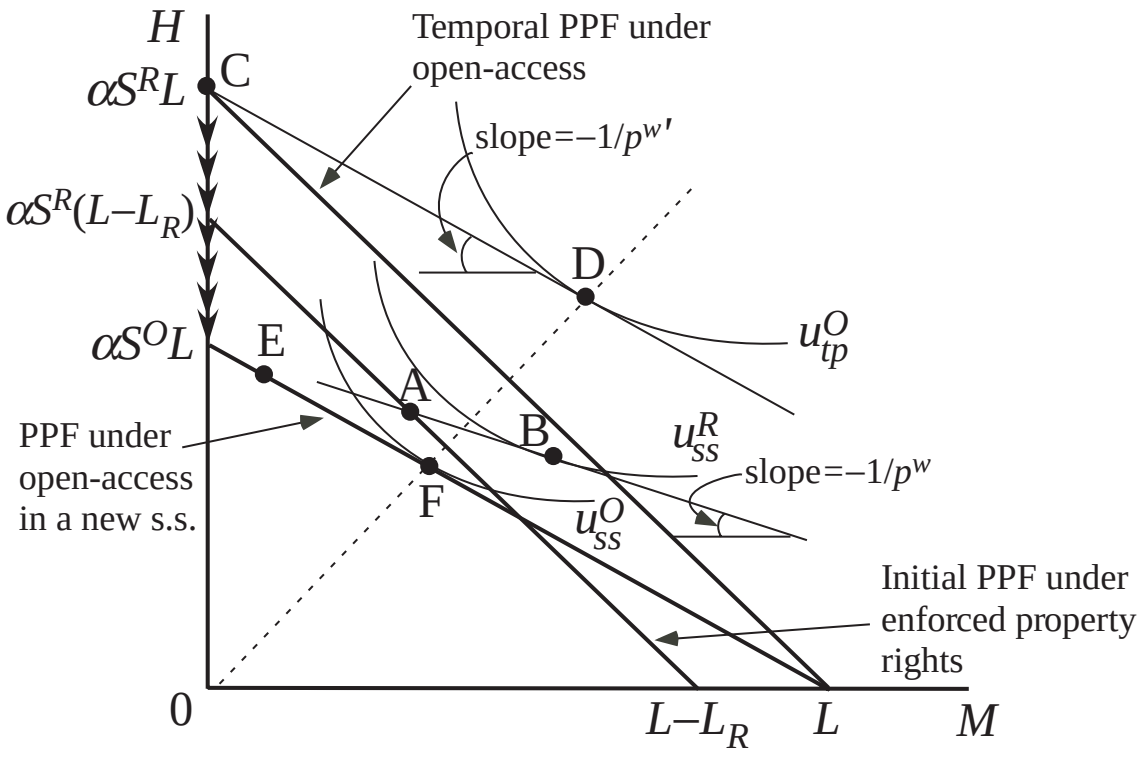


Figure 6. PPF in the small open economy: The low-enforcement cost case

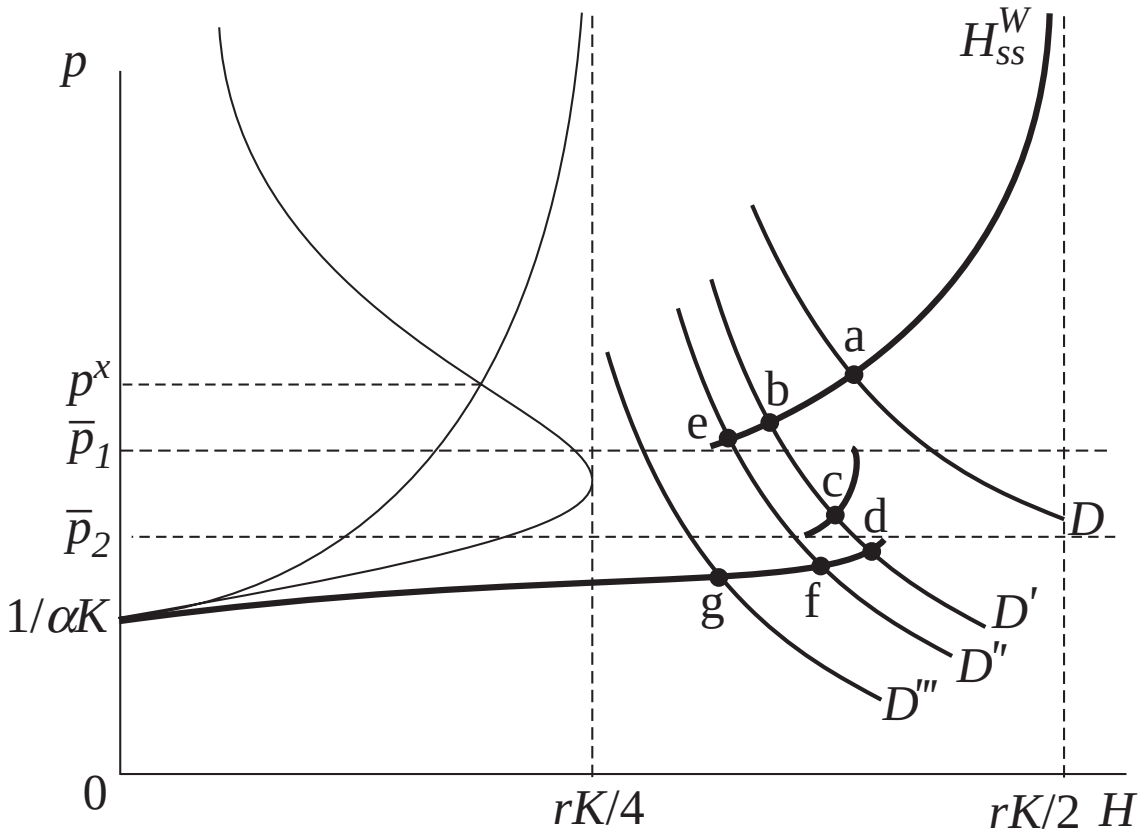


Figure 7. Two large countries exporting timber: The low-enforcement cost case

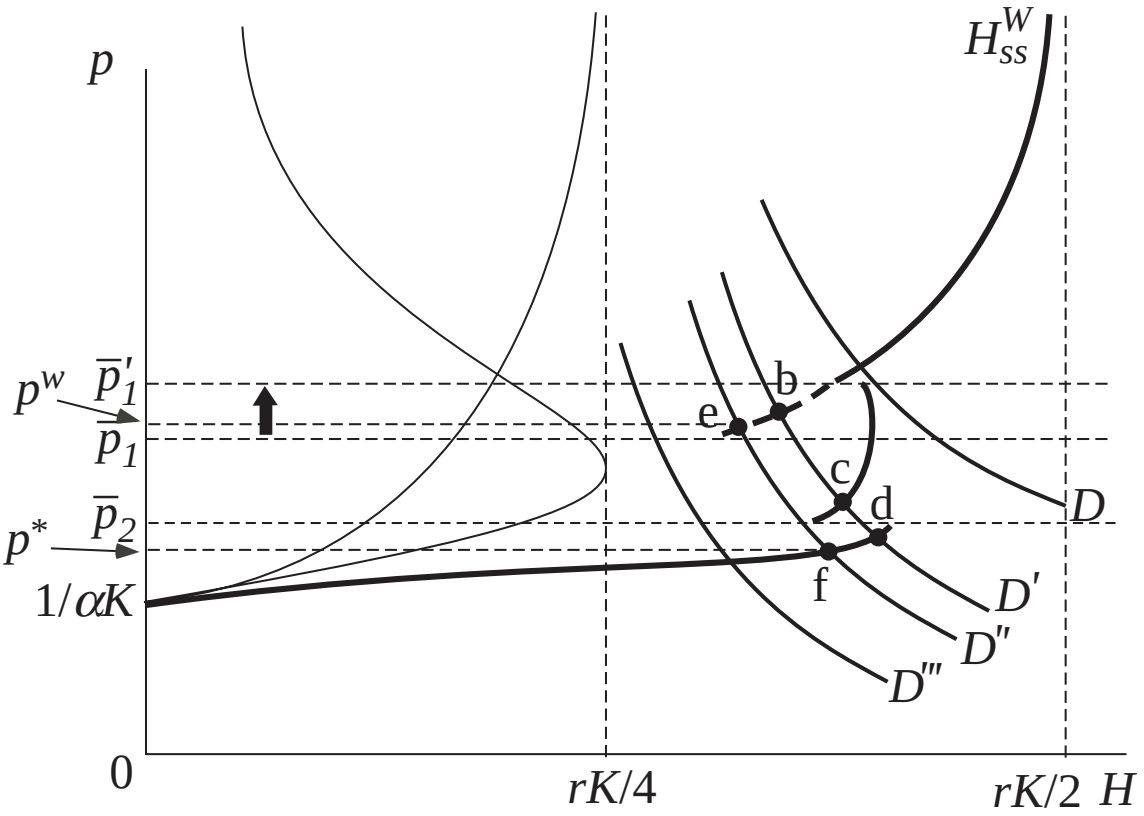


Figure 8. The regime switch due to a change in L_{R1} in a two-country case