Reaping What You Sow:
An Empirical Analysis of International Patent Harmonization*

Phillip McCalman*
Department of Economics
University of California
Santa Cruz CA 95064

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Abstract

This paper extends analysis of the GATT Uruguay Round by quantifying the impact of international patent harmonization as implied by the TRIPs agreement. What emerges is a picture of patent protection as an important method for appropriating the rents of an invention. On this basis patent harmonization has the capacity to generate large transfers of income between countries, the US being the major beneficiary. While developing countries are major contributors to these transfers, Canada, UK and Japan also make sizable contributions. These transfers significantly alter the perceived distribution of benefits from the Uruguay Round, with the US benefits substantially enhanced, while those of developing countries and Canada are considerably diminished. Furthermore, the increase in dead weight loss from higher standards of patent protection undermines the aggregate benefits of the Uruguay Round package, with the increase in dead weight loss amounting to as much as one fifth of the efficiency gains from trade liberalization.

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Introduction

The decision to foster technological innovations through policy instruments such as patents involves a trade-off between the rents appropriated by an inventor and the dead weight loss associated with granting an exclusive right to use the new technology. At the national level, culture, history and level of economic development condition preferences relating to this trade-off. However, the most important innovations rarely impact just a single country. Consequently, international attitudes regarding this trade-off shape an innovators incentive to conduct research and development. It is the recognition of this fact which underlies the long history of efforts to co-ordinate patent policy at the international level.

Until recently the primary agreement relating to the international aspects of intellectual property rights was the Paris Convention of 1883. This convention established a system in which inventors could access patent institutions in other countries on terms no less favorable than the terms available to the nationals of those countries. While such access provided an opportunity to appropriate rents from an invention in more than one country, only minimal structures were placed on the form of the patent institutions with these details left up to individual countries. Such flexibility lead to a diverse set of international standards. Moreover, if a country failed to honor even the minimal discipline imposed by the Paris Convention, very little could be done to enforce it, since the agreement contained no formal dispute settlement institution.

Frustrated by an inability to appropriate adequate rents from innovations, technology-exporting countries (US, EU and Japan) lobbied to have intellectual property rights included on the agenda of the Uruguay Round of GATT negotiations. The end result of these negotiations was the agreement on the Trade Related Aspects of Intellectual Property Rights (TRIPs). The obligations contained within the TRIPs agreement represent a major change in international consensus concerning patents and intellectual property rights. In contrast to the Paris Convention, the TRIPs agreement imposes minimum standards on the form of patent protection, with these standards either in-line with or exceeding the practices of most industrialized countries. In addition, the agreement also establishes a dispute settlement mechanism to enforce these minimum standards.

In a previous paper[1] I examined the rationale for an international agreement on the standards of patent protection, which extends the discipline of the international patent system beyond that of the Paris Convention.[2] It was concluded that, without extra discipline, countries tend to adopt standards of protection below those of a social planner, with the difference due to the externalities individual countries experience when evaluating the benefits of patent protection. However, in characterizing the set of patents that achieve the globally efficient level of innovation, it emerges that there are infinitely many sets of patent standards that are consistent with global efficiency if countries experience the same proportional dead weight loss. Under these conditions a social planner is not concerned with the source of funds, just the level of funds an inventor needs to appropriate in order to be induced to undertake the optimal level of innovation. While patent harmonization across countries is an element of the efficient set, the harmonization embodied by the TRIPs agreement requires substantial policy changes for a number of countries, with the largest changes required by the lesser developed countries. This asymmetric policy reform program has raised concerns over the distributional consequences of the TRIPs agreement.

Despite these concerns, a view has emerged that developing countries, and more generally technology importing countries, will gain substantially from the Uruguay Round package - any losses which these countries experience from patent harmonization will be more than offset by the gains from market access in other areas (Chin and Grossman (1990), Maskus (1990), Eby-Konan et. al. (1995) and Gruen et. al. (1996)). However, no detailed analysis of the TRIPs agreement has yet been conducted with much of what is known about the *international* aspects of intellectual property rights drawn from surveys of the owners of intellectual property. For example, the USITC (1988) reported that in response to a 1986 survey, 269 respondents estimated aggregate worldwide losses as a result of inadequate protection of *all* intellectual property at $23.8 billion in 1986. However, incentives to exaggerate the losses undermine the credibility of such survey evidence.

In contrast, this paper estimates a structural model of innovation in an international setting in order to analyze the implications of the TRIPs agreement, with particular attention paid to its implication for

[1] See McCalman (1997).

[2] Other work on the TRIPs agreement includes the static models of Chin and Grossman (1990), Deardorff (1992), Diwan and Rodrik (1991) and the dynamic general equilibrium model of Helpman (1993).

patent protection. The structural model allows the value of patent rights held by 29 countries to be estimated and provides a basis for the examination of how the value of these rights are affected by patent harmonization. These estimates are derived from an adapted version of the model set out in Eaton and Kortum (1996). The basic framework relates innovations to productivity growth through a quality ladders model with the source of innovations (domestic or foreign) related to patent applications. Importantly, the decision to seek a patent is modeled as one that is taken by a profit maximizing inventor, with a patent sought only in those countries which provide patent protection and whose protection is sufficiently valuable to warrant paying the cost of a patent.

A important feature of this paper is that it models the relationship between the value of patent rights and both the scope of patent protection and the enforcement institutions offered by a country. By incorporating this level of detail, the model identifies the relationship between patent institutions and the rents associated with patent protection. Estimation of this relationship then enables the counterfactual experiment to be conducted in which all countries adopt standards consistent with the TRIPs agreement. This allows inferences to be drawn on the international redistribution of income due to the TRIPs agreement, and the size of the increase in dead weight loss associated with strengthening patent protection to be calculated.

What emerges from this analysis is a picture of patent protection as an important method for appropriating the rents of an invention. Although it is not the primary method of rent appropriation, patent harmonization nevertheless has the capacity to generate large transfers of income between countries. The US is the major beneficiary with a net increase in the present value of patent rights of $4.5 billion (1988 dollars) on the patents applied for in 1988. Although developing countries contribute to these transfers, Canada ($1 billion), UK ($0.5 billion) and Japan ($0.5 billion) also make sizable contributions. These transfers significantly alter the perceived distribution of benefits from the Uruguay Round, with the benefits of the US substantially enhanced, while those of developing countries and Canada considerably diminished. The overall benefit of the Uruguay Round package is also diminished once the increase in dead weight loss is included. The increase in dead weight loss from higher standards of patent protection generates an increase in the present value of world wide dead weight loss of $17.5 billion (1988 dollars) on patents applied for in 1988, which amounts to as much as one fifth of the efficiency gains associated with the trade liberalization benefits of the Uruguay Round.

1. Calculation of Patent Values

The object of this study is to estimate the relationship between the value of patent rights and national patent institutions. However, a major difficulty arises in this calculation since patent rights are rarely traded. As a result, data on transactions which would allow the value of patent rights to be directly observed does not exist. Consequently, any attempt at assessing the value of patent rights must be based on some method of imputation.

There appear to be at least two feasible methods for deriving the value of patent protection. One is set out in Pakes and Schankerman (1984), and exploits data on the annual renewal of patent rights. This approach attempts to fit a return function which generates renewal proportions as closely as possible to the observed proportions, conditional on a patent having been taken out. This method has now been used to estimate the value of patent protection in a number of countries (such as France, Germany, UK, Scandinavia and India). However, the prospect of extending this approach to evaluate the international patent system is constrained by the fact that the US did not charge renewal fees prior to 1982.

An alternative approach to gauging the value of patent protection is contained in Eaton and Kortum (1996). The primary purpose of their model is to isolate the contribution that foreign and domestic innovations make to a country's productivity growth. In their framework international patenting provides information on the origin and diffusion of innovations. By assuming that this data is consistent with optimizing behavior of the inventors, inferences can be drawn about the size of innovations. It is the step size of an invention that an inventor uses to calculate the expected value of an invention and consequently the merit of patent protection. The estimated parameters allow these calculations to be reconstructed, revealing the value of patent protection.

While the study of Eaton and Kortum implies a method for quantifying the value of patent protection, this was not the focus of their work. Instead they employed the model to conduct a growth accounting exercise for 19 OECD countries, finding that (except for the US) growth is largely determined by research done elsewhere. In contrast, this paper specifically examines the role that patent institutions play in determining the value of patent rights for both developed and developing countries. To derive these values, Eaton and Kortum's framework is modified in two key respects.

First, the model is extended to incorporate a fuller description of national patent institutions. Eaton and Kortum summarize the institutional characteristics of each country by employing a single summary measure as developed by Rapp and Rozek (1990). While there is some variation in the patent institutions of the countries considered by Eaton and Kortum, a single summary measure would seem appropriate for a relatively homogeneous group (such as the OECD). However, when considering countries with a more varied structure of intellectual property protection, this index becomes inadequate and the parameter estimates are subject to omitted variables bias.[3] To overcome this problem, a range of variables are used to describe national institutions. These variables provide detailed information about patent institutions by summarizing the extent of coverage offered (e.g. are any sectors excluded from patent protection?), restrictions on the form of exploitation of patents (e.g. do imports satisfy working requirements?) and the availability of enforcement institutions (injunctions, burden of proof, etc.). Aside from mitigating omitted variables bias, a disaggregated specification can be mapped directly into the changes implied by the TRIPs agreement, allowing a precise counterfactual experiment to be conducted.

A second modification to the model is a simplification of the structure underlying the innovation production function. Eaton and Kortum utilize data on the employment of research scientists and engineers to proxy the flow of innovations. However, such data is not available for a large number of countries. This can be circumvented by using dummy variables to account for differences in the level of inventiveness between countries.[4] By simplifying the model in this way, a relatively large and diverse sample of countries can be constructed.

[3] A more complete discussion of this problem is given in section 3.2.

[4] Eaton and Kortum also suggest the use of dummies rather than data on research scientists and engineers as it will avoid concerns over the endogeniety of research effort. The exclusion of researchers from the model means that counterfactuals based on exgoneous changes in research effort can not be conducted.

2. The Model

Following Eaton and Kortum (1996), a quality ladders model of productivity growth is employed.[5] In any country, output is produced by combining a given set of intermediate inputs, subject to a constant returns to scale Cobb-Douglas production function:

$$(1) \qquad \ln Y = J^{-1}\int_0^J \ln[Z(j)X(j)]dj$$

where Y is quantity of output, $X(j)$ is the quantity of input j, $Z(j)$ is the quality of input j, and J is an index of the range of inputs. Output is assumed to be homogeneous and tradable across countries, while inputs are non-traded. The range of inputs, J, is assumed to be fixed and the same across countries.[6] Units are chosen so that the production of input j at rate x requires local labor services at rate x.

The expansion of output over time is related to improvements in the quality of inputs. To measure this improvement, the following is used as an index of the aggregate level of technology in country n:

$$(2) \qquad \ln A = J^{-1}\int_0^J \ln Z(j)dj$$

The improvement in the quality of an input is described by the step size of the invention, with an invention of size q applicable to input j raising the quality of that input from $Z(j)$ to $Z(j)' = e^q Z(j)$.

An important aspect of the model is that an innovation can come from either domestic or foreign inventors. If an invention comes from abroad, then the quality of the invention is scaled up or down depending upon the relative technology positions of the source and recipient countries. Specifically, it is assumed that the step size of an innovation is a random variable drawn from an exponential distribution; $\Pr[Q < q] = 1 - e^{-\theta_{ni}q}$, where $\theta_{ni} = \theta\left(\frac{A_i}{A_n}\right)^{-\omega}$ and the catch up parameter, ω, is assumed to be strictly greater than zero. The average step size of an invention employed in country n, but originating in country i, is then equal to $1/\theta_{ni}$. Since the process of research and development (R&D) is

[5] The presentation of the model will be brief, a more detailed exposition can be found in Eaton and Kortum (1996).
[6] The J parameter serves a number of purposes in this model. First, it determines the extent to which a given improvement in an input contributes to output growth (i.e. a higher J implies a smaller aggregate effect). Second, it allows the rate of obsolescence to be derived in a straight forward manner (see (3)). Finally, it provides an extra degree of freedom when

not directly modeled, it is assumed that the type of input to which an invention applies is a draw from a uniform distribution on [0, J].

The model incorporates two further parameters that describe the production of inventions and the diffusion of technology. It is assumed that country i produces a flow of inventions at a rate α_i, with the probability of an invention from country i diffusing to country n given by ε_{ni}.

Using this setup the growth rate for country n is:

$$g_n = \frac{\dot{A}}{A} = \frac{1}{J\theta}\sum_{i=1}^{N}\varepsilon_{ni}\alpha_i\left(\frac{A_i}{A_n}\right)^{\omega}$$

Furthermore, given the structure of the model, the steady state involves each country growing at a common rate (i.e. $g_n = g$). In addition, the solution of the model also identifies the relative technology level (A_i/A_n) in the steady state.

Eaton and Kortum show that under their assumptions about market structure there is a proportional relationship between labor productivity and the technology index:

$$y_n \equiv \frac{Y_n}{L_n^P} = \Gamma_n A_n$$

where,

$$\Gamma_n = \frac{\exp\left(-\sum_{i=1}^{N}\phi_{ni}/\theta_{ni}\right)}{\sum_{i=1}^{N}\phi_{ni}\theta_{ni}/(1+\theta_{ni})}$$

and $\phi_{ni} \equiv \varepsilon_{ni}\alpha_i\left[\sum_{j=1}^{N}\varepsilon_{nj}\alpha_j\right]^{-1}$, is the fraction of invention diffusing into country n from country i.

The inclusion of this equation in the subsequently estimated system ensures that the estimated value of

estimating the model (see footnote 19).

patent protection is in line with observed labor productivity growth.

3. The Patenting Decision

The above provides a description of the general environment in which inventors operate. However, whether or not an invention is patented depends upon two further elements, market structure and national patent institutions. Market structure determines the potential strategic advantage associated with an innovation, and therefore determines the flow of rents that an inventor may appropriate. In turn, national patent institutions dictate the ability of an inventor to reap these strategic advantages. At this point it is important to recognize that patents are only one of a number of ways that innovators use to appropriate rents from an innovation.[7] Consequently, patent protection is modeled as extending the expected duration of the flow of rents an innovator receives, rather than as the sole determinant of an innovators tenure as technological leader.

3.1 Market Structure

Suppliers of intermediate inputs are assumed to engage in Bertrand style competition under constant returns to scale technology. An innovator takes advantage of this competitive behavior by charging a price for the right to use the innovation (which may or may not be patented) that leaves the input suppliers just willing to use the new technology. In this way the owner of the invention can extract rents surrounding the innovation.

The size of these rents is given by the demand conditions faced by the input suppliers. Under Cobb-Douglas production of the final good, demands for all intermediate inputs have a unit elastic form given by $X(j) = Y_n/P_n(j)J$, where $P_n(j)$ is the price of input j in country n. Assuming Bertrand competition among the suppliers of technology and employing a wage rate of w_n, the equilibrium price of an intermediate input of an improved quality is $P_n = e^q w_n$. From these assumptions it follows that the instantaneous rents extracted by the owner of an invention of size q are given by
$\pi_n(q) = (1 - e^{-q})Y_n/J$.

[7] See Levin et. al. (1987).

3.2 Role of Patent Institutions

An inventor earns rents generated by an invention in a country as long as it has diffused there and has been neither imitated nor rendered obsolete by a more advanced technology. The hazard of imitation depends in part on whether the invention has been patented in that country. The protection afforded by a patent, in turn, depends on the strength of national institutions.

Let ι_{ni}^{pat} denote the hazard of imitation if an invention is patented, while ι_{ni}^{not} is the hazard of imitation without a patent. The structure of the model explicitly rules out exports as a method for an inventor to exploit their new technology. Therefore, it is assumed that an inventor appropriates rents from the use of their technology in a foreign country through a licensing agreement. Licensing is assumed to involve the licensee paying $(e^q-1)w_n$ for each unit of intermediate good produced until the expiration of the patent.[8] Under such a contract the marginal cost of the licensee is $e^q w_n$. This implies that when facing a local imitator, with the two firms competing Bertrand style, the licensee produces nothing and the imitator satisfies local demand under a limit pricing strategy. Consequently, the inventor's rents fall to zero when a technology is imitated.

Aside from the risk of imitation, inventors also face the possibility that their technology will be surpassed by new inventions. This hazard of obsolescence depends upon the rate at which innovations flow into a country and the probability that they apply to a particular industry, with the steady-state rate of obsolescence in country n given by:

$$(3) \qquad o_n = \frac{1}{J}\sum_{i=1}^{N} \varepsilon_{ni}\alpha_i$$

In assessing the benefits of patent protection an inventor compares the expected present value of the invention both with a patent (less any costs of obtaining the patent) and without. To analyze the decision, consider the expected value at time t of an invention from country i of size q that has diffused to country n, $V_{ni}(q)$. The probability of its not having become obsolete by time $s > t$ is $e^{-o_n(s-t)}$, while

[8] This contract is not subject to a double marginalization problem due to the limit pricing strategy which is adopted by the licensee in the intermediate input market. By setting the per unit license fee in this way, the patent holder can extract all the

the probability of its not having been copied by then is $e^{-\iota_{ni}^{k}(s-t)}$, where $k \in$ {pat, not} depending on whether or not the invention has been patented. Therefore,

$$V_{nit}^{k}(q) = \int_{0}^{\infty} \pi_{nt+s}(q) e^{-(r+\iota_{ni}^{k}+o_n)s} ds,$$

where r is the discount rate which is assumed to be constant overtime. Evaluating this expression at the steady state implies that Y_n will grow at a constant rate g, with the associated expected value of:

$$(4) \qquad V_{ni}^{k}(q) = \frac{(1-e^{-q})Y_n}{J(r+\iota_{ni}^{k}+o_n-g)}$$

A patent gives the inventor the incremental benefits of a lower hazard of imitation, so is worth $V_{ni}^{pat}(q) - V_{ni}^{not}(q)$. Hence, an inventor from country i will seek patent protection in country n if the value of patent protection in country n exceeds the costs of obtaining a patent, C_{ni}. Since the incremental value of patent protection is increasing in the step size of the invention, q, the following implicitly defines a quality threshold, $\bar{q}_{ni}$, above which all inventions are patented, while those that are of a lower quality are not:

$$V_{ni}^{pat}(q) - V_{ni}^{not}(q) = C_{ni}$$

Solving this equation for the cut off quality yields:

$$\bar{q}_{ni} = -\ln\left(1 - \frac{J(r+\iota_{ni}^{pat}+o_n-g)(r+\iota_{ni}^{not}+o_n-g)C_{ni}}{(\iota_{ni}^{not}-\iota_{ni}^{pat})Y_n}\right)$$

The fraction of inventions which diffuse from country i to country n that are patented in country n, f_{ni}, can now be determined by combining the cut-off quality with the distribution function for the inventive

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rents from the innovation, provided it has not been imitated.

step.

$$(5) \qquad f_{ni} = \Pr[Q > \bar{q}_{ni}] = e^{-\theta_{ni}\bar{q}_{ni}} = \left(1 - \frac{J(r + \iota_{ni}^{pat} + o_n - g)(r + \iota_{ni}^{not} + o_n - g)C_{ni}}{(\iota_{ni}^{not} - \iota_{ni}^{pat})Y_n}\right)^{\theta_{ni}}$$

Note in particular that the more effective the national patent institutions are at lowering the hazard of imitation, the higher is the fraction of inventions that are profitable to patent.

The reduction in the hazard of imitation due to patent protection is assumed to be related to the modes of legal redress that an inventor can access. Specifically, it is assumed that patent protection lowers the hazard of imitation in the following manner:

$$(6) \qquad \iota_{ni}^{pat} = \begin{cases} \iota_{dom}^{not} e^{-\gamma PG_n} & for\ i = n \\ \iota_{for}^{not} e^{-\gamma PG_n} & for\ i \neq n \end{cases}$$

where PG_n is an index describing national enforcement institutions adapted from Park and Ginarte (1997). In contrast to Eaton and Kortum, this specification allows the hazard of imitation to depend on whether the innovation being patented is of domestic or foreign origin. This is achieved by incorporating additional information on the hazard of imitation of non-patented innovations.[9] Note also that since the index employed is continuous, this specification allows for the estimation of one domestic and one foreign hazard of imitation rate associated with patents for each country, for a total of fifty eight, in contrast to Eaton and Kortum's two.

Given the flow of inventions from country i, α_i, the fraction of these that diffuse to country n, ε_{ni}, and the fraction of these which it pays to patent, f_{ni}, the number of patents taken out in country n by inventors located in country i, P_{ni}, would then be given by:

$$P_{ni} = \alpha_i \varepsilon_{ni} f_{ni}$$

[9] For details on the different treatment of the hazard of imitation see footnote 18.

This derivation assumes that once an invention has diffused to another country the only relevant factor determining patenting behavior is the size of the innovation. However, a number of countries either exclude from patentability inventions in a particular field or require that the patents be worked within the country. It is therefore possible that inventions that satisfy the quality threshold are nonetheless not patented. To capture this possibility, the model is augmented by a parameter representing the scope of patent protection, s_{ni}. This parameter is assumed to enter the bi-lateral patenting equation in a multiplicative manner. s_{ni} is interpreted as the fraction of inventions of patentable quality that are also applicable to an industry which is covered by patent protection.[10] Therefore, bi-lateral patenting is described by

$$(7) \qquad P_{ni} = \alpha_i \varepsilon_{ni} f_{ni} s_{ni}$$

Bi-lateral patenting is then the result of the following process of elimination. Country i generates a flow of α_i inventions which diffuse to country n with probability ε_{ni}. A fraction of these diffused inventions, f_{ni}, are of a sufficiently high quality to make patenting profitable, with this fraction being higher the more effective are the national patent institutions at lowering the hazard of imitation. However, only a fraction, s_{ni}, will apply to industries which are covered by patent protection. The inventions that survive this filtering process are the ones that are ultimately patented.

The motivation for including extra information on the scope of patent protection is twofold. First, one of the major changes required by the TRIPs agreement is that patent protection be offered to all inventions without regard to country of origin or how the patent is exploited. Therefore, by including information on the scope of protection, the impact of this broadening of patent protection can be directly assessed. The second motivation is to overcome the possibility of omitted variables bias. The potential for this bias to arise is related to Eaton and Kortum's assumption that the role of national patent institutions affect patenting decisions solely through reductions in the hazard of imitation. However, if otherwise profitable patents are not taken out because they are excluded from patentability, then the estimated hazard rate for a patent will be biased upward. This will tend to understate the

[10] This specification is consistent with the model developed above as the type of input to which an invention applies is

consequences of patent harmonization. Both of these reasons suggest that the scope of patent protection plays an important role in the operation of the patent system and needs to be incorporated directly into the model.

The scope of patent protection, s_{ni}, is assumed to determine the fraction of high quality innovations that receive patent protection. This fraction is directly related to the industries that a country excludes from patent protection. In addition many countries specify that patent protection brings with it an obligation to undertake production that employs the new technology within the country granting the patent. This restriction may deter inventors of high quality innovations from taking out a patent, preferring instead to serve that market by exports.[11] It is also the case that the scope of patent protection can effect source countries differently. For example, a country which itself excludes chemicals from patent protection is unlikely to have an active R&D sector in chemicals.[12] In this situation, the bi-lateral scope of patent protection between two countries that both exclude chemicals is higher than the scope of protection for a country which covers chemicals but its bi-lateral partner does not. This effect is captured by the interaction terms for the sectoral dummies in the specification set out in (8).

It is the combination of excluded industries and working requirements that is taken to define the scope of patent protection offered by a country. To capture the variation in institutional arrangements, the following relates the scope of patent protection to national policies:

$$(8) \qquad s_{ni} = (1 - s^{ph} D_n^{ph}(1 - D_i^{ph}))(1 - s^{fd} D_n^{fd}(1 - D_i^{fd}))(1 - s^{ch} D_n^{ch}(1 - D_i^{ch}))(1 - s^{wr} D_n^{wr}),$$

where the D's represent dummy variables that take on the value of one if patent protection is not

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assumed to be drawn from a uniform distribution.

[11] Modeling a domestic working requirement in this way is admittedly ad hoc. To analyze the role of this restriction requires a model which includes a choice over how a market is served (licensing, exports or direct investment).

[12] There is a possible endogeniety problem here since it may be the case that chemicals are not offered patent protection because there are no domestic chemical innovations to be patented *or* there are no domestic chemical innovations to patent because there is no domestic patent protection. However, as detailed in Levin et. al. (1987) and Mansfield (1986), although patents are part of an innovators rent appropriation strategy, they are not the primary instrument for appropriating rents. Therefore, if a country wanted to create a domestic chemical R&D sector it would need to do more than simply provide patent protection for chemical innovations. Assuming that no chemical innovations implies no patent protection for chemicals does contradict the assumption that innovations are distributed uniformly across the *J* inputs. Nevertheless, countries which exclude industries can still experience improvements in quality across all *J* inputs, and in any event these countries are responsible for only a small fraction of all innovations.

provided in the pharmaceutical (*ph*), food (*fd*) and chemical (*ch*) industries or if there is a restriction that the working of a patent is not satisfied by imports (*wr*) into a country, while s^{ph}, s^{fd}, s^{ch} and s^{wr} are parameters to be estimated. To get a feel for how this specification of scope operates, assume that $D_n^{fd} = D_n^{ch} = D_n^{wr} = D_i^{fd} = D_i^{ch} = 0$ (i.e. both countries provide patent protection in the food products and chemical industries and neither imposes a working requirement), so that $s_{ni} = (1 - s^{ph} D_n^{ph} (1 - D_i^{ph}))$. Now if $D_n^{ph} = D_i^{ph} = 1$ the effective scope of protection afforded inventors from country *i* in country *n* is 1. However, if $D_i^{ph} = 0$, then the effective scope of protection is $(1 - s^{ph}) < 1$. Therefore, the exclusion of an industry from patent protection or the imposition of a working requirement leads to a proportional reduction in the number of patents sought in country *n* by inventors in country *i*.

4. Empirical Implementation

The above parameters of the theoretical model can be estimated by assuming that the data is generated by steady state equilibrium. The two basic equations investigated are the bi-lateral patenting equation and the labor productivity equation:

$$P_{ni} = \alpha_i \varepsilon_{ni} f_{ni} s_{ni}$$
$$y_n = \Gamma_n A_n$$

These two equations are jointly estimated in order to impose the restriction that patenting behavior, and the implied patent values, are consistent with productivity growth.[13]

To estimate this system assume that the bi-lateral patenting equation is subject to a multiplicative error, u_{ni}, which is taken to be independently and identically distributed with a variance of σ_u^2. This implies the following empirical relationship:

$$P_{ni} = \alpha_i \varepsilon_{ni} f_{ni} s_{ni} e^{u_{ni}}$$

As noted in Eaton and Kortum, a difficulty arises in estimating this equation when the predicted

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[13] Eaton and Kortum estimate the same two equations with the exception that the introduction of extra information on national patent institutions in this paper alters the definition of f_{ni} and introduces the scope parameter, s_{ni}..

fraction of patentable inventions hits zero. In this situation the model should fit perfectly. To overcome this problem, two alternative strategies are considered. First, following Eaton and Kortum it is assumed that a fraction of inventions η that are not worth patenting (i.e. involve a step size below $\overline{q}_{ni}$) are patented by mistake. The bi-lateral patenting equation then becomes:

(9) $$P_{ni} = \alpha_i \varepsilon_{ni}[f_{ni} + (1 - f_{ni})\eta] s_{ni} e^{u_{ni}}$$

The second alternative explored is to estimate the patenting equation under a Tobit specification (see section 6).

Consider next the relationship between labor productivity and the technology index. To gain a measure of this index, the dynamic system is solved with the eigenvector yielding the implicit value of the technology index. However, since the eigenvector is only defined up to a scalar multiple, the model only has implications for relative productivity levels. Hence the following relative productivity equation is estimated:

(10) $$\frac{y_n}{y_N} = \frac{\Gamma_n A_n}{\Gamma_N A_N} e^{v_n - v_N}$$

where each country's productivity is measured relative to that of the US. It is assumed that the error, v_n, is independently and identically distributed with a variance of σ_v^2.

5. Data

The sample consists of 29 countries, a mix of both developing and industrialized countries. This provides 841 bi-lateral patenting observations and 28 relative labor productivity observations. Table 1 provides a list of the countries along with some summary statistics.

The dependent variables are bi-lateral patenting of inventions from country *i* in country *n*'s market, P_{ni}, and country *n*'s productivity relative to that of the US, y_n/y_N. The patent variable is patent applications by reporting country and country of residence of the inventor for 1988. These data are taken primarily from WIPO (1990), with additional data obtained directly from WIPO.[14] Table 1 summarizes the full matrix of patenting data, reporting patenting in the country by residents (domestic patents), by non-residents (foreign patents) and patenting in foreign countries by domestic residents (patents abroad). The data reveal substantial levels of cross-country patenting, with all countries except Japan, Israel and the US receiving more patent applications from foreigners than from domestic residents.[15] The productivity variable is real GDP per worker, averaged over 1986-88, from Summers and Heston (1991) in 1988 dollars.

The explanatory variables governing the return to patenting relate primarily to data on national patent institutions. Data on the scope of patent protection is taken from WIPO (1988) and Baxter and Sinott (1989). These data consist of dummy variables taking on a value of unity if a sector is excluded from patent protection and zero otherwise. The sectors most subject to exclusion are pharmaceuticals (D^{ph}), foods (D^{fd}) and chemicals (D^{ch}). In addition, some countries do not consider importation of products as consistent with the exploitation of patent rights and impose a domestic working requirement (D^{wr}). The value of these dummy variables are listed in Table 1.

Once a patent has been obtained, its exploitation is dependent on the national enforcement institutions that protect a patent holder from imitators. Recall that patent enforcement is given by (6) and enters (9) through f_{ni}. Information on these institutions is contained in an index adapted from Park and Ginarte (1997), that has a range from zero to five (PG_n). This index summarizes information on the availability of injunctions, prosecution for contributory infringement, the possibility of criminal prosecution, the burden of proof procedures and the duration of patent protection.[16]

The cost of applying for a patent, (C_{ni}), which includes official application fees, agent's fees and translation fees, are constructed from Helfgott (1993). Recall that C_{ni} enters (9) through the definition of f_{ni}. These costs range from a minimum of \$460 in India, for an application which does not require

[14] I would like to thank Lise Mcleod of WIPO for supplying the additional data.
[15] Based on Okada (1992) and following Eaton and Kortum (1996) the data from Japanese domestic application has been adjusted to account for the idiosyncratic domestic patenting of the Japanese. Okada finds that the Japanese exhibit substantially different patenting behavior than foreigners, with a foreign patent application containing an average of 4.9 times as many inventive claims as those submitted by Japanese inventors. The adjustment involves translating 4.9 Japanese domestic patent applications to be equivalent to one from somewhere else.
[16] I would like to thank Walter Park for providing these data.

translation to English, to $4,772 in Japan, which does require translation. GNP taken from the World Bank (Y_n) scales these costs (see (5)). The modeling of diffusion follows that of Eaton and Kortum (for the exact specification, see the Appendix). Data on the determinants of diffusion are distance in kilometers, KM_{ni}, bi-lateral imports as a share of GNP, IM_{ni}, (IMF (various years)) and human capital, HK_n, (Barro and Lee (1996)).[17]

Finally, a number of parameters have been pre-determined due to difficulties in identifying all the parameters of the model. These are domestic and foreign imitation rates of non-patented technology $(\iota_{dom}^{not},\ \iota_{for}^{not})$, the real rate of interest (r) and the growth rate (g). The foreign imitation rate of non-patented material is based on estimates of Mansfield and Romeo (1980) about the rate at which technology "leaks out" from US firms to non-US competitors. This hazard rate is set at 0.25. Comparable numbers for the domestic market are reported in Mansfield (1985), which imply a domestic hazard of imitation of 0.8.[18] Finally, the model is solved to attain a steady-state growth rate of 2.8%, which is the average of the countries in the sample over the period 1985-90, and the real interest rate is set at 7%.[19]

6. Simultaneous estimation of the patent and productivity equations

The system of equations estimated is given as:[20]

$$P_{ni} = \alpha_i \varepsilon_{ni}[f_{ni} + (1 - f_{ni})\eta] s_{ni} e^{u_{ni}} \qquad i, n = 1,........, N.$$

$$\frac{y_n}{y_N} = \frac{\Gamma_n A_n}{\Gamma_N A_N} e^{v_n - v_N} \qquad n = 1,........, N-1.$$

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[17] This measure of human capital differs from that used in Eaton and Kortum and was adopted due to its wider country coverage.

[18] The treatment of the foreign hazard of imitation follows that of Eaton and Kortum, while the domestic hazard is calculated differently. It was decided for the sake of consistency that foreign and domestic imitation parameters would be taken from comparable sources. Eaton and Kortum chose to set foreign imitation rates based on Mansfield and Romeo (1980) and attempted to estimate the domestic imitation rate. While this proved unsuccessful, they concluded from their experience that the domestic imitation rate should be set at a large number. Similarly I tried to estimate this rate but found that the estimated value became arbitrarily small. Ultimately it was decided that unless both imitation rates could be estimated, the most satisfactory solution is to set both consistently (i.e. derived from a comparable methodology).

[19] At each iteration of the model during the estimation routine, growth is constrained to equal 2.8%. This is achieved by calibrating the J parameter, conditional on all the estimated parameters, to generate a growth rate of 2.8% (see Appendix for details).

[20] The Appendix sets out the components of each equation.

The parameter vector estimated is:

$$\Theta = [\gamma, s^{ph}, s^{fd}, s^{ch}, s^{wr}, \varepsilon_{dom}, \varepsilon_{km}, \varepsilon_{km2}, \varepsilon_{hk}, \varepsilon_{imp}, \alpha_i, \omega, \eta, \theta]$$

which consists of a total of forty-two parameters. The exogenous variables for source country *i* and destination country *n* are given by the vector:

$$x_{ni} = [PG_n, D^{ph}, D^{fd}, D^{ch}, D^{wr}, DH_{ni}, KM_{ni}, HK_n, IM_{ni}, C_{ni}, Y_n]$$

This system is estimated in log form with additive errors and can be expressed compactly as:

$$\begin{bmatrix} p \\ y \end{bmatrix} = G(\Theta, x) + \Psi$$

where p and y represent a vector of logs of patents and productivity, Θ is a vector of parameters, x is a matrix of exogenous variables and Ψ is a vector of errors which are assumed to satisfy $E[\Psi|x] = 0$, with an assumed covariance matrix of

$$\Omega = \begin{bmatrix} \sigma_u^2 I_{N^2} & 0 \\ 0 & \sigma_v^2 \Omega_v \end{bmatrix}$$

where I_k is a kxk identity matrix and $\Omega_v = [I_{N-1} + e_{N-1}e'_{N-1}]$ with e_{N-1} is an N-1 vector of ones.

Estimation employs a two step feasible generalized nonlinear least squares procedure. The first step imposes a value on the ratio of σ^2_u/σ^2_v, which allows $\hat{\Omega}$ to be constructed up to a scalar multiple. A numerical routine is then used to find the value of $\hat{\Theta}$ that minimizes:

$$\left[\begin{pmatrix} \mathrm{p} \\ \mathrm{y} \end{pmatrix} - G(\Theta, x)\right]' \hat{\Omega}^{-1} \left[\begin{pmatrix} \mathrm{p} \\ \mathrm{y} \end{pmatrix} - G(\Theta, x)\right]$$

This first step yields consistent but not efficient parameter estimates. To obtain efficient estimates the residuals are used to calculate estimates of $\hat{\sigma}_u^2$ and $\hat{\sigma}_v^2$ and construct a new estimate of $\hat{\Omega}$, which is then used in the minimization routine.[21]

Under the Tobit specification, it is assumed that the of log bi-lateral patenting is censored at zero. This gives rise to the following specification for bi-lateral patenting:

$$p_{ni}^* = G_1(\Theta, x) + u_{ni}$$

and

$$p_{ni} = \begin{cases} G_1(\Theta, x) + u_{ni} & \text{if } p_{ni} > 0 \\ 0 & \text{if } p_{ni} \leq 0 \end{cases}$$

where $\{u_{ni}\}$ are assumed to be independent drawings from $N(0, \sigma^2_u)$. The system of equations is then estimated using maximum likelihood techniques.

7. Parameter Estimates

Table 2 contains the parameter estimates. As can be seen from this table, there is very little difference between the parameter estimates derived from the feasible generalized non-linear least squares and the maximum likelihood procedures. Given this similarity, the remainder of the paper will discuss the conclusions based on the feasible generalized least squares procedure in order to maintain comparability to Eaton and Kortum.

All the parameters are significant except for the catch up parameter, ω, and the scope parameters for the exclusion from patent protection of the chemical and pharmaceutical industries , s^{ch} and s^{ph}. Taking account of the differences in the size of the sample and the characterization of national patent institutions, the remaining parameters generally conform to those found by Eaton and Kortum.

Turning to the role of patent institutions, the scope variables reveal that restrictions on both sectoral coverage of patents and how they are worked has a substantial impact on patenting behavior. For

[21] The Appendix shows how the technology index, A_n/A_N,, is derived from the parameter values and how it relates to the estimated equations.

example, a country which excludes pharmaceuticals, foods and chemicals from patenting while requiring that the remaining patents be worked locally, reduces the number of patents taken out in their economy on a bi-lateral basis by 80% compared to a situation where the quality of an invention is the only determinant of patenting (calculated using equation (8) and assuming $D_n^{ph} = D_n^{fd} = D_n^{ch} = D_n^{wr} = 1$ and $D_i^{ph} = D_i^{fd} = D_i^{ch} = 0$).

The parameter on the index of enforcement institutions, γ, shows that these institutions also play a significant role. This parameter implies that the most stringent enforcement institutions lower the risk of imitation by 10% compared to a non-patented outcome (calculated using equation (6)). However, to fully appreciate the role of patent institutions, the present value of protection that is offered by these institutions needs to be derived (not just the impact on the hazard of imitation).

8. Patents and Rent Appropriation

A major concern associated with the adoption of the TRIPs agreement is that technology-importing countries are likely to be exploited by the owners of technology. However, studies of the utilization of the patent system reveal that patent protection is not the sole method used to appropriate the benefits from an invention. Other appropriation strategies based on secrecy, lead time, learning curves and sales/service efforts have all been identified as prominent determinants of the ability to appropriate rents.[22] This suggests that any analysis of the TRIPs agreement must attempt to isolate the role of patent protection in rent appropriation, or risk overestimating the role of patents in rent appropriation.[23]

The parameter estimates reported in Table 2 are used to derive the private value of patent protection based on the institutions which were in place prior to the TRIPs agreement. This value is defined as the increase in the present value of rents accruing to the inventor due to the lower hazard of imitation associated with patent protection, conditional on the estimated flow of innovations. Calculation of this quantity involves a comparison of the present value of rents appropriated both with and without patent protection (i.e. $V_{ni}^{pat}(q) - V_{ni}^{not}(q)$, with these values derived from (4)). The value of patent protection is then the present value of the incremental rents that an inventor appropriates from their extended

[22] See Levin et. al. (1987).

[23] The static models of Maskus, Subrumanian and others do not allow for alternative rent appropriating methods and equate market power solely with the existance of patent protection.

tenure as technology leader due to the lower hazard of imitation associated with patent protection.

At the bi-lateral level, the private value of patent protection is calculated by multiplying the mean present value of patent rights by the number of patent applications. Combining the exponential distribution of the quality of the invention and the quality threshold for profitable patents identifies the mean value of patent rights as:

$$\int_{\bar{q}_{ni}}^{\infty} \left[V_{ni}^{pat}(Q) - V_{ni}^{not}(Q)\right] f(Q \mid Q > \bar{q}_{ni})\,dQ$$

$$= \frac{(1 - \frac{\theta_{ni}}{1+\theta_{ni}} e^{-\bar{q}_{ni}})(\iota_{ni}^{not} - \iota_{ni}^{pat})Y_n}{J(r + \iota_{ni}^{pat} + O_n - g)(r + \iota_{ni}^{not} + O_n - g)}$$

$$\equiv PV_{ni}^{prof}$$

The empirical model also allows for the possibility that a certain fraction of inventions with a step size below $\bar{q}_{ni}$ are also patented in country *n* by residents of country *i*. The mean present value of patent rights associated with these mistakes is given by:

$$\int_{\bar{q}_{ni}}^{\infty} \left[V_{ni}^{pat}(Q) - V_{ni}^{not}(Q)\right] f(Q \mid Q \le \bar{q}_{ni})\,dQ$$

$$= \frac{(1 - \frac{\theta_{ni}}{1+\theta_{ni}} (\frac{1 - e^{-(1+\theta_{ni}\bar{q}_{ni})}}{1 - e^{-\theta_{ni}\bar{q}_{ni}}}))(\iota_{ni}^{not} - \iota_{ni}^{pat})Y_n}{J(r + \iota_{ni}^{pat} + O_n - g)(r + \iota_{ni}^{not} + O_n - g)}$$

$$\equiv PV_{ni}^{mistake}$$

Hence, the aggregate present value of rents appropriated from patents in country *n* held by inventors in country *i* is given by:

$$\varepsilon_{ni}\alpha_i s_{ni}[f_{ni}PV_{ni}^{prof} + \eta(1 - f_{ni})PV_{ni}^{mistake}] - P_{ni}C_{ni}$$

Table 3 reports these values aggregated to give the total present value of a country's patent rights in

1988 dollars under the pre-TRIPs system.[24] The most striking feature of this column is the value of rights held by US residents. The aggregate value of US owned patent rights are not only calculated to be greater than any other country's, but are in fact greater than all other countries taken as a whole. With such a stake in the patent system it is not surprising that the US has played such an active role in its reform.

Table 4 helps to put these numbers into perspective and provides a check on their plausibility. The first column provides a general measure of the importance of patent protection, by comparing the present value of patent rights to R&D expenditures by business enterprises.[25] This ratio provides a measure of the importance of patent protection as a rent appropriating mechanism. For example, with free entry into the R&D market we would expect this ratio to be approximately one if patents represented the sole source of rent appropriation. With no country recouping more than a quarter of R&D expenditures through patent protection (see the first column of Table 4), these predictions are in line with qualitative work which suggests that patents are not the primary method used by inventors to appropriate rents (Levin et. al. (1987)). They are also similar to predictions from patent renewal models which report ratios with a close resemblance to those in the first column for France, Germany and the UK (see Lanjouw (1993), Schankerman (1991), Pakes (1986) and Pakes and Schankerman (1986)). These ratios are also consistent with survey evidence for the US which finds that patents tend to raise imitation costs by a median of 11% (Mansfield et. al. (1981)). Schankerman (1991) interprets this 11% as an approximate return to a patent holder. This is derived by assuming that without a patent, entry based on the new technology will occur until normal profits are made. However, if a patent raises the entry costs of the imitators by 11%, then the patent holder will be able to make pure profits by avoiding these extra costs. The estimated return for the US is 15%, with a standard error of 2.3%, and 11% falls within the associated confidence interval.

The ranking in the first column of Table 4, which shows the most developed countries (US, France, Germany, UK and Italy) rely on the patent system more than less-developed countries (India, Mexico, Korea, and Portugal), also seems plausible. Such a ranking is consistent with the notion that R&D

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[24] While the present value of patent rights is constructed from two components, profitable patents and mistakes, the mistakes represent less than 1% of any countries the total value of patent rights.

[25] For OECD countries the R&D numbers are for 1988. The remaining numbers are for years other than 1988, although

efforts of less developed countries are directed primarily towards adaptive ends rather than purely innovative ends (Evenson (1984)). However, two elements of this ranking are somewhat surprising, the low ranking of Japan and the highest ranking of Switzerland. As noted in Footnote 15, an adjustment was made to the number of domestic patents that the Japanese apply for. This adjustment is a crude way of dealing with the idiosyncratic patenting behavior of the Japanese, with an associated tendency to distort the value of Japanese held patent rights if it is incorrect. On the other hand, the highest ranking of Switzerland does seem a plausible result. Nearly 50% of Swiss business R&D expenditures are devoted to chemicals and drugs, in comparison to only 10% for the US. Given the higher than average reliance of chemical and drug firms on patents to appropriate rents (Mansfield (1986)), this suggests that the Swiss ranking is indeed appropriate.

As a final check on the calculated size and distribution of the value of patent rights under the pre-TRIPs system, the second column of Table 4 provides a breakdown between the rents appropriated from the domestic market and foreign markets. As is to be expected, all but the largest countries appropriate most of their rents from abroad.[26] The breakdown for the US is particularly encouraging, given that Mansfield et. al. (1979) find that approximately one third of the returns to US R&D projects are expected to come from abroad. Taken together, the evidence presented in Table 4 suggests that the approach adopted in this paper captures important elements of what is known about the value and distribution of patent rights under the pre-TRIPs system of patent protection.

Since the estimated parameters contain information on how inventors respond to different institutional settings when evaluating patent protection, this framework can be used to address the question: What are the transfers of income between countries implied by the TRIPs agreement? This question can be answered by setting the institutional parameters in line with those required by the TRIPs agreement. It should be emphasized that an important caveat to the results derived from this experiment is that the level of innovation is assumed to be constant. This restriction limits the ability of this model to fully characterize the welfare outcome of the TRIPs agreement since only the costs of higher standards of patent protection can be evaluated but not the potential benefits it achieves through greater innovation.

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they have been converted to 1988 dollars. See the Footnote on Table 3 for source information.

[26] The breakdown reported in column 3 differs substantially from that reported in Eaton and Kortum (1995). This discrepancy is attributable primarily to the different domestic hazard of imitation used in this paper compared to Eaton and

Compliance with the TRIPs agreement requires all countries to adopt the same broad scope of protection.[27] This requires that coverage be extended to the pharmaceuticals, food and chemical industries. The TRIPs agreement also allows a patent holder to service a market through imports without fear of revocation of patent rights.[28] Finally, the TRIPs agreement requires that a basic enforcement infrastructure be erected to allow patent holders to defend their intellectual property.[29] The implication of these changes can be approximated by setting the scope dummies (D^{ph}, D^{fd}, D^{ch} and D^{wr}) to zero and the enforcement index (PG_n) to five. Under these assumptions, the experiment being conducted is equivalent to asking what would the present value of patent rights have been for patents applied for in 1988 if all countries adopted the standards set by the TRIPs agreement in that year.[30]

Table 5 presents the transfers induced by these changes. The first column sets out the net transfers associated with the TRIPs agreement, which are defined as the increase in the present value of patent rights held by residents of a country less the increase in the present value of patent rights granted by that country in 1988.[31] This column can be used to provide a ranking of the winners and losers from the TRIPs agreement. On this basis only six countries stand to benefit from the TRIPs agreement: US, Germany, France, Italy, Sweden and Switzerland. All other countries experience a net loss from raising their standards of patent protection. The US stands out as the major beneficiary, gaining nearly six times as much as the second largest beneficiary. Somewhat surprisingly, Canada is the largest loser - over $1 billion - but this is consistent with Canada's alignment with developing countries in the negotiation of the TRIPs agreement (Cottier (1991)). While the size of Canada's projected loss is surprising, it is still plausible. The potential for this transfer lies in Canada's proximity, size and shared language with the US, factors that combine to make Canada the largest trading partner for the US. However, Canada ranks only fifth in terms of destination for US owned patents. In addition, in

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Kortum. See footnote 18 for further discussion of this .

[27] See TRIPs Article 27(2) and (3).

[28] See TRIPs Article 27(1).

[29] On term of protection see Article 33, for burden of proof see Article 34(1), injunctions see Article 44 and criminal procedures see Article 61.

[30] It is important to note that no allowance has been made for the transitional periods for developing countries that are allowed under the TRIPs agreement. In part, these transitional periods were designed to avoid the capital gains to holders of existing patents. Since this experiment considers only applications for new patents, the capital gains dimension is naturally excluded.

[31] France and Italy are the only countries which do not increase the value of the patents rights they grant, since based on the

1988 US inventors sought only 14,687 patents in Canada while seeking over 75,000 domestically. In contrast, Canada seeks more patents in the US than any other country (including Canada itself). Consequently, the harmonizing of patent standards at a high level of protection provides ample incentive and opportunity for US inventors to seek patents in Canada, without a corresponding opportunity for Canadian inventors. In particular, the TRIPs agreement requires Canada to improve the enforcement of patent rights by making infringement subject to criminal action and by providing for preliminary injunctions to be granted. In addition, the requirement that patents granted in Canada be worked in Canada will be removed under the TRIPs agreement.

Other significant losers are Brazil, UK, India, Mexico, Japan, Spain and Korea. Of these, the poor performance of the UK and Japan is somewhat unexpected. While the estimated net transfers for both these countries is subject to relatively high standard errors, their ranking is a reflection of the higher standard of enforcement that TRIPs requires of them. Prior to the TRIPs agreement, the UK ranked twenty-fourth on the basis of enforcement, yet still managed to be the second most popular destination for seeking patents among foreign innovators. Under the TRIPs agreement the UK will be required to provide for the granting of preliminary injunctions when infringement of a patent is suspected, along with the reversal of the burden of proof in certain cases involving process patents.[32] In addition, the UK is required to make the infringement of a patent subject to criminal action. These factors combine to generate a substantial increase in the value of UK patent protection, a rise which is not matched by the increase in value of foreign patents held by UK inventors. A similar, though less pronounced, story lies behind the ranking of Japan. A full breakdown of the net bi-lateral transfers is given in Table 10.

Table 6 helps to decompose transfers into those associated with a broadening of the scope of protection and a raising of the enforcement efforts. Since most countries end up paying, the focus is on the gross transfers abroad and the share of these transfers attributable to the broadening of the scope of protection. The first column reveals that transfers from developing countries are generally associated with an increase in the standard of enforcement rather than a widening of the scope of protection. For developed countries the relative importance of transfers deriving from scope or enforcement changes is

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measures of patent protection used in this paper their standards were in compliance with TRIPs in 1988.

[32] The burden of proof is typically on the plaintiff, a requirement which becomes particularly onerous in cases involving process patents since the plaintiff usually is not privy to the exact production process employed by a competitor. However,

divided roughly fifty fifty. Overall, this breakdown provides some insight into the source of future tensions over intellectual property protection, especially for developing countries. Since the transfers from the developing countries are primarily determined by an increase in enforcement efforts, this suggests that these countries will be more willing to extend the coverage of patent protection as required by TRIPs, but may be less willing to devote adequate resources to enforcement. Hence, future North-South tensions over intellectual property rights are likely to be centered around enforcement issues rather than the scope of protection offered.

Given the distribution of benefits from patent harmonization, it is interesting to try to evaluate the relative importance of the TRIPs agreement compared to other aspects of the Uruguay Round. There have now been a large number of studies trying to evaluate the benefits of the Uruguay Round as they relate to liberalization of goods trade.[33] Columns 1 and 2 of Table 7 report the results from a representative study by Harrison et. al. (1995) that was performed on a sufficiently disaggregated level to enable comparisons to be made at a country level.[34] The work of Harrison et. al. evaluated the market liberalization consequences of the following three policy changes: (i) tariff reductions on manufactured goods; (ii) liberalization of agricultural protection; and (iii) the elimination of the Multifibre Arrangement. While caution should be applied to the interpretation of comparisons made across models, it appears that the TRIPs agreement does play a prominent role in shaping the outcome of the Uruguay Round.[35] Columns 3 and 4 report the estimates of Harrison et. al. net of the transfers implied by TRIPs. Taking account of the TRIPs agreement, the US finds that its gains from the Uruguay Round are substantially enhanced by patent harmonization (an increase of 40% in the short run and increase of 20% in the long run). For Mexico, Canada and Brazil patent harmonization also plays a large role in determining the outcome of the Uruguay Round. All of these countries now find that the Uruguay Round is of questionable benefit in the short run and that patent harmonization reduces substantially the magnitude of any long run gains.

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the TRIPs agreement allows this burden of proof to be reversed in certain situations (see Article 34(1)).

[33] See Francois et. al. (1995) for a survey

[34] The short run setting reported by Harrison et. al and reported in Table 5 refers to a situation in which the capital stock is fixed. In contrast, the long run outcome allows for the capital stock to be adjusted in response to changes in relative prices. This long run outcome ignores adjustment costs and therefore serves as an upper bound on the welfare gains of the Uruguay Round.

[35] One precaution that has been taken is the selection of a study that reports simulations for 1992, which are then discounted to 1988 to make the numbers comparable. Other studies report implications for 2005 when the Uruguay Round will be fully

A related issue is the impact that patent harmonization has on the dead weight loss associated with the granting of patents. However, due to the assumptions relating to market structure, markups are independent of intellectual property rights (i.e. the price of the input employing the new technology is the same both before and after imitation). Nevertheless an approximation to the increase in dead weight loss associated with the TRIPs agreement may be gained by decomposing the dead weight loss in a similar way to that employed to isolate the rents appropriated from patent protection (as opposed to other appropriation mechanisms). Therefore, the dead weight loss can be decomposed and attributed to patent protection, other appropriation mechanisms and the market power that an imitator possesses (see section 3.2).

The calculation of the dead weight loss follows directly from the assumptions on market structure and the limit pricing strategy that it implies for a patent holder. In this limit pricing equilibrium the dead weight loss is defined as the difference between the surplus appropriated by the patent holder and the surplus when the invention is freely available (i.e. the price of the input produced with the new technology is w_n rather than $e^q w_n$). By isolating that part of dead weight loss attributable to patent protection, the present value of the mean dead weight loss for inventions that are profitable to patent is given by:

$$\frac{Y_n\left(\bar{q}_{ni}+\frac{1}{\theta_{ni}}-1+\frac{\theta_{ni}}{1+\theta_{ni}}e^{-\bar{q}_{ni}}\right)}{J(r+\iota_{ni}^{pat}+o_n-g)}\equiv dwl_{ni}^{prof}$$

Similarly the present value of the mean dead weight loss on patents taken out by mistake is given by:

$$\frac{Y_n\left(\frac{\bar{q}_{ni}}{1-e^{-\theta_{ni}\bar{q}_{ni}}}+\frac{1}{\theta_{ni}}-1+\frac{\theta_{ni}}{1+\theta_{ni}}\left(\frac{1-e^{-(1+\theta_{ni})\bar{q}_{ni}}}{1-e^{-\theta_{ni}\bar{q}_{ni}}}\right)\right)}{J(r+\iota_{ni}^{pat}+o_n-g)}\equiv dwl_{ni}^{mistake}$$

Together these imply a total present value of dead weight loss from patents taken out in country *n* by

implemented, which includes the benefits of projected growth between 1992 and then.

inventors from country *i* of:

$$\varepsilon_{ni}\alpha_i s_{ni}[f_{ni}dwl_{ni}^{prof} + \eta(1-f_{ni})dwl_{ni}^{mistake}]$$

The "increase" in dead weight loss attributable to enhanced patent protection as a result of the TRIPs agreement is reported in the first column of Table 8. This column is constructed by subtracting the dead weight loss attributable to patents under the pre-TRIPs regime from the dead weight loss attributable to patents under TRIPs.[36] Combining the dead weight loss and transfers gives a more detailed welfare characterization of the TRIPs agreement (see second column, Table 8). The incorporation of dead weight loss exacerbates the losses experienced by those countries which make net transfers, while undermining the size of the benefits for those that gain. Indeed, both Sweden and Switzerland experience a dead weight loss greater than the net transfers from patent harmonization. In aggregate, the dead weight loss totals over $17.5 billion, which represents roughly one fifth of the efficiency gains that have been calculated to flow from the trade liberalization program of the Uruguay Round.

One factor that might mitigate such negative conclusions is that higher standards of patent protection may induce greater innovation. As mentioned above, the calculations reported do not account for any response of innovation to the TRIPs agreement. While there is reason to suspect that higher standards of patent protection and innovation may not necessarily be positively related (see Helpman (1993)), there is a general expectation that innovation will increase. Since the production of inventions is not directly modeled, the results of this paper can not be used to clarify this issue. Nevertheless, some insight may be gained from examining the returns to innovation under the TRIPs institutions. Table 9 provides information on the returns to R&D from patent harmonization. The first column reports the increase in the value of patent holding by the residents of each country, while the third and fourth columns put the increase in rent appropriating ability into perspective. The third column shows that each country expects a substantial increase in the value of patent holdings, with a mean increase in the value of rights of 60%. The fourth column translates these enhanced values into ratios of R&D expenditures. The most pronounced increases in these ratios are for Australia and Switzerland, rising from 22% to 39% and from 24% to 36% respectively. For all other countries these ratios remain below

[36] Note that the increase in the present value of the dead wieght loss comes from the inceased tenure of the patent holder as

one quarter after TRIPs is implemented. However, whether or not the change in R&D incentive is sufficient to generate a substantial increase in innovation is unclear. No firm conclusions can be drawn without modeling the process of innovation itself, which is beyond the scope of this paper.

Finally, the last column of Table 9 looks at the share of rents from abroad under TRIPs institutions. The most interesting aspect of this column is that the major technology producers (US, France, Germany, Japan and Italy) will become more dependent on returns from abroad. If, as Diwan and Rodrik (1991) have argued, countries have different preferences over the types of R&D projects initiated, then some of the countries may experience some offsetting efficiency gains through the creation of innovations more closely related to their needs. For instance, an increase in the value of pharmaceutical patents in developing countries may generate increased R&D on drugs dealing with tropical diseases. However, further consideration of these issues is outside of the scope of this paper.

9. Conclusion

This paper extends the analysis of the Uruguay Round by quantifying the impact of international patent harmonization as implied by the TRIPs agreement. What emerges from this analysis is a picture of patent protection as an important method for appropriating the rents of an invention. Although it is not the primary method of rent appropriation, patent harmonization has the capacity to generate large transfers of income between countries, with the US being the major beneficiary. The developing countries are not alone in financing transfers, with Canada, UK and Japan also making sizable contributions. These transfers significantly alter the perceived distribution of benefits from the Uruguay Round, with the US benefits substantially enhanced, while those of developing countries and Canada considerably diminished. Furthermore, accounting for the increase in dead weight loss from higher standards of patent protection undermines the aggregate benefits of the Uruguay Round package, with the increase in dead weight loss amounting to as much as one fifth of the efficiency gains from trade liberalization. However, dynamic efficiency gains from increased innovation may go some way to offsetting the increase in dead weight loss, which is an issue for future research.

A number of restrictive assumptions were made when deriving the estimates of this paper. In

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technology leader since higher standards of patent protection reduce the hazard of imitation.

particular, the model precluded from consideration both the role of trade in patented inputs and the role of multinationals. By precluding trade in inputs, possible efficiency enhancing aspects of the TRIPs agreement may have been overlooked. If an inventor finds that the requirement to produce locally is accompanied by an increase in costs, which may be the case if there are increasing returns to scale in production, then there will be additional efficiency gains under TRIPs from the removal of "working requirements". This may go some way to offsetting the large dead weight loss estimated to be associated with the TRIPs agreement. On the other hand, the inclusion of multinationals may have a more ambiguous effect on the predicted outcome. The modeling of multinationals would allow the link between foreign direct investment and technology transfer to be studied more directly. In particular, the concern that developing countries have expressed over the removal of the working requirement can be evaluated. Their concern is that without a local production requirement, multinationals will only set up plants to assemble imported components, thereby reducing both the amount of technology transferred and the spill-over benefits associated with that technology. Such an effect will further undermine the productivity differential and has implications for both the distribution of income and global efficiency.

Finally, this paper only manages a partial welfare appraisal of the TRIPs agreement since innovation is assumed to be exogenous. By endogenizing innovation, the optimal rate of innovation can be derived, and an assessment made about the potential for the TRIPs agreement to move the world closer to this optimum.

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Appendix[37]

To solve the model begin by defining:

$$\mu_n = A_n{}^{\omega}$$

This implies

$$\frac{d\mu_n}{dt} = \frac{dA_n^{\omega}(t)}{dt} = \omega A_n^{\omega-1}\frac{dA_n}{dt} = \omega A_n^{\omega-1}\dot{A}_n = \dot{\mu}_n$$

Recalling that

$$g_n = \frac{\dot{A}}{A} = \frac{1}{J\theta}\sum_{i=1}^{N}\varepsilon_{ni}\alpha_i\left(\frac{A_i}{A_n}\right)^{\omega}$$

then

$$\dot{A}_n = \frac{1}{J\theta}\sum_{i=1}^{N}\varepsilon_{ni}\alpha_i A_i^{\omega} A_i^{1-\omega}$$

$$\omega A_i^{\omega-1}\dot{A}_n = \frac{\omega}{J\theta}\sum_{i=1}^{N}\varepsilon_{ni}\alpha_i A_i^{\omega}$$

$$\dot{\mu}_n = \frac{\omega}{J\theta}\sum_{i=1}^{N}\varepsilon_{ni}\alpha_i\mu_n$$

This defines a system of linear differential equations

$$\begin{bmatrix}\dot{\mu}_1\\ \\ \\ \dot{\mu}_n\end{bmatrix} = \frac{\omega}{J\theta}\begin{bmatrix}\varepsilon_{11}\alpha_1 & \ldots\ldots & \varepsilon_{1n}\alpha_n\\ & & \\ & & \\ \varepsilon_{n1}\alpha_n & \ldots\ldots & \varepsilon_{nn}\alpha_n\end{bmatrix}\begin{bmatrix}\mu_1\\ \\ \\ \mu_n\end{bmatrix}$$

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[37] I would like to thank Sam Kortum for supplying the Gauss code from Eaton and Kortum. Aside from the modifications cited already, the numerical routine was changed from the amoeba algorithm to the routines contained within optmum.

or $$\dot{\mu} = \frac{\omega}{J\theta}\Delta\mu$$

Under a wide range of parameter values this system has a single, strictly positive eigenvalue, λ^F, with a corresponding eigenvector, μ^F, which satisfies $\frac{\omega}{J\theta}\lambda^F\mu^F = \frac{\omega}{J\theta}\Delta\mu^F$. This allows the range of inputs, J, to be calibrated, conditonal on all the estimated parameters, to achieve the desired growth rate, g (i.e. $J = \lambda^F/g\theta$). From the eigenvector the relative technological indices are given by:

$$\frac{A_i}{A_N} = \left(\frac{\mu_i}{\mu_N}\right)^{\frac{1}{\omega}}$$

Using this index and the parameter values the predicted bi-lateral patenting behavior is:

where $\hat{P}_{ni} = \alpha_i \varepsilon_{ni} s_{ni}[f_{ni} + (1 - f_{ni})\eta] \qquad \mathrm{i, n} = 1,..........,29$

$$\varepsilon_{ni} = \exp[\varepsilon_{dom} DH_{ni} + \varepsilon_{km} KM_{ni} + \varepsilon_{km2} KM^2 - \varepsilon_{hk}(1/HK)] IM_{ni}^{\varepsilon imp}$$

$$s_{ni} = (1 - s^{ph} D_n^{ph}(1 - D_i^{ph}))(1 - s^{fd} D_n^{fd}(1 - D_i^{fd}))(1 - s^{ch} D_n^{ch}(1 - D_i^{ch}))(1 - s^{wr} D_n^{wr})$$

$$f_{ni} = \left(1 - \frac{J(r + \iota_{ni}^{pat} + o_n - g)(r + \iota_{ni}^{not} + o_n - g)C_{ni}}{(\iota_{ni}^{not} - \iota_{ni}^{pat})Y_n}\right)^{\theta_{ni}}$$

$$\iota_{ni}^{pat} = \begin{cases} \iota_{dom}^{not} e^{-\gamma PG_n} & \text{for i = n} \\ \iota_{for}^{not} e^{-\gamma PG_n} & \text{for i} \neq \text{n} \end{cases}$$

$$o_n = \frac{1}{J}\sum_{i=1}^{N} \varepsilon_{ni}\alpha_i$$

$$\theta_{ni} = \theta\left(\frac{A_i}{A_n}\right)^{-\omega}$$

The relative technology index also generates a predicted value for relative labor productivity.

$$\frac{\hat{y}_n}{y_N} = \frac{\Gamma_n A_n}{\Gamma_N A_N} \qquad n = 1,\ldots\ldots, 28$$

where

$$\Gamma_n = \frac{\exp\left(-\sum_{i=1}^{N} \phi_{ni} / \theta_{ni}\right)}{\sum_{i=1}^{N} \phi_{ni}\theta_{ni} / (1+\theta_{ni})}$$

$$\phi_{ni} \equiv \varepsilon_{ni}\alpha_i \left[\sum_{j=1}^{N} \varepsilon_{nj}\alpha_j\right]^{-1}$$

With ε_{ni} and θ_{ni} defined above.

The errors are then given by

$$u_i = \log(P_{ni}) - \log(\hat{P}_{ni}) \qquad \text{n, i} = 1,\ldots\ldots\ldots\ldots,29$$

$$v_i = \log(\frac{y_n}{y_{us}}) - \log(\frac{\hat{y}_n}{y_{us}}) \qquad n = 1,\ldots\ldots\ldots\ldots 28$$

The objective function is to minimize

$$u'u + \sigma_u^2/\sigma_v^2 \, (v'\Omega_v^{-1}v)$$

where Ω_v^{-1} is defined in section 6 of the text. The solution is gained by iterating this system until the specified criterion is met.

Table 1

	Domestic Patents	Foreign Patents	Patents Abroad	Pharmaceuticals Excluded	Food Excluded	Chemicals Excluded	Imports Excluded	*PG* Index
US	75,633	69,097	177,529	0	0	0	0	4.00
Japan (JP)	63,053	35,219	96,952	0	0	0	0	3.75
Germany (GE)	31,981	51,140	117,131	0	0	0	0	4.00
UK	20,903	58,448	47,353	0	0	0	0	2.00
France (FR)	12,438	52,343	47,822	0	0	0	0	5.00
Australia (AL)	6,573	15,399	10,567	0	0	0	0	2.80
Korea (KR)	5,699	11,618	897	1	1	1	0	4.75
South Africa (ZA)	4,829	4,870	1,323	0	0	0	1	3.00
Israel (IL)	4,829	2,835	2,223	0	0	0	1	3.00
Sweden (SW)	3,413	34,076	16,872	0	0	0	0	4.00
Switzerland (SWI)	3,251	33,151	25,483	0	0	0	1	3.90
Canada (CA)	2,773	28,295	8,780	0	0	0	1	3.00
Brazil (BR)	2,343	9,803	508	1	1	1	1	0.75
Italy (IT)	2,290	41,900	22,454	0	0	0	0	5.00
Austria (AU)	2,228	29,626	6,578	0	0	0	1	4.00
Netherlands (NL)	2,162	37,667	18,879	0	0	0	1	5.00
Finland (FI)	2,039	7,191	6,160	1	1	0	1	4.00
Spain (SP)	1,817	23,963	2,526	1	0	1	0	4.00
Denmark (DK)	1,332	9,693	5,923	0	1	0	1	4.00
India (IN)	1,034	2,737	134	1	1	1	1	2.00
Norway (NOR)	929	8,400	2,600	1	1	0	1	4.00
New Zealand (NZ)	804	3,607	711	0	0	0	1	2.80
Mexico (MX)	733	4,459	177	1	1	1	1	1.82
Ireland (IR)	728	3,157	921	0	0	0	1	0.80
Belgium (BE)	637	32,377	5,663	0	0	0	1	4.00
Greece (GR)	375	13,118	223	1	0	0	1	2.75
Columbia (CO)	85	195	178	1	1	0	1	2.50
Portugal (PT)	55	2,407	156	1	1	1	1	2.88
Panama (PA)	10	60	128	0	0	0	1	1.88

Table 2

		FGNLS		MLE	
		Estimate	Std Error	Estimate	Std Error
Enforcement	γ	0.03	0.004	0.03	0.011
Scope Variables	s^{ph}	0.19	0.124	0.22	0.236
	s^{fd}	0.51	0.071	0.56	0.130
	s^{ch}	0.03	0.148	0.00	0.239
	s^{im}	0.48	0.049	0.49	0.089
Step Size	θ	3.73	0.782	4.19	1.693
Catch Up	ω	34.93	75.12	88.32	171.379
Mistakes	η	0.02	0.004		
Diffusion Variables	ε_{imp}	0.15	0.043	0.16	0.080
	ε_{hk}	3.67	0.687	4.02	2.064
	ε_{dom}	1.21	0.245	1.28	0.480
	ε_{km}	-0.23	0.029	-0.20	0.059
	ε_{km2}	0.001	0.0002	0.001	0.0004
Inventiveness Dummies	α_{al}	9.76	0.291	9.56	0.605
	α_{as}	8.21	0.306	8.26	0.719
	α_{be}	7.99	0.263	7.95	0.540
	α_{ca}	8.12	0.279	8.03	0.501
	α_{dn}	8.01	0.302	7.92	0.625
	α_{fi}	8.12	0.306	8.01	0.618
	α_{fr}	10.00	0.244	10.03	0.631
	α_{ge}	10.40	0.218	10.43	0.518
	α_{gr}	5.10	0.367	5.03	0.702
	α_{ir}	6.38	0.330	6.23	0.701
	α_{it}	9.39	0.257	9.39	0.593
	α_{jp}	10.26	0.223	10.21	0.488
	α_{ne}	9.10	0.256	9.09	0.598
	α_{nz}	7.19	0.303	7.09	0.618
	α_{nr}	7.04	0.370	6.83	0.838
	α_{pr}	4.53	0.366	4.46	0.813
	α_{sp}	7.41	0.300	7.28	0.628
	α_{sw}	9.03	0.272	9.02	0.525
	α_{swi}	9.56	0.265	9.54	0.622
	α_{uk}	9.87	0.234	9.85	0.553
	α_{us}	11.03	0.193	11.13	0.458
	α_{br}	6.37	0.340	6.20	0.698
	α_{in}	4.84	0.403	4.67	0.731
	α_{mx}	4.84	0.364	4.69	0.648
	α_{pa}	4.66	0.535	4.49	0.852
	α_{co}	5.36	0.389	5.19	0.725
	α_{kr}	5.53	0.320	5.32	0.529
	α_{za}	8.08	0.336	7.81	0.739
	α_{il}	7.72	0.326	7.58	0.691

Table 3
$US Millions 1988

	Present Value of Patent Rents (Pre-TRIPs)	standard error
US	15329	(2287)
GE	3092	(545)
JP	2554	(333)
FR	1558	(268)
UK	1223	(245)
SWI	690	(140)
IT	666	(118)
NL	465	(89)
SW	313	(63)
AL	297	(81)
CA	180	(37)
BE	142	(28)
AU	117	(23)
DK	104	(21)
FI	93	(19)
SP	58	(11)
IL	41	(9)
NOR	40	(8)
ZA	24	(1)
IR	17	(4)
NZ	10	(4)
BR	9	(1)
KR	7	(1)
GR	3	(1)
MX	2	(1)
CO	2	(1)
PT	1	(1)
IN	1	(0.3)
PA	1	(0.2)

*Standard errors in parenthesis, derived using the delta method

Table 4

	PV of Patent Rents / R&D Expenditure	Share of Patent Rents from Abroad
SWI	0.24	0.91
AL	0.22	0.71
US	0.15	0.36
NL	0.15	0.84
GE	0.13	0.61
FR	0.12	0.53
AU	0.12	0.89
DK	0.12	0.98
IR	0.12	1.00
UK	0.11	0.81
IT	0.11	0.48
SW	0.10	0.90
BE	0.08	0.91
FI	0.08	0.95
GR	0.06	0.99
JP	0.05	0.18
CA	0.05	0.77
IL	0.05	0.96
NOR	0.05	0.97
IN	0.005	0.64
SP	0.04	0.74
KR	0.003	0.76
PT	0.03	0.99
MX	0.0001	0.92
ZA	NA	0.81
NZ	NA	0.97
BR	NA	0.85
CO	NA	1.00
PA	NA	1.00

Footnote: The R&D variable is expenditure by business enterprises. The numbers for AL, BE, CA, FI, FR, GE, GR, IR, IT, JP, NL, PT, SP and US are for 1988, taken from Table 21 OECD (1994). The remaining numbers are taken from Table 4 of UNESCO (1993).

Table 5
$US Million 1988

TRIPs Net Transfer		std error
US	4553	(874)
GE	788	(280)
FR	568	(117)
IT	231	(47)
SW	71	(39)
SWI	22	(79)
PA	0.3	(0)
AL	-22	(13)
IR	-48	(7)
NZ	-54	(4)
IL	-66	(10)
CO	-77	(9)
PT	-87	(7)
NL	-96	(67)
ZA	-113	(12)
GR	-118	(13)
DK	-174	(28)
AU	-176	(32)
FI	-198	(27)
NOR	-206	(24)
BE	-224	(40)
KR	-326	(31)
SP	-345	(98)
JP	-439	(204)
MX	-444	(60)
IN	-526	(51)
UK	-541	(191)
BR	-926	(95)
CA	-1023	(166)

*Standard errors in parenthesis, derived using the delta method

Table 6
$US Million 1988

	TRIPs Gross Transfer		Percentage of Gross Transfer from Broader Scope
		std error	
CA	1107	(374)	0.41
UK	1044	(349)	0.00
BR	930	(205.	0.11
JP	896	(659)	0.00
IN	526	(102)	0.34
MX	445	(125)	0.29
GE	384	(379)	0.00
SP	367	(148)	0.45
KR	328	(55)	0.92
NL	313	(119)	1.00
BE	293	(84)	0.64
SWI	288	(100)	0.60
FI	238	(52)	0.73
AU	229	(65)	0.64
DK	227	(53)	0.68
NOR	226	(47)	0.71
AL	166	(26)	0.00
ZA	123	(13)	0.40
GR	119	(25)	0.35
SW	104	(59)	0.00
IL	89	(21)	0.32
PT	87	(16)	0.34
CO	78	(19)	0.37
US	73	(163)	0.00
NZ	60	(8)	0.27
IR	58	(14)	0.00
FR	0	(0)	0.00
IT	0	(0)	0.00
PA	0	(0)	0.00

Table 7
$US Millions 1988

	Gains From Trade Liberalization		Gains from Trade Liberalization Net of TRIPs Transfer	
	Short Run	**Long Run**	**Short Run**	**Long Run**
	(1)	(2)	(3)	(4)
Australia	1,017	2,745	994	2,722
EU	33,117	42,020	32,768	41,671
Canada	1,088	2,199	65	1,176
Japan	14,220	19,127	13,780	18,688
New Zealand	336	1,204	281	1,149
US	11,185	22,458	15,738	27,011
Brazil	1,215	3,593	288	2,666
South Asia*	3,130	5,677	2,604	5,151
Mexico	129	1,931	-316	1,486
Korea	4,036	6,270	3,710	5,944
LDC	16,298	46,437		
DEV	64,459	97,167		
World	80,757	143,603		

Footnotes: Columns (1) and (2) adapted from Harrison et. al. (1995)
*South Asia includes a number of countries other than India. However, the efficiency gain net of TRIPS transfers only includes the transfer made by India

Table 8
$US Millions

	TRIPs DWL		TRIPs Welfare Outcome	
		std error		std error
US	682	(127)	3870	(869)
FR	0	(0)	568	(117)
GE	504	(130)	284	(360)
IT	0	(0)	231	(47)
PA	0	(0)	0.3	(0.1)
SW	142	(28)	-71	(54)
IR	126	(25)	-174	(32)
NZ	154	(19)	-209	(29)
IL	176	(32)	-242	(41)
PT	217	(37)	-304	(44)
CO	258	(36)	-335	(46)
GR	218	(40)	-336	(52)
SWI	363	(90)	-340	(149)
AL	410	(78)	-433	(89)
NL	377	(98)	-473	(153)
DK	331	(68)	-505	(92)
AU	334	(72)	-510	(99)
NOR	349	(67)	-555	(88)
ZA	453	(74)	-567	(90)
FI	377	(73)	-575	(96)
BE	351	(81)	-576	(115)
SP	626	(188)	-971	(282)
KR	753	(124)	-1079	(165)
MX	1023	(140)	-1467	(195)
UK	1434	(315)	-1975	(475)
CA	1305	(234)	-2328	(382)
JP	2256	(531)	-2695	(724)
IN	2405	(341)	-2931	(395)
BR	2021	(274)	-2948	(388)
Total	17656	(2981)		

*Standard errors in parenthesis, derived using the delta method

Table 9

	Change in Value of Patent Rents due to TRIPs	std error	% Change in Value	PV of Patent Rents (TRIPs) / R&D Expenditure	Share of Patent Rents from Abroad under TRIPs
US	7168	(1196)	0.47	0.23	0.45
GE	1488	(293)	0.48	0.19	0.67
JP	1342	(198)	0.53	0.07	0.24
UK	872	(169)	0.71	0.18	0.71
FR	568	(117)	0.37	0.16	0.65
SWI	339	(68)	0.49	0.36	0.91
IT	231	(47)	0.35	0.15	0.62
AL	221	(52)	0.74	0.39	0.68
NL	217	(44)	0.47	0.22	0.89
SW	191	(39)	0.61	0.16	0.91
CA	113	(22)	0.63	0.08	0.76
BE	73	(14)	0.51	0.12	0.92
AU	56	(11)	0.48	0.18	0.9
DK	56	(11)	0.54	0.18	0.97
FI	43	(9)	0.47	0.12	0.94
SP	27	(5)	0.46	0.06	0.77
IL	25	(5)	0.62	0.08	0.94
NOR	20	(4)	0.52	0.08	0.96
BR	14	(3)	1.54	NA	0.48
ZA	14	(1)	0.58	NA	0.76
CO	13	(0.3)	0.66	NA	0.98
IR	9	(2.	0.57	0.18	0.99
NZ	7	(2)	0.66	NA	0.93
KR	3	(0.7)	0.4	0.004	0.82
GR	2	(0.3)	0.47	0.09	0.96
MX	2	(0.4)	0.74	0.0002	0.8
PT	1	(0.2)	0.47	0.05	0.98
IN	1	(0.3)	0.87	0.00	0.5
PA	0	(0.1)	0.72	NA	1

Table10

NET Transfers implied by Patent Harmonization
$US Millions, 1988

Country of Residence of Patent Holder

	AL	AU	BE	CA	DK	FI	FR	GE	GR	IR	IT	JP	NL	NZ	NOR	PT	SP	SW	SWI	UK	US	BR	IN	MX	PA	CO	KR	ZA	IL
AL	0	-1.85	-1.77	-3.45	-1.12	-2.16	9.08	12.51	-1.53	-0.58	11.44	-10.9	0.01	-5.29	-1.91	-1	-4.25	1.08	0.83	-4.9	80.62	-15.4	-16.4	-3.28	0	-0.6	-11.9	-3.47	-0.87
AU	1.85	0	0.1	0.43	0.71	-0.1	20.28	56.8	-1.34	0.24	10.64	1.96	5.71	-0.11	-0.84	-0.61	-2.09	5.76	13.27	11.7	62.88	-3.54	-4.77	-0.75	0	-0.17	-1.36	-0.59	0.22
BE	1.77	-0.1	0	0.27	0.42	-0.36	32.5	56.98	-1.29	0.24	10.27	2.38	9.27	-0.25	-1.39	-0.85	-2.99	6.07	12.64	16.3	96.08	-4.34	-5.45	-1.04	0	-0.22	-1.4	-0.64	-0.05
CA	3.45	-0.43	-0.27	0	-0.47	-0.83	14.72	28.55	-0.87	-0.45	5.33	41.85	3.67	-0.46	-1.41	-0.81	-2.6	3.72	5.32	8.3	943.8	-11	-5.09	-5.45	0	-0.89	-3.4	-0.93	-0.08
DK	1.12	-0.71	-0.42	0.47	0	-0.84	16.71	47.58	-1.05	0.18	5.85	1.85	4.76	-0.19	-1.57	-0.66	-2.17	6.84	8.17	11.21	85.93	-3.46	-3.96	0.02	0	-0.23	-0.59	-0.79	-0.06
FI	2.16	0.1	0.36	0.83	0.84	0	18.52	47.04	-0.88	0.29	6.72	3.12	6.13	-0.09	-0.75	-0.49	-0.71	9.98	9.09	14.58	85.25	-3.05	0.01	0.02	0	-0.19	-0.17	-0.79	0.14
FR	-9.08	-20.3	-32.5	-14.7	-16.7	-18.5	0	-40.7	-11.1	-1.52	0	-40.9	-30.9	-3.01	-19	-8.34	-39.4	-8.56	-28.3	-109	-6.23	-37.6	-37.6	-5.41	0	-2.08	-13.7	-8.29	-5.77
GE	-12.5	-56.8	-57	-28.6	-47.6	-47	40.72	0	-27.2	-5.09	16.36	-85.5	-54.4	-6.19	-48.5	-15.3	-61.4	-8.61	-36.4	-165	167	-82.3	-81.6	-17.7	0	-5.62	-30.7	-18.3	-13.9
GR	1.53	1.34	1.29	0.87	1.05	0.88	11.14	27.17	0	0.16	6.6	4.06	3.99	0.07	0.43	0	0.4	3.13	6.12	10.35	36.63	-0.13	0	0	0	-0.01	-0.02	0.18	0.77
IR	0.58	-0.24	-0.24	0.45	-0.18	-0.29	1.52	5.09	-0.16	0	0.28	-0.4	0.2	-0.03	-0.27	-0.14	-0.55	0.27	0.57	6.75	36.55	-0.65	0	0	0	-0.05	-0.24	-0.12	0.04
IT	-11.4	-10.6	-10.3	-5.33	-5.85	-6.72	0	-16.4	-6.6	-0.28	0	-16.2	-10.9	-2.64	-5.55	-2.56	-14.8	-3.35	-12.1	-34.9	-2.2	-16.9	-19.6	-2.98	0	-0.78	-5.63	-3.94	-2.97
JP	10.92	-1.96	-2.38	-41.9	-1.85	-3.12	40.92	85.5	-4.06	0.4	16.21	0	8.52	-3.02	-4.56	-7.15	-32	12.33	16.03	14.57	543.7	-52.4	-64.4	-11.4	0	-2.21	-68.9	-7.68	-0.81
NL	-0.01	-5.71	-9.27	-3.67	-4.76	-6.13	30.9	54.37	-3.99	-0.2	10.89	-8.52	0	-0.94	-7.48	-2.86	-11.1	4.44	7.26	-8.9	104.9	-15.2	-14.4	-3.07	0	-0.91	-5.39	-2.76	-1.55
NZ	5.29	0.11	0.25	0.46	0.19	0.09	3.01	6.19	-0.07	0.03	2.64	3.02	0.94	0	-0.01	-0.05	-0.12	0.73	1.47	3.57	27.59	-0.66	0	-0.16	0	0	-0.32	-0.03	0.18
NOR	1.91	0.84	1.39	1.41	1.57	0.75	19.01	48.45	-0.43	0.27	5.55	4.56	7.48	0.01	0	-0.22	-0.08	8.37	9.14	20.22	79.09	-1.22	-1.36	-0.27	0.02	-0.07	-0.05	-0.19	0.36
PT	1	0.61	0.85	0.81	0.66	0.49	8.34	15.32	0	0.14	2.56	7.15	2.86	0.05	0.22	0	0.44	2.08	4.25	8.46	30.6	-0.03	0	-0.01	0	0	0.01	0.07	0.22
SP	4.25	2.09	2.99	2.6	2.17	0.71	39.44	61.38	-0.4	0.55	14.78	32.01	11.09	0.12	0.08	-0.44	0	7.38	18.14	31.18	118.7	-2.11	-1.79	-0.54	0.04	-0.08	-0.52	0.23	0.97
SW	-1.08	-5.76	-6.07	-3.72	-6.84	-9.98	8.56	8.61	-3.13	-0.27	3.35	-12.3	-4.44	-0.73	-8.37	-2.08	-7.38	0	-1.77	-18.8	37.02	-11.2	-12.9	-2.07	0	-0.74	-5.19	-2.43	-1.63
SWI	-0.83	-13.3	-12.6	-5.32	-8.17	-9.09	28.34	36.36	-6.12	-0.57	12.07	-16	-7.26	-1.47	-9.14	-4.25	-18.1	1.77	0	-28.1	104	-20.2	-22.6	-4.14	0.02	-1.27	-7.6	-4.88	-4.18
UK	4.9	-11.7	-16.3	-8.3	-11.2	-14.6	108.6	164.8	-10.4	-6.75	34.87	-14.6	8.9	-3.57	-20.2	-8.46	-31.2	18.77	28.08	0	444.9	-37.5	-41.1	-8.33	0	-2.06	-14.6	-7.78	-4
US	-80.6	-62.9	-96.1	-944	-85.9	-85.3	6.23	-167	-36.6	-36.6	2.2	-544	-105	-27.6	-79.1	-30.6	-119	-37	-104	-445	0	-604	-189	-378	0.03	-59.3	-155	-51.7	-39.1
BR	15.44	3.54	4.34	10.97	3.46	3.05	37.58	82.3	0.13	0.65	16.89	52.41	15.19	0.66	1.22	0.03	2.11	11.15	20.19	37.46	604.2	0	0.05	0.01	0	0.31	0.25	1.67	1.67
IN	16.4	4.77	5.45	5.09	3.96	-0.01	37.55	81.55	0	0	19.58	64.36	14.36	0	1.36	0	1.79	12.88	22.64	41.09	189.2	-0.05	0	-0.01	0	0	0.35	0	3.74
MX	3.28	0.75	1.04	5.45	-0.02	-0.02	5.41	17.72	0	0	2.98	11.43	3.07	0.16	0.27	0.01	0.54	2.07	4.14	8.33	378	-0.01	0.01	0	0.09	0.09	0.05	0	-0.01
PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.02	0	-0.04	0	-0.02	0	-0.03	0	0	-0.09	0	-0.03	-0.05	0	-0.01
CO	0.6	0.17	0.22	0.89	0.23	0.19	2.08	5.62	0.01	0.05	0.78	2.21	0.91	0	0.07	0	0.08	0.74	1.27	2.06	59.34	-0.31	0	-0.09	0.03	0	0	0	0.1
KR	11.89	1.36	1.4	3.4	0.59	0.17	13.68	30.69	0.02	0.24	5.63	68.88	5.39	0.32	0.05	-0.01	0.52	5.19	7.6	14.58	155.1	-0.25	-0.35	-0.05	0.05	0	0	0	-0.02
ZA	3.47	0.59	0.64	0.93	0.79	0.79	8.29	18.28	-0.18	0.12	3.94	7.68	2.76	0.03	0.19	-0.07	-0.23	2.43	4.88	7.78	51.68	-1.67	0	0	0	0	0	0	0.43
IL	0.87	-0.22	0.05	0.08	0.06	-0.14	5.77	13.92	-0.77	-0.04	2.97	0.81	1.55	-0.18	-0.36	-0.22	-0.97	1.63	4.18	4	39.1	-1.67	-3.74	0.01	0.01	-0.1	0.02	-0.43	0