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On assessing the cost of TRIPS implementation

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Abstract: Efforts to ensure that intellectual property rights are respected and protected world-wide have met increasing resistance by critics who see extreme imbalances in the costs and benefits of implementing stronger intellectual property protection. The WTO's Agreement on Trade-Related Aspects of Intellectual Property (TRIPS) attracts particular criticism as an enforceable multilateral embodiment of these efforts. While few disagree that developed countries stand to benefit more in the short term from TRIPS implementation than developing countries, precisely estimating associated costs and benefits is challenging. This paper comments on an approach to estimating the 'indirect' costs of implementing TRIPS proposed by McCalman (2001) and argues that the approach overestimates the costs born by developing countries. Specifically, this overestimation is due primarily to an inadequate representation of the TRIPS Agreement and a counterfactual assumption that countries would not have strengthened their intellectual property policies in the absence of the TRIPS Agreement.

During the 1990s, intellectual property (IP) law, historically a narrow domain of legal specialists, was propelled into popular debates on economic development, trade and globalization, ultimately, shaping discussions on traditional knowledge, folklore and access to essential medicines. While rapid advances in technology attracted media attention to IP issues, the incorporation in 1995 of the Trade-Related Intellectual Property Rights (TRIPS) Agreement into World Trade Organization (WTO) sparked heated debate on the topic. Questions about whether developing countries could benefit from TRIPS given their weak innovation capacity relative to developed countries were a primary focus of this debate and motivated efforts to quantify respective costs and benefits.

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There are two main costs a country faces when implementing TRIPS. First, there are the *direct* costs of ensuring that the country's legal, administrative and enforcement infrastructure can accommodate TRIPS implementation.[1] Second, there are *indirect* costs associated with more technologies being patented in response to TRIPS implementation and proprietors charging higher prices for access to their newly patented technologies (e.g., via licensing agreements involving license maintenance and royalty payments).[2] In developing countries, the majority of patent holders are foreign inventors. These technology-related payments therefore mostly flow out of developing countries and into foreign pockets. McCalman (2001) proposes an approach to estimating econometrically these indirect costs. McCalman (2001) concludes that 'patent harmonization has the capacity to generate large transfers of income between countries' (p. 163) with the US being the major beneficiary. Using the McCalman approach, others have focused on the indirect costs born specifically by developing countries (Maskus, 2000 and World Bank, 2001a) and have concluded that poor countries will have to pay abroad an additional $20 billion as a result of TRIPS implementation (World Bank, 2001b).

This commentary assesses the validity of the McCalman approach to quantifying the costs of TRIPS implementation. I argue that because of an inadequate treatment of the TRIPS Agreement and of the nuances of its implementation in developing countries the McCalman approach overestimates the costs of implementing TRIPS for developing countries. While developed countries surely still benefit relative to developing countries, the McCalman approach exaggerates the magnitude of the costs incurred by developing countries when implementing TRIPS. The McCalman approach should thus be applauded for its technical merits as an alternative to computable general equilibrium (CGE) models of trade liberalization, rather than as an assessment of the cost of implementing the TRIPS Agreement.

Since a transparent market for patents does not exist, patent values, and hence technology-related payments, cannot be observed directly. McCalman attempts to impute patent values using an econometric approach based largely on Eaton and Kortum (1996). In the McCalman approach, 'the private value of patent protection is calculated by multiplying the mean present value of patent rights by the number of patent applications' (p. 175). Accordingly, McCalman derives an expression for 'the aggregate present value of rents appropriated from patents in country *n* held by inventors in country *i*' (R_{ni}), which in slightly simplified form[3] is

1 For example, since compliance with TRIPS will likely result in more patent applications being filed, developing countries will need to expand their patent processing and examination capacity. Previous studies have aimed at quantifying these direct costs (e.g., see Finger and Schuler, 2000 and UNCTAD, 1996).

2 Since the TRIPS Agreement also requires countries to offer adequate legal enforcement to patent holders wishing to take action against infringement, these indirect costs also include increased risks and costs of infringement.

3 McCalman, following Eaton and Kortum (1996), allows for patenting mistakes to occur. That is, some inventors apply for patent protection even though their inventions are not worth patenting (i.e., the present value of the invention is less than total application costs). Additional complexity in the expression

the following:

$$R_{ni} = P_{ni}(PV_{ni} - C_{ni}) \tag{1}$$

where P_{ni} is the number of patent applications filed in country n by inventors from country i, PV_{ni} is the mean present value of patent rights held in country n by country i inventors (see the Appendix in the electronic version of the paper for details), and C_{ni} is the total cost of applying for a patent in country n including 'official application fees, agent's fees, and translation fees' (p. 171).

With R_{ni} defined in (1), the bilateral Net Patent Rents associated with TRIPS compliance between countries m and k (NPR_{mk}) can be calculated as the change due to TRIPS in patent rents flowing *from* country m to country k inventors minus the change in patent rents flowing *out of* country k to country m inventors. For example, Brazil's bilateral NPR with France ($NPR_{Brazil,France}$) is computed as the change due to TRIPS in patent rents flowing *from* France to Brazilian inventors who hold patent rights in France minus the change in patent rents flowing *out of* Brazil to French inventors who hold patent rights in Brazil. Implementing TRIPS presumably increases the bilateral patent rents flowing in and out of Brazil. The key is whether a stronger IP system means more additional rents accrue to French than to Brazilian inventors, in which case $NPR_{Brazil,France} < 0$. The summation over all foreign countries of these bilateral net patent rents for country k (NPR_k) constitutes the overall cost (if $NPR_k < 0$) or benefit (if $NPR_k > 0$) of implementing the TRIPS Agreement in country k. Thus:

$$NPR_{Brazil} = NPR_{Brazil,France} + NPR_{Brazil,USA} + NPR_{Brazil,UK} + \cdots$$

More generally, NPR_k is defined as:

$$NPR_k = \sum_{m \neq k} NPR_{mk} = \sum_{m \neq k} (R_{mk}^{TRIPS} - R_{mk}^{NoTRIPS}) - (R_{km}^{TRIPS} - R_{km}^{NoTRIPS}) \tag{2}$$

where $m \neq k$ indicates that the summation is over all other countries.

In theory, there are two mechanisms whereby TRIPS compliance affects R_{ni}. First, strengthening patent protection increases the costs of imitation, thus reducing the likelihood of imitation and increasing the value of holding a patent relative to not holding one. McCalman represents this mechanism with the Park-Ginarte index of patent system strength, PG_n.[4] Second, TRIPS requires patent protection to be offered to inventions in key sectors that prior to TRIPS were not open for patenting in many developing countries (e.g., pharmaceuticals, food, chemicals). McCalman constructs a sectoral coverage variable s_{ni} to represent this mechanism. As a result of these mechanisms, implementing TRIPS results in more patent applications

for R_{ni} introduced by this realistic twist in the model, while interesting, is relatively inconsequential for the purposes of this commentary, which focuses on the final estimated cost of TRIPS implementation.

4 Note that this index was developed by Ginarte and Park (1997). To maintain consistency with McCalman (2001), this commentary also refers to the index as the Park-Ginarte (PG) index.

being filed and, by assumption, more patents being granted, each new patent with a higher value relative to pre-TRIPS implementation.

While C_{ni} in (1) can be observed,[5] the number of patent applications filed by country i inventors in country n, P_{ni}, is only observable pre-TRIPS implementation since McCalman proposes an *ex ante* approach and the effect of stronger patent protection on applications is not observable *ex ante*. Likewise, PV_{ni} is not directly observable and must be imputed. In McCalman's approach both of these key variables are predicted according to a complex nonlinear econometric model based on Eaton and Kortum (1996), the details of which are not the primary focus of this commentary.

Although McCalman's approach is econometrically sophisticated and mostly defensible, it fails to reflect key nuances and provisions of TRIPS. This incomplete representation limits the validity of estimates derived from the McCalman approach. There are three main problems with McCalman's treatment of the TRIPS Agreement and its implementation. First, he represents TRIPS compliance with an index that was not devised to indicate TRIPS implementation, which requires the selection of a TRIPS-compliant threshold. McCalman misrepresents the TRIPS Agreement as requiring countries to 'harmonize' their patent systems to 'maximum' levels of patent protection. While the IP standards set by TRIPS are indeed high, the Agreement does not require maximum IP strength as McCalman assumes, nor does it, as a minimum standards agreement, seek complete harmonization. Second, McCalman attributes all changes in net patent rents due to stronger patent protection to TRIPS implementation when in fact many countries chose to strengthen their patent systems *before* they were required to by TRIPS. A more accurate counterfactual would reflect the observation that some of the policy changes mandated by the TRIPS Agreement would have occurred even without these WTO commitments. Third, McCalman erroneously assumes that TRIPS is implemented simultaneously by all countries and thus ignores the effects of Articles 65 and 66 of the TRIPS Agreement that allow developing and least-developed countries, as well as some Central and Eastern European countries to delay TRIPS implementation relative to developed countries. These key oversights are discussed in detail below.

The Index Problem. The calculation of net patent rents based on equation (2) hinges critically on estimating the mean value of patent rights *before* and *after* TRIPS implementation. The PG index is probably as good an index as economists have for a uni-dimensional measure of a multi-dimensional policy environment, but McCalman's use of this index is particularly problematic. Ginarte and Park (1997) developed the PG index in an attempt to identify the national determinants of patent system strength, for which purposes the PG index seems to work well. They did not develop the index to identify compliance with the TRIPS Agreement, which

5 McCalman uses application cost data from Helfgott (1993).

extends beyond patents to encompass many other forms of intellectual property (e.g., copyrights, trademarks, geographical indications, etc.). Consequently, some elements of strong patent protection and enforcement in the PG index are not mentioned even in the patent section of the TRIPS Agreement (Articles 27–34). The PG index is simply not well suited to proxy for TRIPS compliance.

Because the PG index was not designed to indicate TRIPS compliance, a threshold index value must be chosen to represent TRIPS compliance. McCalman decides, without justification, that the maximum PG value of 5 represents TRIPS compliance.[6] A closer look at the composition of the PG index (Ginarte and Park, 1997) with an appreciation for the inherent flexibility of the TRIPS agreement (e.g., see Heald, 2002) illustrates that this choice is indefensible and overestimates the cost to developing countries of implementing TRIPS. Table 1 decomposes the PG index, then reconstructs an index to represent minimum TRIPS compliance. Although most of the inherent flexibilities of the TRIPS Agreement are not apparent in this table because the PG index speaks to less than 10 of the 73 Articles contained in the Agreement, a few of the patent-related flexibilities are evident. For example, TRIPS does not require that patent protection be extended to plants and animals or utility models, nor does it require countries to offer contributory infringement.[7]

Table 1 suggests that if a country began with no patent system at all and created one that complied minimally with the TRIPS Agreement, it would have a PG index of approximately 3.7.[8] Because the PG index is not designed to measure TRIPS implementation, my objective here is not to argue that PG = 3.7 represents a critical TRIPS-compliant threshold of patent protection, but rather to suggest that PG = 5 surely overestimates TRIPS compliance. Most countries, including many developing countries, however, had patent systems in place prior to implementing TRIPS. Some such countries had a patent system that was, prior to TRIPS, 'stronger' than mandated by TRIPS in some respect. For such countries, implementing TRIPS could push its PG index above the TRIPS minimum of 3.7, unless it redrafted its IP legislation to conform perfectly with minimum TRIPS compliance, an unlikely response. Thus, if the TRIPS Agreement were fully implemented world-wide, all countries would have a PG index of at least 3.7. But because the TRIPS Agreement does not *harmonize* international patent law as McCalman assumes, but rather

6 The World Bank (2001a) made significant improvements in this regard. Recognizing that TRIPS did not mandate maximum IP strength according to the PG index, they selected 4.5 as their TRIPS compliance threshold and selected, albeit arbitrarily, an even lower threshold for some developing countries.

7 Contributory Infringement is a term used in United States patent legislation. It is defined in 35 U.S.C. §271(c) as follows: 'Whoever offers to sell or sells within the United States or imports into the United States a component of a patented machine, manufacture, combination or composition, or a material or apparatus for use in practicing a patented process, constituting a material part of the invention, knowing the same to be especially made or especially adapted for use in a an infringement of such patent, and not a stable article or commodity of commerce suitable for substantial noninfringing use, shall be liable as a contributory infringer' (35 U.S.C. §271(c)).

8 Note that the PG index is calculated as the sum of the scores for each of the five categories. For example, the Min TRIPS score for category two (Membership in international treaties) is 1/3.

Table 1. PG index decomposition (see Ginarte and Park, 1997) and minimum TRIPS requirements

	Calculation of PG index: Yes	No	Min. TRIPS	Notes
1. Patentability coverage				
Pharmaceuticals	1	0	1	TRIPS Article 27.1 (see also TRIPS Article 65.4)
Chemicals	1	0	1	ibid.
Food	1	0	1	ibid.
Plant and animal varieties	1	0	0	TRIPS Article 27.3(b)
Surgical products	1	0	1	TRIPS Article 27.3(a) permits the exclusion from patentability of 'surgical methods' but not surgical products. (Watal, 2001, p. 102)
Microorganisms	1	0	1	TRIPS Article 27.3(b)
Utility models	1	0	0	Utility model protection is not an obligation under TRIPS.
2. Membership in international treaties				
Paris convention	1	0	1	TRIPS Article 2.1
Patent cooperation treaty	1	0	0	While most WTO members are in fact PCT members, PCT membership is not an obligation under TRIPS.
UPOV	1	0	0	TRIPS Article 27.3(b). While a *sui generis* system is required for protection of plant varieties, this obligation need not be fulfilled via UPOV membership.
3. Measures against loss of protection				
No working requirements (at any point during the patent term)	1	0	1	Paris Article 5A(2) identifies failure to work a patent as justifiable grounds for granting a compulsory license (CL), but TRIPS Article 27.1 disallows discrimination 'as to … whether products are imported or locally produced'. Thus, TRIPS does not explicitly disallow working requirements but will likely be interpreted to have this effect (see Watal, 2001, p. 318).
No compulsory licensing (within 3 (4) years of grant (application) date)	1	0	1	Paris Article 5A(4) states that no CL can be issued before 3 years from the grant date or 4 years from the application date, whichever is longer.

Table 1 (*cont.*)

	Calculation of PG index: Yes	No	Min. TRIPS	Notes
No revocation of patents (for non-working)	1	0	1	TRIPS Article 32 only mandates a judicial review of any revocation decision. As noted in Watal (2001, p. 329), the European Community's proposal that revocation could not be based on non-working was dropped in the process of negotiating the TRIPS Agreement. However, this proposal was dropped precisely because it was agreed that the Paris Convention sufficiently clearly prevented revocation for non-working alone.
4. Enforcement				
Preliminary injunctions (pre-trial actions in response to alleged infringement)	1	0	1	TRIPS Article 44 states that, 'judicial authorities shall have the authority to order a party to desist from an infringement'. TRIPS Article 50 adds significantly to this obligation by mandating pre-trial injunctions based on alleged infringement.
Contributory infringement	1	0	0	Not an obligation under TRIPS.
Burden-of-proof reversal	1	0	1	TRIPS Article 34.1
5. Duration of patent (*x* years)	**Value**			
Application-based standard:				
x at least 20 years	1		1	TRIPS Article 33
x less than 20 years	*x*/20			
	PG Index (Min. TRIPS) = 3.7			

imposes certain *minimum* patent standards, the TRIPS Agreement would not cause convergence to a single PG index value.

Adjusting the minimum PG index value does not resolve the more fundamental problem that the PG index is not well suited to proxy for TRIPS compliance, but it does lead one to wonder how sensitive the final estimates of the McCalman approach are to the choice of the TRIPS compliant PG index value. Basing R_{ni}^{TRIPS} on $PG_n = 3.7$ instead of 5 for developing countries would reduce technology-related payments to foreigners since such an adjustment would reduce the value of patenting in developing countries and hence reduce the flow of patent rents from these countries to foreign inventors. Furthermore, since many developed countries voluntarily have PG indexes above 3.7, the value to foreign inventors of patents in developed countries is largely unaffected by the threshold PG index choice. Using a lower TRIPS-compliant PG value therefore disproportionately benefits developing countries because the value to developed country inventors of patenting in these countries falls while the value to developing country inventors of patenting in developed countries is relatively unchanged.

According to calculations by the author (see the Appendix in the electronic version for details) and given the parameter values reported by McCalman (2001), the arc elasticity of the change in PV_{ni} with respect to a change in PG_n appears to be at least one. In other words, if the PG index post-TRIPS for a developing country was lowered from 5 to 3.7 (25 %), but was maintained at 5 for a developed country, patent rents flowing from the developing to the developed country would fall by at least 25 %, while rents flowing from the developed to the developing country would remain unchanged. Of course, the aggregate effect of this adjustment could be significant as this NPR balance for this developing country is summed over all other countries (see equation (2)).

The Counterfactual Problem. McCalman's counterfactual is very simple: if the TRIPS Agreement did not compel a developing country to strengthen its IP system, its IP system would not change. This is a very convenient counterfactual since it means that net patent rents associated with TRIPS are precisely *all* net patent rents. Everything is attributed to TRIPS. Unfortunately, this counterfactual also betrays reality. There were several pressures and trends in the 1990s that likely would have caused countries to strengthen their IP regime regardless of the outcome of the Uruguay Round of negotiations. The US, for example, coerced several countries to strengthen their patent protection by applying bilateral pressure through the use of Section 301 provisions (see Watal, 2001). While it is unclear whether the continuation of such bilateral pressures would have yielded a system less favourable to developing countries, it is amply clear that absent TRIPS patent policy in these countries would have remained unchanged.

As further evidence that all changes in patent policy cannot be attributed to the TRIPS Agreement, several countries implemented provisions of the TRIPS Agreement *before* they were required to do so by the Agreement. For example, Brazil, Argentina and Morocco introduced patent protection for pharmaceutical products and processes in 1997, 2000 and 2000, respectively, several years before TRIPS requires them to do so in 2005. The impetus for such changes in national legislation is multifaceted, but clearly these countries were not compelled solely by the TRIPS Agreement to make these changes. Attributing everything to TRIPS surely overestimates the actual cost of implementing TRIPS.

The Implementation Timing Problem. The TRIPS Agreement recognizes that developing and least-developed countries require more time to implement TRIPS than developed countries by including transitional arrangements (Articles 65, 66). Specifically, while developed countries were generally required to implement TRIPS by January 1996, developing countries and economies-in-transition[9] were given until January 2000, and least-developed countries have until January 2006, with the possibility of further extensions. Developing and least-developed countries that prior to 1995 did not cover pharmaceuticals in their patent system have until 2005 and 2016,[10] respectively, to introduce patent protection in this important sector.

McCalman, who includes seven developing countries in his analysis,[11] fails to acknowledge the transitional arrangements of the TRIPS Agreement and instead assumes that the Agreement is implemented simultaneously world-wide. Allowing for staggered implementation in the McCalman approach would reduce the number of applications filed during the transition period in countries availing themselves of these provisions by lowering the sectoral coverage variable, s_{ni}. Clearly, this would reduce the payments flowing out of developing and least-developed countries while payments to these countries from developed countries would remain unchanged. Simultaneous world-wide implementation is only defensible if McCalman's aim is to simulate the bilateral transfers likely to occur once TRIPS is *fully* implemented by *all* countries, in which case it is unfortunate that he fails to indicate that in reality these transfers will not occur until at least 2005 and that conducting such a forward-looking simulation with 1988 data takes considerable faith.

In addition to an inadequate treatment of the TRIPS Agreement as explained in the three problems above, two final aspects to McCalman's approach are worth highlighting. First, McCalman offers a static approach to analyzing an inherently dynamic problem[12] and openly admits that this limits the usefulness of the approach as an assessment of TRIPS.[13] McCalman's approach is static for good reason: it is simply too difficult to represent the dynamic side of the equation in a tractable model that includes the degree of detail he seeks. Even though short-term dynamic benefits to most developing countries may be relatively small, only if there are no benefits whatsoever would McCalman's figures reflect the *net* cost of

9 Eastern and Central European countries.

10 The extension to 2016 for least-developed countries was effected after McCalman's analysis by the Doha Ministerial Declaration of November 2001.

11 Brazil, Columbia, India, Korea, Mexico, Panama, and South Africa.

12 Economists tend to view patents abstractly as an attempt to balance static social costs with dynamic social benefits. Patents create static costs by allowing patent holders to act as monopolists, charging higher prices and imposing inefficiencies in the market. Patents are thus socially sub-optimal when static costs are considered in isolation. Society can gain from patents, however, when the dynamic benefits are considered. Patents stimulate investment and encourage innovation, which generate new and better technologies that benefit society generally. See Maskus, 2000, for a detailed survey of the economics of intellectual property.

13 McCalman (2001) acknowledges this limitation with the following statement: '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 characterize fully 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' (p. 177).

implementing TRIPS. The possibility of such dynamic benefits is illustrated by preliminary evidence that some pharmaceutical firms in India, which have focused historically on producing generic versions of patented drugs, appear to be turning somewhat to research-based strategies that involve patenting in developed countries (Lanjouw and Cockburn, 2001). Future responses of the Indian pharmaceutical sector to the higher copying costs arising from stronger patent protection may reveal one specific dynamic benefit, namely, the strategic diversion of technical expertise and resources from copying to innovating. In short, even if the McCalman approach were modified to address the three main problems identified above, the resulting NPRs would still represent at best upper-bounds on the net cost of TRIPS implementation.

Secondly, McCalman estimates NPRs based on predicted patent *applications*, instead of patent *grants* (see equation (1)). He does this because the former is generally considered to be more reliable and less idiosyncratic (i.e., less dependent on application examination resources, which can fluctuate dramatically in small national patent offices) than the latter. McCalman further justifies the use of patent applications instead of grants by pointing out that applications give a relatively more complete picture of the current state of innovation since there are no administrative or examination lags associated with patent applications.[14] While this justification seems plausible in the analysis of Eaton and Kortum (1996) who use bilateral patent application data to proxy for the diffusion of ideas between countries, it is less plausible in concept in McCalman's analysis, which aims to estimate the patent rents extracted by an inventor *after* a patent is granted. Indeed, McCalman interprets his results as if he were estimating the value of 'patent rights', instead of the value of ideas as codified in patent applications.

How much does using patent applications instead of grants really affect the estimated net patent rents? Because McCalman, following Eaton and Kortum (1996), jointly estimates the productivity and patenting equations, the average value of a 'patent' reflects its contribution to relative productivity. Thus, using patent application data lowers average 'patent' values (PV_{ni}) relative to using patent grant data. McCalman therefore claims that the calculation of patent rents (see equation (1)) adjusts for the use of applications rather than grants. That is, while patent applications (P_{ni}) are greater than patent grants, the average value of patent applications (PV_{ni}) is less than the average value of grants.[15] So it appears that the use of patent applications instead of grants may not substantially affect the estimated NPRs. One should nonetheless keep in mind when interpreting these estimates that they are derived from the value of patent applications, rather than the value of 'patent rights' *per se*.

In summary, while McCalman's approach to estimating the indirect cost of implementing TRIPS is promising and sophisticated, it misrepresents the TRIPS

14 McCalman, personal communication.
15 McCalman, personal communication.

Agreement as requiring WTO Members to simultaneously harmonize their patent systems at maximal strength as measured by the PG index. In reality, while the intellectual property standards set by the Agreement are indeed high, they represent minimum, not harmonizing, standards that offer more flexibility than implied by McCalman, and TRIPS allows for staggered implementation. This inadequate treatment of the TRIPS Agreement exaggerates the costs born by developing countries and the benefits reaped by developed countries. While the general distribution of benefits and costs associated with TRIPS implementation implied by the McCalman (2001) approach accurately depicts the TRIPS Agreement as costly to developing countries, the approach overstates the magnitude of these indirect costs. Indeed, for a variety of reasons the net patent rent figures generated by the McCalman approach better represent the potential transfers arising from a fictional scenario of simultaneous international patent harmonization than the indirect costs of implementing the TRIPS Agreement.

Appendix: Approximating the arc elasticity of PV_{ni} with respect to changes in PG_n

This appendix presents a few key equations from McCalman (2001), but includes only a very abbreviated discussion of these equations. The reader should refer to McCalman (2001) for an excellent and complete description and derivation of these equations.

McCalman assumes Bertrand competition in input markets and derives the instantaneous rents extracted by the owner of an invention of size q as:

$$\pi_n(q) = \frac{(1-e^{-q})Y_n}{J}$$

where 'Y_n the value of the market in country n and J is the index of the range of inputs'. He then treats this instantaneous rent flow as a perpetuity in order to calculate the expected present value of patent rights 'along the steady state growth path' as follows:

$$V_{ni}^{k}(q) = \frac{\pi_n(q)}{r + \iota_{ni}^{k} + o_n - g} = \frac{\pi_n(q)}{\iota_{ni}^{k} + \delta_n}$$

where r is the discount rate, o_n is the rate of obsolescence, g is the long-run innovation growth rate, $k \in \{pat, not\}$, and the hazard rate of imitation under patent protection is:

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

where ι_{ni}^{not} is the hazard of imitation without patent protection, subscripts *dom* and *for* indicate whether the invention was the creation of a domestic or foreign inventor, respectively, and PG_n is the Park–Ginarte index of patent strength for country n (see Ginarte and Park, 1997).

As McCalman explains, ‘a patent gives the inventor the incremental benefits of a lower hazard of imitation’ (i.e., $\iota_{ni}^{pat} < \iota_{ni}^{not}$) so the a patent on an invention of size q in country n is worth

$$d_{ni}(q) = V_{ni}^{pat}(q) - V_{ni}^{not}(q) = \frac{\pi_n(q)}{\iota_{ni}^{pat} + \delta_n} - \frac{\pi_n(q)}{\iota_{ni}^{not} + \delta_n}$$

to an inventor from country i. After determining the size (‘quality’) of invention that is exactly worth patenting (i.e., $q_{ni}^* \ni d_{ni}(q_{ni}^*) = C_{ni}$, where C_{ni} is the total cost to an inventor of country i of applying for a patent in country n), McCalman combines the exponential distribution of the quality of the invention (with a *pdf* $f(q)$) and the quality threshold for profitable patents (q_{ni}^*) to calculate the mean value of patent rights as follows:

$$PV_{ni} \equiv \int_{q_{ni}^*}^{\infty} d_{ni}(Q) f(Q | Q > q_{ni}^*) dQ$$

Given this formulation, a lower-bound on the arc elasticity of PV_{ni} with respect to a change in the PG index from PG_n^0 to PG_n^1 can be calculated as follows:

$$\left(\frac{\Delta PV_{ni}/PV_{ni}}{\Delta PG_n/PG_n^0}\right) \geqslant \left(\frac{\Delta d_{ni}(q)/d_{ni}(q)}{\Delta PG_n/PG_n^0}\right) = \left(\frac{\iota_{ni}^{not} + \delta_n}{\iota_{ni}^{pat(1)} + \delta_n}\right) \cdot \left(\frac{e^{\gamma PG_n^0} - e^{-\gamma PG_n^1}}{1 - e^{-\gamma PG_n^0}}\right) \cdot \left(\frac{PG_n^0}{\Delta PG_n}\right)$$

This arc elasticity represents a lower-bound because decreasing (increasing) the PG index also decreases (increases) q_{ni}^*, thereby magnifying the effect on PV_{ni}. For the parameter values used by McCalman (assuming $o_n = 0.10$), this lower-bound arc elasticity is approximately one.

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