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Does the species protection index for 198 countries converge over time?

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ABSTRACT

Sustainable Development Goals adopted by The United Nations seek to protect and prevent the extinction of threatened species by 2020. Several countries even in the 1990s began expanding species protection to reach the 2020 goal earlier. On the other hand, there are multiple countries with very low level of species protection, thus creating a wide gap between the two groups of countries. This research investigates whether countries with low level of species protection efforts in the early years have been catching up faster in recent year. If so, how fast is the speed of catch-ups? We used 198 countries during the period of 1990 to 2015 for the total as well as for the ten subgroups of countries defined by income levels and regions. Key findings from this research indicates that those groups of countries with lower species protection in the early years have been catching up fast to leading groups of countries. Thus, the gap between the leading and lagging groups have narrowed during the period. This study also identifies several regions which will play a critical role of enhancing species protection in the future.

Key words : *Species Protection Indicator, PSPU, PSPW, Convergence analysis, α and γ indexes, Speed of catch-up*

Introduction

Human impacts on the environment are imperiling the species and ecosystems of earth at ever increasing rates (Tilman *et al.,* 2017; Steffen *et al.,* 2015; Pimm *et al*., 2014). Land-use change and habitat fragmentation, overhunting, invasive species and pollution already threaten 25% of all mammal species and 13% of all bird species with extinction (IUCN, 2016). Land-use change is associated with declining biodiversity worldwide (Newbold *et al.,* 2015; Joppa *et al.,* 2016). Overhunting by humans also imperil 40~50% of all threaten bird and mammal species (Ripple *et al.,* 2015; Wittemyer *et al.,* 2014). Climate change will probably pose more serious future threat to biodiversity (Maclean and Wilson, 2011; Urban, 2015).

In fact, several scholars (Ceballos *et al.,* 2015; Pimm *et al.,* 2014; Barnosky *et al.,* 2011; Dirzo and Raven, 2003; Wake and Vredenburg, 2008) suggest that extinction rates for birds, mammal and amphibians are similar to those of the five global mass-extinction events of the past 500 million years, when the earth lost more than three-quarters of its species in a short interval (Jablonski, 1994). When current extinction rates are compared to those before human actions elevated them – i.e. the background rate of distinction, present extinction rates are likely a thousand times higher than the background rate (Pimm *et al*., 2014). Thus, these multiple pressures which are pushing today's species towards passible extinction in the future need to be relieved now (Barnosky *et al.,* 2011).

The global expansion of species protection has been guided by the 20 Aichi Biodiversity targets which were adopted in 2010 at the Convention on

Biological Diversity (CBD) to be realized by 2020 (CBD, 2010). More specifically, Aichi Target 11 states that by 2020, at least 17 percent of terrestrial and inland water areas are conserved through effectively and equitably managed ecologically representative and well-connected systems of protected areas. Target 12 states that by 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained. Target 13 states that by 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained to minimize genetic erosion and safeguard their genetic diversity. These targets have stimulated many governments to develop their own national conservation goals.

These Aichi targets were further strengthened when the United Nations adopted Sustainable Development Goals (SDGs) in 2015 (United Nations, 2016). For example, SDG 15.4 states that by 2020, ensure the conservation of mountain ecosystem, including their biodiversity. And SDG 15.5 states to take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and by 2020, protect and prevent the extinction of threatened species. Furthermore, SDG 15.9 states that by 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts.

To measure species protection outcomes, the Environment Performance Index (EPI, 2016) calculates the average area of species - bird, mammals and amphibians- distributions in a country under protection designated as code: PSPU. The EPI also calculates the average areas of species- bird, mammals, and amphibians- distributions in a country under protection and weighted by a country's stewardship for each species designated as code: PSPW. The species protection indicators are measured in two ways because not all protection outputs are equal. For instance, it would be much more important when a country protects a bird which is rare outside of its border, because it matters much more for the world than to protect a bird that is plentiful elsewhere. The proportions under protection are quantified and updated on an annual basis to reflect any changes in protected areas and sustainable habitat.

One of the most notable accomplishments in species protection is the fact that several countries even in the early 1990's have been providing leadership roles of achieving the Aichi target of 17%. Some of these countries include Czech Republic, Denmark, Japan, Slovakia, United Kingdom, The U.S., Venezuela, and Zambia. On the other hand, there are multiple countries with very low level of species protection, thus creating a wide gap between the two groups of countries. For example, this research will show that the 1990 averaged PSPU measure for 19 countries in the Middle East North Africa region was only 3.1% in comparison to 8.08% for the total of 199 countries.

Therefore, the major question of this research is to determine whether countries with lower level of species protection in the early years have been improving faster to catch-up to countries with higher level of species protection? If so, how fast is the speed of catch-ups? We use a total sample of 198 to 199 countries during the period of 1990 to 2015. The same questions will be examined for ten subgroups of countries defined by income levels and regions. To our best of knowledge, such a systematic convergence analysis on species protection has not been published, making this research a possible new contribution.

After this introduction, the article is organized in four additional sections. Convergence methodology to determine catch-up speed will be explained in the second section, followed by data and data sources in the third section. Analysis of results will be presented in the fourth section. And then, the fifth section will summarize the key findings and discuss some policy implicates and limitations of this research.

Convergence Methodology

The traditional convergence analysis attempts to examine two basic questions (Barro, 1991, Barro and Sala-I-Martin, 1992). First, do countries initially lagging in such performance measures as species protection index tend to improve faster so that they catch up to the performance levels of leading countries over time? Second, does the dispersion of species protection index measures among countries get reduced over time? γ convergence is used to examine the first question, while σ convergence is used to analyze the second question.

A simple approximation to Quah (1996)'s methodology was proposed by Boyle and McCarthy (1997) where they use Kendall's index of rank con-

cordance (Siegel, 1956) to measure changes in the ordinal ranking of countries over time. They label their method as γ convergence.

By using γ convergence with a simple measure of ó convergence, they suggest that one can identify the nature of convergence and a sense of the dynamics of the cross-country distribution of performance measures.

For our methodology, we use γ convergence (Boyle and McCarthy, 1997) and σ convergence (Friedman, 1992). Common measures of dispersion include the standard deviation or coefficient of variation. For ó convergence, we have selected to use the coefficient of variation. Using the coefficient of variation enables us to compare the speed of changing dispersion across different dimensions of penetration measures of internet, mobile-cellular, and fixed broadband. Since then, a large number of studies using γ convergence methodology have been published in such areas as energy, economic growth, inflation, employment, and healthcare (Agovino and Rapposelli, 2017; Carrasco and Ferreiro, 2014; Ferrara and Nistico, 2015; Chang *et al.,* 2019; Jaunky and Zhang, 2016; Kallioras and Tsiapa, 2015; Liddle, 2012; Morales-Zumaquero and Sosvilla-Rivero, 2016).

For the γ convergence model, Boyle and McCarthy (1997) suggested the use of Kendall's index of rank concordance which measures the mobility of the individual countries over time within the cross-country distribution of a particular performance. In other words, γ convergence measures the degree of changing the ranking order of countries between a given year and the initial year. The γ convergence we use is Kendall's binary index version and is defined as follows:

$$\gamma_t = \left[\frac{var(AR(Y)_{it} + AR(Y)_{io})}{var(2 * AR(Y)_{io})}\right]$$

where $AR(Y)_{it}$ = the actual rank of country *i*'s performance measure in year *t*

$AR(Y)_{i0}$= the actual rank of country *i*'s performance measure in year *0*

γ_{ta}= Binary Gamma Index in year *t*.

The γ index has the advantage of being of a single number traced over time in two-dimension, analogous to the σ convergence index. The value of rank concordance ranges from zero to unity.

If no change in rank order takes place, the rank concordance becomes unity. If a catch-up process is present, the index will be less than unity. The statistic is distributed as chi-square and we test the null hypothesis that γ convergence is an identical difference between ranks of different years (Siegel, 1956).

How do we use the σ and γ index together to evaluate the reduction of dispersion as well as the catch-up process? There are four different cases. The simplest case is when both σ and γ indexes are increasing in values. Under the circumstance, neither reduction of dispersion nor catch up may be taking place.

The second case is that both σ and γ indexes are decreasing which indicates that both reductions of dispersion and catch-up processes are taking place. The third case occurs where convergence measure is constant, while γ convergence value is in decline. Since γ convergence is a necessary but not a sufficient condition for σ convergence, this indicates that the catch-up process is taking place, while the reduction of dispersion is not. The fourth case occurs where the γ index does not decrease while a decline of σ index occurred. This indicates that no rank change among countries takes place. However, performance differences among countries have decreased considerably.

Data and data source

For this study, there are two basic measures of PSPW and PSPU which have been downloaded from Environmental Performance Index web site at *http://epi2016.yale.edu/downloads*. Yearly PSPW and PSPU measures during the period of 1999 to 2014 were available for 211 countries. Eliminating 13 countries with missing data, the final sample size of this study was 198 countries for PSPU and 199 countries for PSPU.

For categorizing four subgroups of countries by income level, World Bank's Gross National Income (GNI) per capita which converts the GNI of each country into US dollars using the World Bank Atlas method is used. According to the World Bank, four income groups are defined in 2015 as follows (*https://blogs.worldbank.org/opendata/updated-income-classifications*). The high income group contains those countries whose GNI per capita of $12,746 or more, followed by the upper middle-income group with GNI per capita between $4,126 and $12,745. The lower middle-income group contains those countries with GNI per capita between $1,045 and $4,125, while the lower income group contains those countries with $1,045 or less. GNI per capita using the Atlas

method in current US dollars for countries in the world are available from the World Bank's web site at https://data.worldbank.org/indicator/ny.gnp.pcap.cd.

Out of a total of 198 countries, high income subgroup included 69 countries, followed by upper middle income subgroup of 52 countries, lower middle income subgroup of 48 countries and finally low income subgroup of 30 countries.

Analysis of results

Historical averaged yearly PSPW for the total group of 198 countries increased rapidly from 8.7848% in 1990 to 12.3186% by 2014 at the compounded annual growth rate (CAGR) of 1.42%, as shown in Table 1. Similarly, historical averaged yearly PSPU also increased from 8.6793% in 1990 to 12.3392% by 2014 at the CAGR of 1.48%.

When the average yearly PSPW and PSPU measures were analyzed by the four income subgroups, all four subgroups also displayed increasing trends supporting the increasing trends of both measures for the total group. However, the annual rate of increase varied somewhat by the income subgroups. For PSPW, the lower middle income group displayed the most rapid rate of increase at 2.09%, followed by the upper middle group at 1.53%, the high income group at 1.24%. Similarly, PSPU measures increased most rapidly at 2.02% by the low middle, 1.55% by the upper middle, and 1.36% by the high income in the same order. The low income group displayed the slowest CAGR at 0.92% for PSPW and 0.98% for PSPU.

As for the values of PSPW, the high income group displayed the highest values of 10.8268% in 1990 increasing to 14.5438% by 2014, while the upper middle income group showed 8.2773% in 1990 and 11.9179% in 2014 and the lower middle income group displayed the lowest values of 6.1333% in 1990 and 10.6677% by 2015. Similarly, PSPU values were the highest in the high income group with 10.4184% in 1990 to 14.4119% in 2014, while the lowest values were recorded by the lower middle income group with 6.3754% in 1990 increasing to

Table 1. Averaged PSPW Measures for Total and Four Income Subgroups of 198 Countries (1990-2014)

Year	Total (198)	High Income (68)	Upper Middle Income (52)	Low Middle Income (48)	Low Income (30)
1990	8.7848	10.8268	8.2773	6.1333	9.2783
1991	8.8926	10.9694	8.3610	6.2281	9.3700
1992	9.1129	11.4079	8.4431	6.3465	9.4980
1993	9.4117	11.5526	8.5933	7.2048	9.5087
1994	9.6003	11.9196	8.7662	7.2727	9.5130
1995	9.8178	12.2635	8.9000	7.5129	9.5527
1996	10.0119	12.4726	9.0579	7.7621	9.6877
1997	10.1764	12.7553	9.1602	7.8338	9.8407
1998	10.3573	12.8975	9.4319	8.0550	9.8870
1999	10.5180	12.9450	9.5877	8.4244	9.9790
2000	10.8220	13.2440	10.0321	8.6590	10.1623
2001	10.9913	13.3734	10.2852	8.8148	10.2980
2002	11.2271	13.5178	10.7571	8.8638	10.6307
2003	11.3655	13.6299	10.9538	8.9963	10.7373
2004	11.4641	13.6562	11.0721	9.1035	10.9517
2005	11.5836	13.7131	11.2483	9.2675	11.0437
2006	11.6760	13.7426	11.4817	9.3119	11.1107
2007	11.8131	13.7778	11.5833	9.6942	11.1487
2008	11.9467	14.0297	11.6508	9.7446	11.2617
2009	11.9889	14.0631	11.7135	9.7915	11.2807
2010	12.0689	14.1509	11.7440	9.8808	11.4140
2011	12.2257	14.5021	11.8312	9.9344	11.4157
2012	12.2921	14.5365	11.8821	10.0306	11.5337
2013	12.3136	14.5432	11.9158	10.0502	11.5707
2014	12.3186	14.5438	11.9179	10.0677	11.5707
CAGR	1.42%	1.24%	1.53%	2.09%	0.92%

Table 2. Averaged PSPU Measures for Total and Four Income Subgroups of 199 Countries (1990-2014)

Year	Total(199)	High Income (69)	Upper Middle Income (52)	Low Middle Income (48)	Low Income (30)
1990	8.6793	10.4184	8.2792	6.3754	9.0590
1991	8.8042	10.5810	8.3940	6.5015	9.1130
1992	9.0199	11.0014	8.4962	6.6210	9.2087
1993	9.3286	11.1396	8.6610	7.5090	9.2320
1994	9.5337	11.5364	8.8446	7.5890	9.2337
1995	9.7427	11.8461	8.9729	7.8263	9.3057
1996	9.9369	12.0439	9.1456	8.0748	9.4417
1997	10.1244	12.3928	9.2669	8.1494	9.5533
1998	10.3117	12.5778	9.5294	8.3481	9.5973
1999	10.4566	12.6467	9.6825	8.6269	9.6887
2000	10.7724	12.9472	10.1252	8.8906	9.9030
2001	10.9532	13.0745	10.4015	9.0513	10.0733
2002	11.2196	13.2735	10.8656	9.1035	10.4950
2003	11.3442	13.3517	11.0392	9.2569	10.5950
2004	11.4427	13.3978	11.1562	9.3508	10.7893
2005	11.5917	13.5414	11.3192	9.5244	10.8870
2006	11.6822	13.5767	11.5369	9.5804	10.9397
2007	11.8146	13.6264	11.6479	9.9038	10.9937
2008	11.9561	13.8693	11.7165	9.9606	11.1640
2009	12.0021	13.9158	11.7698	10.0169	11.1797
2010	12.0698	13.9842	11.7960	10.0867	11.3143
2011	12.2351	14.3390	11.8888	10.1602	11.3163
2012	12.3026	14.3945	11.9337	10.2638	11.3927
2013	12.3341	14.4106	11.9810	10.2846	11.4493
2014	12.3392	14.4119	11.9823	10.3027	11.4493
CAGR	1.48%	1.36%	1.55%	2.02%	0.98%

10.3027% in 2014, as shown in Table 2.

In sum, the higher the income level, the higher were the PSPW and PSPU measures throughout the period. Furthermore, the higher the PSPW and PSPU measures, the slower became the CAGR's, supporting the theory that countries with lower PSPW and PSPU measures would improve faster to catch-up to leading countries. There was an exception, however, in the low income subgroup which displayed high PSPW and PSPU measures but slow CAGRs.

Table 3 shows normalized σ and γ indexes of PSPW for the total group of countries during 1990 to 2014. Both indexes displayed declining trends indicating σ and γ convergence. The speed of σ convergence is about 5 times faster at the CAGR of -1.81% over the speed of γ convergence at -0.36%. Each yearly γ index met the statistical test of significance at less than 1% level. The test for yearly σ indexes were also significant but only from 1998 to 2014. Table 3 also shows the distribution of yearly σ and γ indexes for PSPU for the total group of countries during 1990 to 2014. Once again, both indexes decreased during the period indicating σ and γ convergence. The speed of σ convergence is about 3 times faster at the CAGR of -1.89% over the speed of γ convergence at -0.54%. Each yearly γ index met the statistical test of significance at less than 1% level. Yearly σ index from 1997 to 2014 also met the significance test, as shown in Table 5.

When σ and γ indexes of PSPW were analyzed by four income subgroups in Table 4, all four income groups displayed of downward trends supporting the σ convergence of the total group. In contrast, the γ indexes for the high income group displayed a stationary trend, while the remaining three income subgroups displayed declining trends which supported the γ convergence of the total group. The speed of σ convergence varies from -2.42% for the high income group followed by -2.0% for the upper middle income group, -1.7% for the lower middle group and lastly -0.96% for the low income group. Yearly σ indexes from 2000 to 2014 met the statistical significance test for high income group, as did

Table 3. Normalized Sigma and Gamma Indexes of PSPU and PSPW (1990-2014)

Year	PSPW (198)		PSPU (199)	
	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	0.9928	0.9997***	0.9906	0.9989***
1992	0.9780	0.9933***	0.9720	0.9918***
1993	0.9392	0.9778***	0.9373	0.9752***
1994	0.9193	0.9712***	0.9143	0.9680***
1995	0.8980	0.9652***	0.8894	0.9620***
1996	0.8745	0.9608***	0.8669	0.9579***
1997	0.8615	0.9574***	0.8478*	0.9545***
1998	0.8399 *	0.9516***	0.8276**	0.9466***
1999	0.8216 **	0.9497***	0.8082**	0.9431***
2000	0.7959 **	0.9372***	0.7810***	0.9328***
2001	0.7798 ***	0.9369***	0.7636***	0.9301***
2002	0.7604 ***	0.9361***	0.7420***	0.9262***
2003	0.7413 ***	0.9322***	0.7263***	0.9229***
2004	0.7303 ***	0.9352***	0.7168***	0.9226***
2005	0.7141 ***	0.9368***	0.7008***	0.9168***
2006	0.7065 ***	0.9336***	0.6957***	0.9137***
2007	0.6891 ***	0.9297***	0.6768***	0.9094***
2008	0.6745 ***	0.9277***	0.6641***	0.9075***
2009	0.6718 ***	0.9277***	0.6618***	0.9042***
2010	0.6633 ***	0.9276***	0.6548***	0.9021***
2011	0.6500 ***	0.9172***	0.6377***	0.8914***
2012	0.6464 ***	0.9151***	0.6351***	0.8790***
2013	0.6448 ***	0.9178***	0.6325***	0.8793***
2014	0.6443 ***	0.9178***	0.6320***	0.8791***
CAGR	-1.81%	-0.36%	-1.89%	-0.54%

*p<0.05, **p<0.01, ***p<0.001

the upper middle and lower middle group for some selected years. However, none of the yearly σ index met the statistical significance test for the low income group.

The speed of γ convergence again varied by income subgroups. The most rapid rate of reduction was -0.89% for the lower middle income group, followed by -0.39% for the upper middle group, -0.15% for the low income group, and finally +0.01% for the high income group. All γ indexes met the test of statistical significance at less than 1% level every year during the period.

The results from σ and γ indexes of PSPU, as shown in Table 5 were quite similar to the results for PSPW. Both σ and γ convergence determined for the total group of 199 countries were repeated by the respective income subgroups. The speed of σ convergence was again the fastest by the high income subgroup (-2.54%), followed by the upper middle subgroup (-1.96%), the lower middle subgroup (-1.94%) and the low income subgroup (-1.08%). In contrast, the speed of ã convergence was led by the lower middle subgroup (-0.93%), followed by the upper middle subgroup (-0.46%), the high income subgroup (-0.42%) and the low income subgroup (-0.20%).

In short, the slowest CAGR for PSPW and PSPU measures (high income group), was associated with rapid annual speed of σ convergence, while the rapid CAGR (lower middle income group), was associated with slow annual speed of σ convergence. On the other hand, the slowest CAGR (high income group) was associated with the slowest annual speed of γ convergence, while the most rapid CAGR (lower middle income group) was associated with the most rapid speed of γ convergence.

When the average yearly PSPW measures were analyzed by six regions, three regions of SA, LAC, and MENA displayed somewhat faster rate of increase than the total group with 2.27%, 2.23% and 1.55% respectively. In contrast, the remaining regions of EAP, ECANA, and SSA showed slower

Table 4. Normalized Sigma and Gamma PSPW Indexes of Four Income Subgroups (1990-2014)

	High Income (68)		Upper Middle Income (52)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.00001 ¡¡	1.0000	1.0000
1991	0.9841	0.9985***	0.9919	0.9994***
1992	0.9572	0.9888***	0.9756	1.0001***
1993	0.9344	0.9875***	0.9621	0.9982***
1994	0.8812	0.9762***	0.9382	0.9915***
1995	0.8384	0.9687***	0.9191	0.9912***
1996	0.8256	0.9677***	0.8961	0.9889***
1997	0.8014	0.9644***	0.8807	0.9880***
1998	0.7958	0.9625***	0.8450	0.9784***
1999	0.7908	0.9659***	0.8266	0.9725***
2000	0.7498 **	0.9548***	0.7954	0.9614***
2001	0.7343 **	0.9614***	0.7673	0.9643***
2002	0.7130 **	0.9823***	0.7369 *	0.9494***
2003	0.6917 **	0.9782***	0.7171 *	0.9431***
2004	0.6902 **	1.0056***	0.7032 *	0.9394***
2005	0.6800***	1.0200***	0.6872 **	0.9303***
2006	0.6775***	1.0187***	0.6641 **	0.9194***
2007	0.6725***	1.0185***	0.6536 **	0.9175***
2008	0.6333***	1.0129***	0.6406 **	0.9159***
2009	0.6304***	1.0155***	0.6366 **	0.9112***
2010	0.6084***	1.0137***	0.6338 **	0.9115***
2011	0.5562***	0.9958***	0.6256***	0.9067***
2012	0.5561***	1.0020***	0.6177***	0.9081***
2013	0.5554***	1.0020***	0.6166***	0.9095***
2014	0.5553***	1.0020***	0.6165***	0.9095***
CAGR	-2.42%	0.01%	-2.00%	-0.39%

*p<0.05, **p<0.01, ***p<0.001

rates at 1.2%, 1.19%, and 1.07% respectively, as shown in Table 6. For PSPU, three regions with faster rate of increase than the total group were in the order of MENA (3.88%), EAP (1.90%). and EACNA (1.71%). In contrast, the remaining three regions with slower rate of increase were led by SA(1.26%), SSA(1.0%), and LAC(0.98%), as shown in Table 7.

In general, the high levels of 1990 PSPW measures of ECA+NA(10.09%), SSA(8.92%), and EAP(8.86%) regions were associated with slow CAGRs, while the remaining regions of SA(5.24%), LAC(7.34%) and MENA(8.91%) with lower level of 1990 PSPW were associated with more rapid CAGRs, once again supporting a catch-up theory. Similarly, two regions of LAC(10.82%) and SSA(9.57%) with high level of 1990 PSPU were associated with slow CAGR while MENA(3.11%) and EAP(7.39%) regions with low 1990 PSPU were associated with more rapid CAGR, once again, supporting a catch-up theory. ECA+NA and SA provided exceptional cases of relatively high 1990 PSPU with a rapid CAGR.

It is interesting to note that regional analysis by PSPW versus PSPU have generated statistically different results compared to the results from the income subgroup analysis. For example, the two countries (SA and LAC) with the most rapid CAGR of PSPW have been replaced with MENA and EAP in the analysis of PSPU. The second most rapid CAGR of PSPW displayed by LAC at 2.23% now became the slowest CAGR of PSPU at 0.98%.

When normalized σ and γ indexes were analyzed by six regional subgroups, all σ and γ indexes showed declining trends, each region supporting ó and ã convergence displayed by the total groups of countries for both PSPW and PSPU. Every γ indexes met the statistical test of significance at less than 1% level. As for σ indexes, three regions of ECANA, LAC and SSA for PSPW and three regions of ECANA, LAC and EAP for PSPU successfully met the significance test typically in the years between 2002 to 2014.

Table 4. [Continued] Normalized Sigma and Gamma PSPW Indexes of Four Income Subgroups (1990-2014)

	Lower Middle Income (48)		Low Income (30)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	1.0010	0.9995***	1.0003	0.9978***
1992	0.9807	0.9933***	0.9885	0.9962***
1993	0.9003	0.9171***	0.9861	0.9962***
1994	0.9000	0.9119***	0.9866	0.9958***
1995	0.8867	0.9139***	0.9780	0.9951***
1996	0.8443	0.9075***	0.9507	0.9933***
1997	0.8399	0.9076***	0.9265	0.9913***
1998	0.8015	0.8923***	0.9249	0.9870***
1999	0.7767	0.8891***	0.9098	0.9848***
2000	0.7631	0.8635***	0.9046	0.9844***
2001	0.7584	0.8678***	0.8905	0.9855***
2002	0.7542	0.8678***	0.8668	0.9737***
2003	0.7365	0.8638***	0.8450	0.9744***
2004	0.7279	0.8608***	0.8185	0.9686***
2005	0.6975 *	0.8535***	0.8193	0.9684***
2006	0.6977 *	0.8466***	0.8196	0.9704***
2007	0.6611**	0.8267***	0.8183	0.9756***
2008	0.6560**	0.8272***	0.8127	0.9792***
2009	0.6543**	0.8264***	0.8122	0.9788***
2010	0.6534**	0.8242***	0.8030	0.9699***
2011	0.6519**	0.8172***	0.8029	0.9699***
2012	0.6523**	0.8087***	0.7985	0.9643***
2013	0.6514**	0.8080***	0.7933	0.9643***
2014	0.6507**	0.8077***	0.7933	0.9643***
CAGR	-1.77%	-0.89%	-0.96%	-0.15%

*p<0.05, **p<0.01, ***p<0.001

Table 5. Normalized Sigma and Gamma PSPU Indexes of Four Income Subgroups (1990-2014)

	High Income (69)		Upper Middle Income (52)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	0.9840	1.0013***	0.9859	0.9977***
1992	0.9520	0.9817***	0.9635	0.9941***
1993	0.9382	0.9788***	0.9473	0.9945***
1994	0.8833	0.9629***	0.9247	0.9883***
1995	0.8401	0.9524***	0.9049	0.9884***
1996	0.8298	0.9426***	0.8825	0.9901***
1997	0.7852 *	0.9395***	0.8652	0.9886***
1998	0.7739 *	0.9272***	0.8352	0.9851***
1999	0.7698 *	0.9245***	0.8171	0.9788***
2000	0.7266 **	0.9222***	0.7909	0.9678***
2001	0.7136 **	0.9240***	0.7621	0.9654***
2002	0.6867***	0.9290***	0.7336 *	0.9530***
2003	0.6794***	0.9235***	0.7136 *	0.9486***
2004	0.6786***	0.9295***	0.7004 **	0.9478***
2005	0.6644***	0.9285***	0.6891 **	0.9383***
2006	0.6611***	0.9480***	0.6773 **	0.9152***
2007	0.6501***	0.9507***	0.6644 **	0.9059***
2008	0.6165***	0.9467***	0.6502 **	0.9024***
2009	0.6115***	0.9414***	0.6475 **	0.9001***
2010	0.5969***	0.9305***	0.6446***	0.8999***
2011	0.5399***	0.9173***	0.6315***	0.8992***
2012	0.5403***	0.9045***	0.6244***	0.8989***
2013	0.5398***	0.9039***	0.6213***	0.8961***
2014	0.5397***	0.9039***	0.6213***	0.8961***
CAGR	-2.54%	-0.42%	-1.96%	-0.46%

*p<0.05, **p<0.01, ***p<0.001

Table 5. [Continued] Normalized Sigma and Gamma PSPU Indexes of Four Income Subgroups (1990-2014)

	Lower Middle Income (48)		Low Income (30)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.00001	1.0000
1991	1.0001	0.9996***	0.9975	0.9980***
1992	0.9796	0.9970***	0.9885	0.9971***
1993	0.9047	0.9222***	0.9839	0.9969***
1994	0.8939	0.9125***	0.9841	0.9969***
1995	0.8736	0.9035***	0.9671	0.9958***
1996	0.8339	0.8949***	0.9401	0.9945***
1997	0.8298	0.8952***	0.9208	0.9939***
1998	0.7956	0.8809***	0.9188	0.9888***
1999	0.7589	0.8760***	0.9027	0.9865***
2000	0.7407	0.8631***	0.8929	0.9836***
2001	0.7323	0.8646***	0.8721	0.9862***
2002	0.7284	0.8627***	0.8382	0.9706***
2003	0.7097 *	0.8625***	0.8170	0.9713***
2004	0.7025 *	0.8565***	0.7928	0.9677***
2005	0.6705**	0.8493***	0.7924	0.9655***
2006	0.6704**	0.8422***	0.7903	0.9664***
2007	0.6343**	0.8252***	0.7879	0.9644***
2008	0.6301**	0.8290***	0.7931	0.9615***
2009	0.6305**	0.8306***	0.7929	0.9615***
2010	0.6282**	0.8303***	0.7841	0.9560***
2011	0.6260**	0.8208***	0.7840	0.9560***
2012	0.6267**	0.7963***	0.7811	0.9522***
2013	0.6258**	0.7998***	0.7715	0.9522***
2014	0.6248**	0.7998***	0.7715	0.9522***
CAGR	-1.94%	-0.93%	-1.08%	-0.20%

*p<0.05, **p<0.01, ***p<0.001

Table 6. Averaged PSPW Measures for Six Regional Subgroups of 198 Countries (1990-2014)

Year	EAP(31)	ECA+NA(55)	LAC(40)	MENA(19)	SA+SSA(7)	SSA(46)
1990	8.8561	10.0927	7.3420	8.9111	5.2371	8.9152
1991	8.9065	10.1887	7.4593	9.1179	5.2971	9.0341
1992	9.1600	10.4280	7.7668	9.3416	5.3914	9.1511
1993	9.5813	10.5891	8.5625	9.3879	5.7671	9.1926
1994	9.7306	10.6585	8.9383	9.5853	5.8029	9.4067
1995	10.0023	10.8542	9.3093	9.6342	5.9429	9.5620
1996	10.1116	11.1253	9.6543	9.8389	5.9500	9.6141
1997	10.2113	11.2836	9.8450	10.1395	6.5957	9.6774
1998	10.2461	11.3764	10.0578	10.4689	6.7071	9.9835
1999	10.2684	11.4822	10.2638	10.5605	6.7214	10.3146
2000	10.3461	12.1082	10.4993	11.0253	6.8386	10.4078
2001	10.5435	12.2495	10.7028	11.3732	6.9000	10.5043
2002	11.1145	12.5649	10.7855	11.6147	6.9000	10.5857
2003	11.2142	12.7356	10.9213	11.7200	7.7071	10.6259
2004	11.2735	12.8320	11.1413	11.8395	7.8114	10.6385
2005	11.2977	12.9065	11.2220	11.9437	8.5500	10.8217
2006	11.4410	12.9404	11.2735	12.0647	8.5543	10.9870
2007	11.4690	13.1358	11.3143	12.1053	8.7257	11.2465
2008	11.5355	13.1665	11.5365	12.5242	8.9729	11.3361
2009	11.6223	13.2095	11.5680	12.5789	8.9729	11.3578
2010	11.6616	13.2353	11.7783	12.6574	8.9729	11.4298
2011	11.6668	13.2962	12.3800	12.7295	8.9729	11.4750
2012	11.7413	13.3535	12.4655	12.8816	8.9729	11.5050
2013	11.7935	13.3833	12.4725	12.8863	8.9729	11.5187
2014	11.7935	13.3985	12.4725	12.8874	8.9729	11.5215
CAGR	1.20%	1.19%	2.23%	1.55%	2.27%	1.07%

Table 7. Averaged PSPU Measures for Six Regional Subgroups of 199 Countries (1990-2014)

Year	EAP(32)	ECA+NA(55)	LAC(40)	MENA(19)	SA+SSA(7)	SSA(46)
1990	7.3934	9.2298	10.8245	3.1095	7.2186	9.5730
1991	7.5031	9.4807	10.8943	3.1326	7.3543	9.6463
1992	7.6425	10.0020	10.9548	3.2416	7.8943	9.6796
1993	8.6191	10.3031	11.0788	3.4089	8.3814	9.7243
1994	8.8566	10.4731	11.1758	4.3037	8.3814	9.7893
1995	8.8903	10.9725	11.3180	4.4184	8.6657	9.8585
1996	9.1431	11.2355	11.4338	4.6958	8.8129	9.9707
1997	9.3159	11.5889	11.5190	5.0037	8.8186	10.0367
1998	9.4559	11.8040	11.7745	5.2900	9.0186	10.1217
1999	9.7259	12.0387	11.8128	5.3300	9.0914	10.2191
2000	9.9922	12.3473	12.0655	5.7242	9.1743	10.6361
2001	10.1472	12.6044	12.1703	5.9947	9.2029	10.7957
2002	10.3338	12.8382	12.4795	6.0447	9.2586	11.2409
2003	10.5091	13.0113	12.5143	6.2174	9.2771	11.3465
2004	10.7056	13.1004	12.5553	6.2600	9.3443	11.4659
2005	11.0025	13.1782	12.8003	6.2684	9.3743	11.5898
2006	11.0394	13.3896	12.8385	6.3195	9.3957	11.6454
2007	11.0756	13.4280	13.0753	6.6884	9.3986	11.7883
2008	11.3922	13.6002	13.1110	6.7368	9.4000	11.9233
2009	11.4431	13.6735	13.1423	6.7516	9.4371	11.9602
2010	11.4628	13.6964	13.2033	6.9526	9.7100	12.0343
2011	11.5175	13.7285	13.6240	7.5932	9.7114	12.0424
2012	11.6025	13.7767	13.6668	7.7368	9.7443	12.1159
2013	11.6075	13.8347	13.6903	7.7453	9.7457	12.1552
2014	11.6081	13.8513	13.6908	7.7453	9.7471	12.1567
CAGR	1.90%	1.71%	0.98%	3.88%	1.26%	1.00%

Table 8. Normalized Sigma and Gamma PSPW Indexes of Six Regional Subgroups (1990-2014)

	East Asia & Pacific (31)		Europe & Central Asia& North America (55)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	0.9992	0.9994***	0.9925	0.9992***
1992	0.9716	0.9948***	0.9793	0.9939***
1993	0.9295	0.9914***	0.9552	0.9907***
1994	0.9084	0.9890***	0.9551	0.9900***
1995	0.8937	0.9811***	0.9442	0.9908***
1996	0.8950	0.9815***	0.8901	0.9830***
1997	0.8742	0.9817***	0.8865	0.9810***
1998	0.8743	0.9797***	0.8747	0.9805***
1999	0.8726	0.9797***	0.8609	0.9779***
2000	0.8720	0.9814***	0.7945	0.9477***
2001	0.8598	0.9697***	0.7766	0.9560***
2002	0.8131	0.9485***	0.7368 *	0.9641***
2003	0.8014	0.9496***	0.7083 **	0.9567***
2004	0.7981	0.9474***	0.6911 **	0.9628***
2005	0.7962	0.9470***	0.6809 **	0.9805***
2006	0.7660	0.9398***	0.6773 **	0.9800***
2007	0.7648	0.9464***	0.6538 ***	0.9706***
2008	0.7502	0.9466***	0.6509 ***	0.9679***
2009	0.7467	0.9472***	0.6489 ***	0.9641***
2010	0.7441	0.9462***	0.6473 ***	0.9657***
2011	0.7441	0.9462***	0.6356 ***	0.9652***
2012	0.7465	0.9386***	0.6260 ***	0.9766***
2013	0.7383	0.9386***	0.6264 ***	0.9900***
2014	0.7383	0.9386***	0.6244 ***	0.9897***
CAGR	-1.26%	-0.26%	-1.94%	-0.04%

*p<0.05, **p<0.01, ***p<0.001

Once again, the speed of σ convergence varied by regional subgroups. For σ indexes of PSPW, three regions of LAC (-2.56%), SA (-2.03%) and ECANA (-1.94%) displayed faster speed of σ convergence compared to the total group's speed at -1.74%. On the other hand, two regions of EAP (-1.26%) and SSA (-1.52%) experienced somewhat slower speeds. The region of MENA displayed a nearly equal speed at -1.82% to the total group's speed, as shown in Table 8. As for σ convergence of PSPU, three regions with faster speed were in the order of EAP (-2.46%), followed by ECANA and LAC tied at -2.31% each. Three regions of MENA (-1.71%), SSA (-1.12%) and SA (-0.64%) displayed slower speed than the total group's speed at -1.82%, as shown in Table 9.

In general, faster CAGRs of PSPW measures are associated with faster speed of σ convergence in a majority of regions. In contrast, faster CAGR of PSPU measures experienced a few exceptional cases of being associated with slower speed of σ convergence. For example, the second fastest speed of σ convergence in PSPW at -2.03% displayed by SA region became the slowest speed of σ convergence in PSPU at -0.64%.

As for PSPW, the fastest speed of γ convergence was -0.72% by LAC, followed by MENA at -0.07%, SA at -0.64%. ECANA displayed a nearly stationary trend at -0.04%. As for the association between CAGR and speed of γ convergence. The three regions (SA, LAC and MENA) with the most rapid CAGRs of PSPW also displayed the most rapid speed of γ convergence. Similarly, the two regions (MENA and EAP) with the most rapid of CAGR of PSPU also displayed the most rapid speed of γ convergence. However, there were a few cases of exceptions in such region as in ECANA.

In summary, results from the subgroup analysis by income and region both support the σ and γ convergence displayed by the total group for both PSPW and PSPU. The ranking order of speed of γ convergence by income subgroups is identical between PSPW and PSPU. For both PSPW and PSPU,

Table 8. [Continued] Normalized Sigma and Gamma PSPW Indexes of Six Regional Subgroups (1990-2014)

	Latin America & Caribbean (40)		Middle East & North Africa (19)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	0.9898	0.9990***	0.9950	0.9965 ***
1992	0.9738	0.9832***	0.9741	0.9702 ***
1993	0.8838	0.9119***	0.9715	0.9699 ***
1994	0.8711	0.9090***	0.9101	0.9737 ***
1995	0.8286	0.8884***	0.9056	0.9576 ***
1996	0.7891	0.8874***	0.8896	0.9658 ***
1997	0.7850	0.8851***	0.8201	0.9501 ***
1998	0.7575	0.8719***	0.8106	0.9357 ***
1999	0.7449	0.8780***	0.8107	0.9357 ***
2000	0.7234	0.8629***	0.7453	0.8954 ***
2001	0.7056	0.8663***	0.7064	0.8884 ***
2002	0.6947	0.8658***	0.6934	0.8867 ***
2003	0.6733 *	0.8644***	0.6937	0.8791 ***
2004	0.6512 *	0.8574***	0.6877	0.8867 ***
2005	0.6403 **	0.8570***	0.6867	0.8718 ***
2006	0.6378 **	0.8580***	0.6847	0.8700 ***
2007	0.6327 **	0.8578***	0.6829	0.8700 ***
2008	0.6111 **	0.8529***	0.6681	0.8560 ***
2009	0.6065 **	0.8597***	0.6654	0.8525 ***
2010	0.5815 **	0.8653***	0.6642	0.8455 ***
2011	0.5395***	0.8461***	0.6541	0.8446 ***
2012	0.5373***	0.8403***	0.6434	0.8508 ***
2013	0.5366***	0.8403***	0.6435	0.8508 ***
2014	0.5366***	0.8403***	0.6435	0.8508 ***
CAGR	-2.56%	-0.72%	-1.82%	-0.67%

*p<0.05, **p<0.01, ***p<0.001

Table 8. [Continued] Normalized Sigma and Gamma PSPW Indexes of Six Regional Subgroups (1990-2014)

	South Asia (7)		Sub Saharan Africa (46)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	0.9835	1.0000 ***	0.9922	0.9942 ***
1992	0.9603	1.0000 ***	0.9876	0.9928 ***
1993	0.8621	0.8929 ***	0.9823	0.9941 ***
1994	0.8546	0.8929 ***	0.9473	0.9891 ***
1995	0.8428	0.8929 ***	0.9245	0.9901 ***
1996	0.8430	0.8929 ***	0.9204	0.9900 ***
1997	0.8613	0.8036 ***	0.9104	0.9910 ***
1998	0.8584	0.8750 ***	0.8659	0.9813 ***
1999	0.8599	0.8750 ***	0.8158	0.9742 ***
2000	0.8400	0.8750 ***	0.8128	0.9678 ***
2001	0.8307	0.8750 ***	0.8027	0.9677 ***
2002	0.8307	0.8750 ***	0.8003	0.9659 ***
2003	0.7316	0.8036 ***	0.7961	0.9640 ***
2004	0.7122	0.8036 ***	0.7959	0.9511 ***
2005	0.6699	0.8750 ***	0.7627	0.9494 ***
2006	0.6692	0.8750 ***	0.7577	0.9450 ***
2007	0.6595	0.8750 ***	0.7142 *	0.9295 ***
2008	0.6117	0.8571 ***	0.7041 *	0.9301 ***
2009	0.6117	0.8571 ***	0.7025 *	0.9311 ***
2010	0.6117	0.8571 ***	0.6972 *	0.9277 ***
2011	0.6117	0.8571 ***	0.6976 *	0.9196 ***
2012	0.6117	0.8571 ***	0.6946 *	0.9200 ***
2013	0.6117	0.8571 ***	0.6934 *	0.9200 ***
2014	0.6117	0.8571 ***	0.6932 *	0.9202 ***
CAGR	-2.03%	-0.64%	-1.52%	-0.35%

*p<0.05, **p<0.01, ***p<0.001

Table 9. Normalized Sigma and Gamma PSPU Indexes of Six Regional Subgroups (1990-2014)

	East Asia & Pacific (32)		Europe & Central Asia & North America (55)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	1.0066	1.0021***	0.9631	0.9986***
1992	0.9821	1.0010***	0.9350	0.9718***
1993	0.8731	0.9049***	0.9133	0.9690***
1994	0.8430	0.8988***	0.8963	0.9649***
1995	0.8403	0.8988***	0.8234	0.9539***
1996	0.8072	0.8937***	0.8089	0.9482***
1997	0.7729	0.8833***	0.7972	0.9517***
1998	0.7492	0.8771***	0.7882	0.9380***
1999	0.7092	0.8844***	0.7559 *	0.9328***
2000	0.6741	0.8737***	0.7256 **	0.9293***
2001	0.6578 *	0.8722***	0.6982 **	0.9292***
2002	0.6397 *	0.8673***	0.6822 **	0.9455***
2003	0.6196 **	0.8667***	0.6553***	0.9462***
2004	0.5926 **	0.8614***	0.6525***	0.9712***
2005	0.5765 **	0.8276***	0.6443***	0.9846***
2006	0.5734 **	0.8276***	0.6246***	0.9834***
2007	0.5689 **	0.8263***	0.6194***	0.9825***
2008	0.5487***	0.8281***	0.5881***	0.9777***
2009	0.5452***	0.8225***	0.5842***	0.9763***
2010	0.5453***	0.8218***	0.5838***	0.9688***
2011	0.5458***	0.8142***	0.5815***	0.9642***
2012	0.5498***	0.7838***	0.5797***	0.9791***
2013	0.5495***	0.7831***	0.5735***	0.9811***
2014	0.5495***	0.7831***	0.5713***	0.9797***
CAGR	-2.46%	-1.01%	-2.31%	-0.09%

*p<0.05, **p<0.01, ***p<0.001

the ranking order of speed for γ convergence is first, the low middle income group followed by the upper middle, and the high income subgroup. The ranking order on the speed of σ convergence between PSPW and PSPU was also identical. For both PSPW and PSPU, the order was reversed in that the high income group is the first, followed by the upper middle, low middle, and low income subgroups.

The annual rate of improvement between PSPW and PSPU measures also follows the identical ranking order of first, the low middle, followed by the upper middle, and the high income subgroup. In other words, the ranking order on the speed of γ convergence by income subgroups displays nearly perfect match to the ranking order of annual improvement rates for the average yearly measures of PSPW and PSPU. Put it another way, faster speed of catch-up appears to be related to the annual improvement rate of PSPW and PSPU measures. In short, faster improvement rate of PSPW and PSPU measures is accompanied by faster catch up-effect among countries in respective income subgroups. On the other hand, a reverse relationship existed between speed of σ convergence and annual improvement rate of PSPW and PSPU measures.

Among the 6 regional subgroups, LAC and SA displayed the most rapid CAGR and speeds of σ and γ convergence in PSPW. On the other hand, EAP displayed the most rapid CAGR as well as speeds of σ and γ convergence in PSPU. MENA region was rated by both PSPW and PSPU to have realized rapid improvement in the CAGRs as well as in the speed of σ and γ convergence. In general, a majority of regions have displayed a positive relationship between the annual rate of increase in PSPW and PSPU measures to the annual speed of σ and γ convergence.

Conclusion

Key findings from this paper can be summarized as follows. First, the annual rates of increase in both PSPW and PSPU were estimated at +1.42% and

Table 9. [Continued] Normalized Sigma and Gamma PSPU Indexes of Six Regional Subgroups (1990-2014)

	Latin America & Caribbean (40)		Middle East & North Africa (19)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	0.9961	0.9968***	0.9890	0.9991 ***
1992	0.9876	0.9962***	0.9719	0.9904 ***
1993	0.9694	0.9976***	0.9271	0.9798 ***
1994	0.9557	0.9970***	1.0215	0.9658 ***
1995	0.9387	0.9952***	0.9963	0.9605 ***
1996	0.9153	0.9953***	0.9459	0.9474 ***
1997	0.9078	0.9946***	0.8669	0.9070 ***
1998	0.8720	0.9968***	0.8108	0.8868 ***
1999	0.8691	0.9887***	0.8007	0.8816 ***
2000	0.8402	0.9866***	0.8032	0.8570 ***
2001	0.8287	0.9839***	0.7885	0.8579 ***
2002	0.7794	0.9834***	0.7826	0.8570 ***
2003	0.7740	0.9841***	0.7703	0.8623 ***
2004	0.7691	0.9828***	0.7706	0.8623 ***
2005	0.7128 *	0.9764***	0.7709	0.8623 ***
2006	0.7092 *	0.9727***	0.7766	0.8623 ***
2007	0.6593 **	0.9694***	0.7202	0.8684 ***
2008	0.6550 **	0.9689***	0.7096	0.8658 ***
2009	0.6514 **	0.9682***	0.7075	0.8658 ***
2010	0.6456 **	0.9648***	0.6766	0.8886 ***
2011	0.5809***	0.9453***	0.6553	0.8816 ***
2012	0.5707***	0.9449***	0.6616	0.8675 ***
2013	0.5714***	0.9458***	0.6606	0.8675 ***
2014	0.5713***	0.9458***	0.6606	0.8675 ***
CAGR	-2.31%	-0.23%	-1.71%	-0.59%

*p<0.05, **p<0.01, ***p<0.001

+1.48% respectively during the 1990 to 2014 period. The annual rates of increasing of PSPW and PSPU varied substantially by the four income subgroups. In general, the low 1990 PSPW and PSPU by the low middle income group generated the more rapid rate of increase, while the highest 1990 PSPW and PSPU by the high income subgroups generated the second slowest rate of increase for the period under analysis.

Second, statistically significant decreasing trends of σ and γ indexes have been determined for both PSPW and PSPU measures indicating the existence of σ and γ convergence for the total group of 198 countries during the period of 1990 to 2014. In other words, countries lagging in their species protection effects in early years have improved faster so that they can catch up to the leading countries over time. In addition, dispersion of PSPW and PSPU measures among countries decreased during the period.

Third, σ and γ indexes of PSPW and PSPU indexes also displayed statistically significant convergence pattern for the four income subgroups of countries, supporting the convergence patterns by the total group of countries. However, speeds of ó and γ convergence varied widely among different subgroups. For example, annual speed of catch-up by the lower middle income group was about six times faster than that by the low income group. Fourth, statistically significant σ and γ convergence patterns have also been estimated for the six regional subgroups for both PSPW and PSPU. Once again, annual speeds of σ and γ convergence varied significantly by respective regions. For example, the overall speed of catch-up by LAC region is about eighteen times faster than that of ECANA region.

Fifth, a positive association between the annual improvement rate of PSPW and PSPU measures to the speed of γ convergence of catch-up appears to exist among the four income subgroups of countries, while a negative relationship exists between the annual improvement rate and the speed of σ convergence. For example, those 48 countries in the lower

Table 9. [Continued] Normalized Sigma and Gamma PSPU Indexes of Six Regional Subgroups (1990-2014)

	South Asia (7)		Sub Saharan Africa (46)	
Year	Sigma	Gamma	Sigma	Gamma
1990	1.0000	1.0000	1.0000	1.0000
1991	0.9794	1.0000***	1.0032	0.9979***
1992	0.8676	0.9464***	1.0047	0.9978***
1993	0.8954	0.9464***	0.9958	0.9967***
1994	0.8954	0.9464***	0.9756	0.9955***
1995	0.9281	0.9286***	0.9569	0.9957***
1996	0.9157	0.9286***	0.9401	0.9943***
1997	0.9151	0.9286***	0.9283	0.9941***
1998	0.9071	0.9286***	0.9169	0.9929***
1999	0.9050	0.9286***	0.8998	0.9891***
2000	0.8841	0.9286***	0.8747	0.9690***
2001	0.8801	0.9286***	0.8575	0.9676***
2002	0.8749	0.9286***	0.8268	0.9431***
2003	0.8732	0.9286***	0.8121	0.9426***
2004	0.8707	0.9286***	0.7962	0.9397***
2005	0.8704	0.9286***	0.7887	0.9354***
2006	0.8693	0.9286***	0.7868	0.9346***
2007	0.8685	0.9286***	0.7813	0.9209***
2008	0.8686	0.9286***	0.7839	0.9133***
2009	0.8591	0.9286***	0.7845	0.9052***
2010	0.8630	0.9286***	0.7770	0.9055***
2011	0.8626	0.9286***	0.7762	0.9040***
2012	0.8585	0.9286***	0.7719	0.8974***
2013	0.8582	0.9286***	0.7638	0.8974***
2014	0.8580	0.9286***	0.7638	0.8974***
CAGR	-0.64%	-0.31%	-1.12%	-0.45%

*p<0.05, **p<0.01, ***p<0.001

middle income subgroup with the initially lowest PSPW and PSPU measures in 1990 displayed fastest annual rate of improvement. At the same time, these 48 countries achieved the fastest speed of catch-up and the slowest speed of ó convergence during the period. On the other hand, those 68 countries in the high income subgroup with the initially highest PSPW and PSPU measures in 1990 displayed the slowest annual rate of improvement. At the same time, these 68 countries realized the slowest speed of catch-up and the fastest speed of ó convergence during the period.

Sixth, the positive relationship, in general, appears to exist between the annual rate of increase in both PSPW and PSPU to the speeds of σ and γ convergence across regions. In other words, those regions with the lowest level of PSPW and PSPU measures in the early years have experience not only the fastest speed of catch-up (γ convergence) and dispersion reduction (ó convergence), but also the most rapid annual rates of improvement in species protection measures.

What are some policy implications for the world and for the specific subgroup of countries? The fact that there are those subgroups with initially low PSPW and PSPU measures like MENA, SSA and low middle income groups have generated more rapid rates of catch-up together with faster rates of increasing PSPW and PSPU suggest that the gap between the leading versus lagging countries has narrowed in the future and is expected to continue. Consequently, the whole world may achieve the minimum Aichi target of 17% soon. As for individual countries with lower level of species protection, they can use the outputs from this research in evaluating their own past progress and setting future targets. The most important outputs for individual countries are annual improvement rates, speed of dispersion reduction and speed of catch-up process for PSPW and PSPU measures. These research has demonstrated that these outputs vary so widely among different income or regional subgroups of countries. Thus, individual countries should select those output measures from the appropriate income or regional subgroup where they belong rather than from the total group of 198 countries.

For example, for a country in the lower middle subgroup, the appropriate annual speed of catch-up is -0.93% for PSPU measure instead of -0.54% for the total group of countries. Likewise, the appropriate annual improvement rate for PSPU measure is 2.02%, rather than 1.48% estimated for the total group of countries. For a country in the LAC region, the appropriate speed of catch-up for PSPW measure is -0.72% instead of -0.36% for the total group, while the appropriate annual improvement rate for PSPW measures 2.23% instead of 1.42% from the total group of countries. All of these appropriate values for respective subgroups should represent the minimum values for individual countries within the respective subgroup.

Furthermore, the positive association identified between annual improvement targets and speeds of catch-up for respective income subgroup may provide some additional insight in setting the future targets for both indicators for a given country. It may also be useful to conduct benchmarking those countries within the same subgroups who have achieved outstanding results in implementation of species protection.

There are several limitations to this research. Perhaps, the most serious limitation is associated with the PSPU and PSPW indicators we have used. Data for these limitations are available for a rapidly growing list of more than 30,000 species (Group on Earth Observations Biodiversity Observation Network, 2015). The indicator uses annual territorial species and environmental data from Landsat and moderate – resolution imaging spectroradiometer (MODIS) to map and measure suitable species satellites habitat at high resolutions. However, limitations stem from its ability to match spatial resolution with the granularity registered for species conservation on the ground (Zellner *et al.*, 2011). Improving the resolution of free or low-cost sources of satellite imagery will improve the accuracy of conservation data in the future. In addition, there are several future research topics which can extend the results from this research. A possible topic is to combine the convergence analysis of both territorial protection indicators with species protection indexes. Another future topic is to use club convergence methodology to examine formation of different subgroups of countries. In spite of these limitations, this research accomplished a modest beginning toward understanding catch-up processes for the total group of 198 countries and identified those middle income, LAC, EAP and MENA subgroups of countries which will play critical roles of controlling species loss in the future.

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