International trends in forest products consumption: Is there convergence?

J. BUONGIORNO

Department of Forest and Wildlife Ecology, University of Wisconsin, Madison WI, USA

E-mail:jbuongio@wisc.edu

SUMMARY

International data from 1961 to 2005 showed that the coefficient of variation of consumption per capita across countries had tended to decrease over time for all forest products except sawnwood. This convergence of per-capita consumption was confirmed by the trends in Theil's inequality coefficients: the distribution of forest products consumption across countries had become more similar to the distribution of population. The rate of convergence had tended to accelerate during the last 10 years of observation: countries had become more similar in their use of all forest products except sawnwood. The rate of convergence was most rapid for fiberboard, veneer and plywood, and paper and paper board excluding newsprint and other printing and writing paper. The convergence of per-capita consumption of forest products stemmed in large part from lower rates of growth of consumption at higher levels of per-capita consumption, and not from a convergence of per-capita income.

Keywords: wood products, consumption, utilization, statistics

INTRODUCTION

The objective of this paper is to determine whether countries have become more similar in their consumption of forest products, over the past 40 years, and to explore the speed and mechanism of this convergence. Are there automatic forces that lead to convergence over time in the level of per-capita consumption of forest products?

Most of past studies of economic convergence have dealt with macroeconomics rather than sectors or industries. There is a large body of literature dealing with the world distribution of income and income inequality, and its evolution over time (Heshmati 2006). Lucas (2000) makes the bold claim, on purely theoretical grounds that "sooner or later...all economies will grow at the same rate common to the wealthiest economies [and the] percentage differences in income level will disappear". But empirical studies are far from agreeing.

Barro and Sala-i-Martin (1992) find that "convergence takes place, but at a very slow pace". This is in agreement with the results of Jones (1997), Bourguignon and Morrisson (2002), and Ball *et al.* (2004). One of the most sanguine statements is in Sala-i-Martin (2006) who argues for "convergence, period".

However, at the other extreme, Prichett (1997) finds "divergence, big time", and Romer (1994) writes that "convergence [of income across countries] clearly fails", a claim also made earlier by De Long (1988) in opposition to the positive finding of Baumol (1986).

A difficulty of macroeconomic studies of convergence lies in the measurement of variables such as national income. Dowrick and Quiggin (1997) find that "changes in price indices lead to convergence". It is therefore helpful to investigate specific sectors and products. For food, Hermann and Röder (1995) conclude that "food consumption converges...in OECD countries", but "when we disaggregate into individual food products, the evidence is less obvious". Similarly, Kónya and Ohashi (2007) find "strong convergence in cross-country consumption patterns with substantial heterogeneity across products and countries."

In the present study we dealt with forest products consumption defined in physical measures (m^3 or t) to lessen the aggregation problem and avoid price indices. We also restricted ourselves to countries that had complete data over a long period of time. The results suggested slow convergence of forest products consumption per capita across countries for all products except sawnwood, as countries with low consumption per capita tended to grow faster.

METHODS AND DATA

In the case of forest products, only country level-data are available for most countries. Thus, indices of convergence must be based on data on total national consumption. To take into account the large differences in population between countries, consumption per capita was used as the basic unit of information. In computing indices and in regression analysis, consumption per capita and income per capita were weighted by population.

In parallel with studies of income distribution, we investigated two aspects of convergence in forest products consumption, the so-called sigma and beta convergence (Sala-i-Martin, 2006). Sigma convergence implies that the spread of consumption per capita across countries decreases over time. Beta convergence means that countries with low consumption per capita have higher growth rates of consumption per capita than countries with high consumption per capita.

Thus, sigma convergence simply measures how fast consumption per capita is becoming similar across countries, while beta convergence describes a particular way in which convergence occurs. Beta convergence suggests a saturation process whereby consumption per capita increases at a decreasing rate up to the point where no more of a product is wanted or needed.

Sigma convergence

Two indices were used to measure the sigma convergence, i.e. the spread of consumption per capita across countries and its change over time. One was the population-weighted coefficient of variation of consumption per capita in a given year, CV_t. For each product:

$$CV_t = SD_t / \bar{c}_t \qquad (1)$$

Where $\bar{c}_t$ was the population-weighted mean consumption per capita across countries in year t, and SD_t was the population-weighted standard deviation:

$$SD_t = \sqrt{\sum_{i=1}^{N} n_{it}(c_{it} - \bar{c}_t)^2 / \sum_{i=1}^{N} n_{it}} \qquad (2)$$

Where n_{it} was the population of country i in year t, c_{it} was the consumption per capita, and N was the number of countries.

As a measure of convergence, the coefficient of variation (1) was preferred to the standard deviation (2) because by measuring variability relative to the mean, $\bar{c}_t$ the coefficient of variation accounted for the fact that the mean consumption per capita of most product had increased substantially over time.

The other measure of sigma convergence was Theil's inequality index (Conceição and Ferreira 2000). For a particular product and year Theil's inequality index was:

$$Theil_t = \sum_{i=1}^{N} s_{cit} \ln \frac{s_{cit}}{s_{nit}} \qquad (3)$$

Where s_{cit} was the country i share of total consumption in year t, and s_{nit} was the country's share of total population in the N countries. Theil's index measured the discrepancy

between the distribution of consumption and the distribution of population in a particular year. If the shares of consumption and population were the same in all countries, then $s_{ci} / s_{ni} = 1$ for all i and $Theil_t = 0$, indicating perfect equality of consumption across countries. The value of the index increased as the distribution of consumption became less equal relative to the distribution of population.

Another version of Theil's index inverts the population share and the income share in equation (3) (Conceição and Ferreira 2000). As both versions led to essentially the same results in this application only the results obtained with Theil's index (3) are reported below.

Beta convergence

Beta convergence meant that the rate of growth over a given time interval was higher for countries with lower initial consumption per capita. One of the simplest models to test beta convergence is (Barro and Sala-i-Martin 1992, Dowdrick and Quiggin 1997):

$$r_{ci} = \alpha + \beta \ln c_i + u_i \qquad i = 1,...,N \qquad (4)$$

In this application r_{ci} was the average annual rate of growth of consumption per capita of a particular product in country i from 1995 to 2005, c_i was the level of consumption per capita in 2005, and u_i was an error term. The rate of growth, r_{ci}, was estimated by fitting an exponential curve to per capita consumption data for each country and product from 1995 to 2005. According to the hypothesis of beta convergence the parameter β should be negative.

An alternative model was also used to account for the fact that another important determinant of the growth of consumption of forest products is the growth of income (see for example Simangunsong *et al.* 2001). This led to the following equation:

$$r_{ci} = \alpha + \beta \ln c_i + \gamma r_{yi} + u_i \qquad i = 1,...,N \qquad (5)$$

Where r_{yi} was the average annual rate of growth of income per capita in country i from 1995 to 2005. r_{yi} was obtained by fitting an exponential curve to the time-series of real per capita income data in each country from 1995 to 2005. One would expect the parameter γ to be positive, and the parameter β to be negative as in equation (4).

To account for the different country sizes, models (4) and (5) were estimated by weighted least squares, the population of each country serving as weight. For example, equation (4) was estimated from the following least-squares regression without a constant (Verbeek, 2008 p.92):

$$\sqrt{n_i} r_{ci} = \alpha \sqrt{n_i} + \beta \sqrt{n_i} \ln c_i + u_i \qquad i = 1,...,N \qquad (6)$$

Data

The data were for the years 1961 to 2005 for the countries and product groups in Table 1. The data came from the FAOSTAT data base (FAO 2008a). For each year and country consumption was equal to production plus imports minus exports. Only countries that had complete data from 1961 to 2005 were used to study convergence.

Each product group is defined succinctly as follows (FAO (2008b) gives complete definitions):

Sawnwood: "Wood that has been produced from domestic and imported roundwood, either by sawing lengthwise or by profile-chipping process".

Veneer sheets: "Thin sheets of wood of uniform thickness, rotary cut (i.e. peeled), sliced or sawn". *Plywood*: "A panel consisting of an assembly of veneer sheets bonded together".

Particleboard: "A panel manufactured from small pieces of wood and other lingo-cellulosic materials...bonded together by use of an organic binder".

Fiberboard: "A panel manufactured from fibers of wood and other lingo-cellulosic materials with the primary bond deriving from the felting of the fibers and their inherent adhesive properties".

Newsprint: "Uncoated paper, unsized (or only slightly sized), containing at least 60 percent of mechanical wood pulp".

Printing and writing paper: "Paper, except newsprint, suitable for printing and business purposes, writing, sketching, drawing, etc..."

Other paper and paperboard: "All other types of paper".

The yearly country data for GDP per capita from 1961 to 2005, in real U.S. $ with base year 2000, were obtained from the World Bank (2008)

RESULTS

Sigma convergence

To recall, sigma convergence was measured by the changes over time of the spread of consumption per capita across countries. The spread was measured by the coefficient of variation of consumption per capita (1), and by Theil's index of inequality (3).

Solid wood products

For *sawnwood* in the 66 countries that had complete data from 1961 to 2005, the mean of the yearly per-capita consumption across countries decreased at an average of 0.4 percent per year. The decline was more rapid after 1988 (Figure 1a). The population-weighted coefficient of variation, *CV*, declined slightly during the 1960's and 1970's, but increased from 136 percent in 1982 to 185 percent in 2005. Thus, there was a divergence in sawnwood consumption per capita across countries during the last 20 years. The Theil index followed a similar trend, indicating that the distribution of consumption relative to population had become more unequal from 1982 to 2005.

For *veneer and plywood*, the average consumption per capita increased at 1 percent per year from 1961 to 2005 in the 54 countries with complete data. The growth was slower after the energy shock of 1973-1975 (Figure 1b). The

TABLE 1 *Countries with complete consumption data from 1961 to 2005, indicated by 'x'*

Countries	Sawnwoood	Veneer & plywood	Particle-board	Fiberboard	Newsprint	Printing & writing paper	Other paper & paperboard
Algeria	x	x	x		x		x
Argentina	x				x	x	x
Australia	x	x	x	x	x	x	x
Austria	x	x	x	x	x	x	x
Belize	x						
Bolivia					x		
Brazil	x	x		x	x	x	x
Burkina Faso							x
Cameroon	x	x					x
Canada	x	x		x		x	x
Central Afr. Rep.	x						x
Chile	x	x			x	x	x
China	x	x		x	x	x	x
Colombia	x				x	x	x
Congo, Dem. Rep.	x					x	x
Congo, Rep.							x
Costa Rica	x	x			x	x	x
Cote d'Ivoire		x					x
Denmark	x	x	x	x	x	x	x
Dominican Rep.	x	x			x	x	x
Ecuador	x	x			x	x	x
Egypt, Arab Rep.	x	x			x	x	x
El Salvador	x	x			x		x
Finland	x	x	x	x	x	x	x
France	x	x	x	x	x	x	x
Gabon	x						
Ghana	x	x			x	x	x
Greece	x	x	x	x	x	x	x
Guatemala	x	x			x	x	x
Guyana					x	x	x
Haiti	x					x	x
Honduras	x				x		x
Hungary	x	x		x	x	x	x
Iceland	x	x		x	x	x	x
India	x	x		x	x	x	x
Indonesia	x	x			x	x	x
Ireland	x	x	x	x	x	x	x
Israel	x	x				x	x
Italy	x	x	x	x	x	x	x

coefficient of variation suggested a continued convergence in the relative consumption per capita across countries. This convergence accelerated in the later part of the period, as the CV dropped from 200 percent in 1985 to 140 percent in 2005. The same trend towards a more equal distribution of consumption of veneer and plywood was indicated by Theil's index.

Particleboard had by far the fastest growth of consumption per capita among solid wood products, 6 percent per year from 1961 to 2005 in the 18 countries that had complete data. The coefficient of variation of per-capita consumption across countries decreased rapidly at

TABLE 1 *contd: Countries with complete consumption data from 1961 to 2005, indicated by 'x'*

Countries	Sawnwoood	Veneer & plywood	Particle-board	Fiberboard	Newsprint	Printing & writing paper	Other paper & paperboard
Japan	x	x	x	x	x	x	x
Kenya	x	x			x	x	x
Korea, Rep.	x	x			x		x
Madagascar							x
Malaysia	x	x			x	x	x
Malta	x	x			x	x	
Mexico	x	x			x	x	x
Morocco	x				x		x
Netherlands	x	x	x	x	x	x	x
New Zealand	x	x		x	x	x	x
Nicaragua					x	x	x
Nigeria	x	x		x	x	x	x
Norway	x	x	x	x	x	x	x
Pakistan	x	x				x	x
Panama	x			x	x	x	x
Papua New Guinea	x						
Paraguay	x				x	x	x
Peru	x	x			x	x	x
Philippines	x	x			x	x	x
Portugal	x			x	x	x	x
Senegal	x	x					x
South Africa	x	x	x	x	x	x	x
Spain	x	x	x	x	x	x	x
Sri Lanka	x	x			x	x	x
Sudan	x	x					x
Sweden	x	x	x	x	x		x
Switzerland	x	x	x	x	x		x
Syrian Arab Rep.	x	x			x	x	x
Thailand		x			x	x	x
Trinidad & Tobago	x	x			x	x	x
Tunisia	x	x					x
United Kingdom	x	x	x	x	x	x	x
United States	x	x	x	x	x	x	x
Uruguay	x	x			x		x
Venezuela, RB	x				x	x	x
Total	66	54	18	27	57	53	69

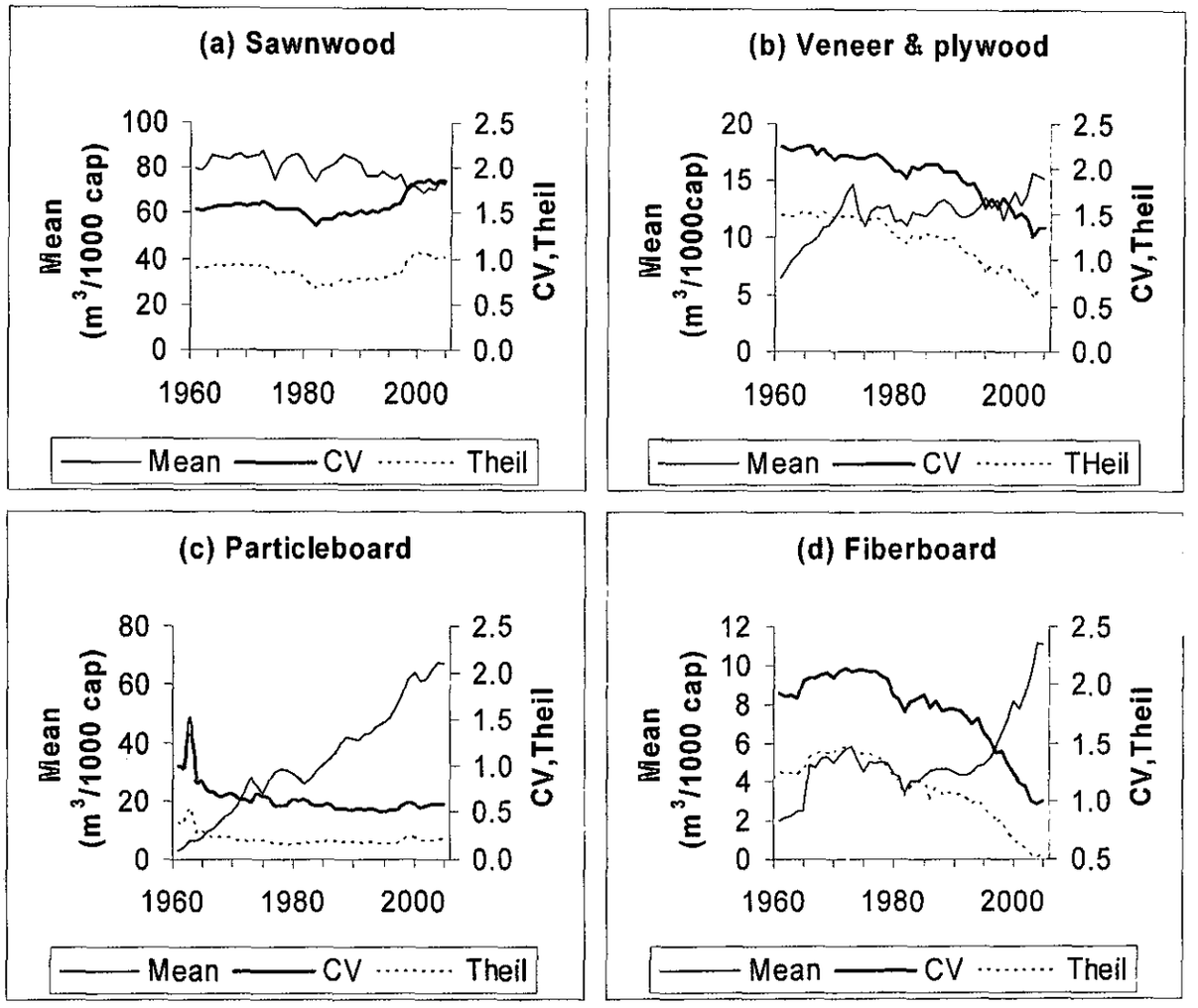
first from 98 percent in 1961 to 58 percent in 1985. But it stayed approximately constant afterwards, suggesting an end to the convergence of consumption per capita during the last decade of observations. Theil's index of inequality confirmed this trend.

For *Fiberboard* (Figure 1d), consumption per capita increased at an average of 2 percent per year from 1961 to 2005 in the 27 countries with complete data. However, from 1985 to 2005, the growth was 8 percent per year, even faster than the growth rate of particleboard. Both the coefficient of variation and Theil's index showed a slight divergence of consumption from 1961 to the late 1970's, followed by a rapid convergence as the CV of consumption per capita decreased from 210 percent in 1975 to 100 percent in 2005.

Paper and paperboard

For *newsprint*, in the 57 countries with complete data from 1961 to 2005, the mean consumption per capita increased at

FIGURE 1 *Mean, coefficient of variation, CV, and Theil inequality index of per-capita sawnwood and wood-based panels consumption across countries. Each observation is weighted by the country population*



an average rate of 1 percent per year, but it stagnated during the last 10 years (Figure 2a). The population-weighted coefficient of variation of consumption per capita increased until the mid 1980's, but then decreased from 201 percent in 1985 to 158 percent in 2005, indicating convergence of consumption per capita during the last ten years. Theil's index followed the same pattern, as the distribution of consumption relative to population was becoming more equal.

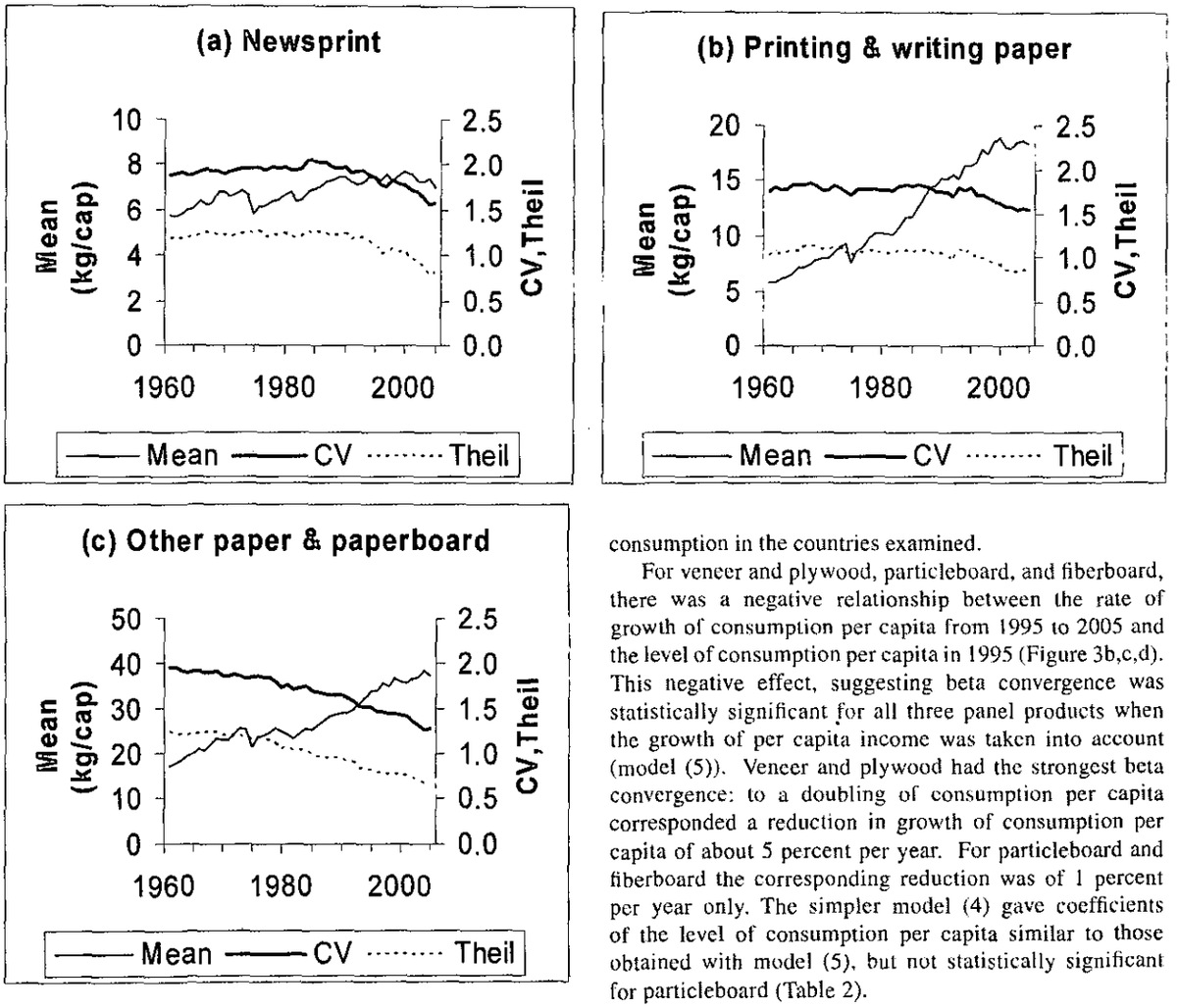
For *printing and writing paper*, the mean consumption per capita in the 53 countries with complete data grew at 3 percent per year from 1961 to 2005, much faster than for newsprint, but like newsprint the growth slowed down during the last 10 years, to 1 percent per year (Figure 2b). There was little change in the coefficient of variation of consumption per capita across countries and in Theil's inequality index until the mid 1980's. Both criteria decreased afterwards, suggesting a convergence in consumption. The CV of consumption per capita went from 183 percent in 1985 to 155 in 2005.

The mean consumption per capita of other *paper and paperboard* in the 69 countries with complete data grew at an average rate of 2 percent per year from 1961 to 2005 (Figure 2c), this was faster than for newsprint but slower than for printing and writing paper. Like newsprint and printing and writing paper, the growth of other paper and paperboard slowed down during the last decade of the data, to1 percent per year. The coefficient of variation of consumption per capita across countries and Theil's inequality index decreased steadily from 1961 to 2005, indicating a convergence of consumption patterns across countries. During the last decade, the CV decreased somewhat faster, from 168 percent in 1985 to 125 percent in 2005.

Beta convergence

Beta convergence occurred if consumption per capita tended

FIGURE 2 *Mean, coefficient of variation, CV, and Theil inequality index of per-capita paper and paperboard consumption across countries. Each observation is weighted by the country population*



to grow slower in countries with higher levels consumption per capita. Table 2 shows the results of estimation of model (4) by population-weighted regression with data from 1995 to 2005, a period of steady growth. The corresponding observed and predicted growth rates of per-capita consumption are shown in Figures 3 and 4.

Solid wood products

For sawnwood, there was a positive relation between the rate of growth of per capita consumption from 1995 to 2005 and the level of consumption per capita in 1995 (Figure 3a). To a doubling of the consumption per capita in 1995 corresponded an average increase in growth rate of consumption per capita of about 2 percent per year (Table 2). This positive relationship, suggestive of beta divergence, was also statistically significant at the 5% level with model (5). Model (5) suggested that, after the level of consumption in 1995 had been taken into account, the growth of income per capita had no effect on the growth of per-capita sawnwood consumption in the countries examined.

For veneer and plywood, particleboard, and fiberboard, there was a negative relationship between the rate of growth of consumption per capita from 1995 to 2005 and the level of consumption per capita in 1995 (Figure 3b,c,d). This negative effect, suggesting beta convergence was statistically significant for all three panel products when the growth of per capita income was taken into account (model (5)). Veneer and plywood had the strongest beta convergence: to a doubling of consumption per capita corresponded a reduction in growth of consumption per capita of about 5 percent per year. For particleboard and fiberboard the corresponding reduction was of 1 percent per year only. The simpler model (4) gave coefficients of the level of consumption per capita similar to those obtained with model (5), but not statistically significant for particleboard (Table 2).

Paper and paperboard

For newsprint, printing and writing paper, and other paper and paperboard, the average annual growth rate of consumption per capita from 1995 to 2005 was negatively related to the level of consumption per capita in 1995, but the effect was small for other paper and paperboard (Figure 4). Both model (4) and model (5) gave statistically significant negative coefficients of the logarithm of consumption per capita. As expected, model (5) also suggested a significant effect of growth of income per capita on consumption per capita, except for printing and writing paper. When the growth of income per capita was accounted for, a doubling of the consumption per capita of newsprint and printing and writing paper implied an average reduction of the annual growth of consumption per capita of about 1.5 percent. The effect was a third that much for other paper and paperboard.

TABLE 2 *Population-weighted regressions of the annual rate of growth of per-capita consumption from 1995 to 2005 on the logarithm of per-capita consumption in 1995, lnc, with and without the annual growth rate of GDP per capita from 1995 to 2005, g_y*

		Model (4)				Model (5)			
Product	**Variable**	**Coef.**	***SE***		***R²***	**Coef.**	***SE***		***R²***
Sawnwood	constant	-0.115	0.025	**	0.29	-0.131	0.031	**	0.28
	lnc	0.023	0.007	**		0.025	0.007	**	
	g_y					0.260	0.285		
Veneer & plywood	constant	0.175	0.013	**	0.76	0.136	0.019	**	0.78
	lnc	-0.052	0.005	**		-0.052	0.005	**	
	g_y					0.959	0.344	**	
Particleboard	constant	0.066	0.031	*	0.41	0.032	0.026		0.62
	lnc	-0.010	0.008			-0.016	0.007	*	
	g_y					3.126	0.916	**	
Fiberboard	constant	0.142	0.011	**	0.83	0.063	0.013	**	0.91
	lnc	-0.013	0.005	**		-0.012	0.003	**	
	g_y					1.640	0.239	**	
Newsprint	constant	0.060	0.006	**	0.66	0.006	0.007		0.86
	lnc	-0.022	0.003	**		-0.013	0.002	**	
	g_y					1.146	0.119	**	
Printing & writing paper	constant	0.064	0.008	**	0.53	0.060	0.012	**	0.52
	lnc	-0.014	0.004	**		-0.014	0.004	**	
	g_y					0.108	0.213		
Other paper & paperboard	constant	0.043	0.006	**	0.51	0.031	0.007	**	0.55
	lnc	-0.005	0.002	*		-0.006	0.002	**	
	g_y					0.347	0.120	**	

*,** coefficients significantly different from zero at 5percent, or 1 percent level.
SE is the standard error, R2 the coefficient of determination corrected for degrees of freedom.

DISCUSSION

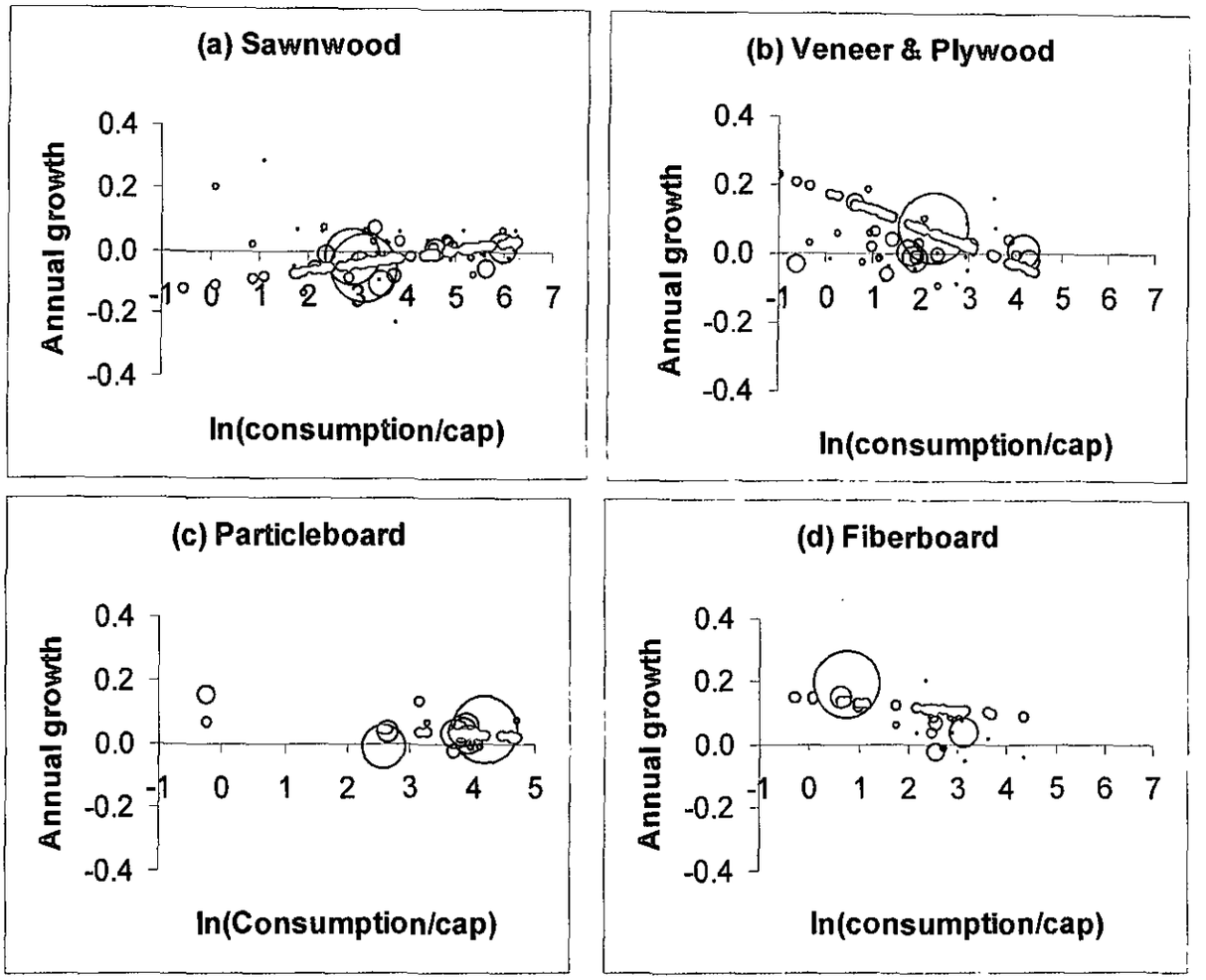
Given the significant positive effect of the growth rate of GDP per capita on the growth rate of consumption per capita for most products (except for sawnwood and printing and writing paper, see Table 2), one might suspect that for the other products the convergence of consumption per capita observed was due to the convergence of income per capita. However, this was not the case.

Table 3 shows the trends of the population-weighted coefficient of variation of GDP per capita, CV_y, across the countries used to calculate the coefficient of variation of consumption per capita, CV_c. Although the countries differed by product, the trends of CV_y were similar. There was a small increase of CV_y from 1961 to 1995 (less than 0.5 percent per year), indicating divergence of GDP per capita, i.e. an increase in economic inequality across countries. This was followed by a decrease of CV_y from 1995 to 2005 (-0.2 to -0.3 percent per year), suggesting a convergence of GDP per capita, i.e. a trend towards economic equality, from 1995 to 2005.

But, there was little relation between the convergence or divergence of GDP per capita and that of consumption per capita. From 1961 to 1995, while GDP per capita diverged, the consumption per capita of all products except newsprint converged (Table 3). From 1995 to 2005, there was agreement between the convergence of GDP per capita and consumption per capita for five of the seven products (the exceptions were sawnwood and particleboard). But, for the products that did converge, the rate of convergence of consumption per capita was much more rapid than that of income per capita (Table 3).

The last column of Table 3 shows the rate of change of the coefficient of variation of per-capita consumption from 1995 to 2005, predicted with equation (5) from the level of per capita consumption in 1995 and the growth rate of GDP per capita from 1995 to 2005. The predicted rate of change had the same sign as the observed from 1995 to 2005, but the absolute values differed substantially for some products. Thus, the saturation process (beta convergence), combined with the convergence of GDP per capita gave only an imperfect explanation of the convergence of forest products consumption.

FIGURE 3 *Annual growth rate of sawnwood and panels per-capita consumption from 1995 to 2005 versus the logarithm of consumption per capita in 2005. Each circle (○) is proportional to the country population. Black circles (●) indicate the population-weighted expected growth rate of consumption, conditional on consumption level*



CONCLUSION

Historical evidence from countries with complete data from 1961 to 2005 suggested that the relative variation of consumption per capita across countries had tended to decrease for all products except sawnwood. This evidence of convergence, or lack thereof for sawnwood, was confirmed by the trends in Theil's inequality coefficients: the distribution of forest products consumption across countries had become closer to the distribution of population. For the products that had converged from 1961 to 2005, the rate of convergence had tended to accelerate during the last decade, except for particleboard. Thus, countries had tended to become more similar in their use of forest products, except sawnwood. The reason for the slight divergence of sawnwood consumption per capita needs further study. It may be due in part to the traditional use of sawnwood in housing in some high income countries of Scandinavia and North America which persists and even expands as income grows[4] due to the perception of solid lumber as a luxury good.

There was evidence that, with the exception of sawnwood, the rate of growth of consumption per capita was inversely related to the level of consumption per capita. This saturation process, or beta convergence, could be used to advantage in developing forecasting models of forest product consumption. Another area of future research might seek the causes of convergence, in particular how it may be tied to expanded trade and globalization (Ben David 1996, Sachs and Warner 1997).

ACKNOWLEDGMENTS

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FIGURE 4 *Annual growth rate of paper and paperboard per-capita consumption from 1995 to 2005 versus the logarithm of consumption per capita in 2005. Each circle (○) is proportional to the country population. Black circles (●) indicate the population-weighted expected growth rate of consumption, conditional on consumption level*

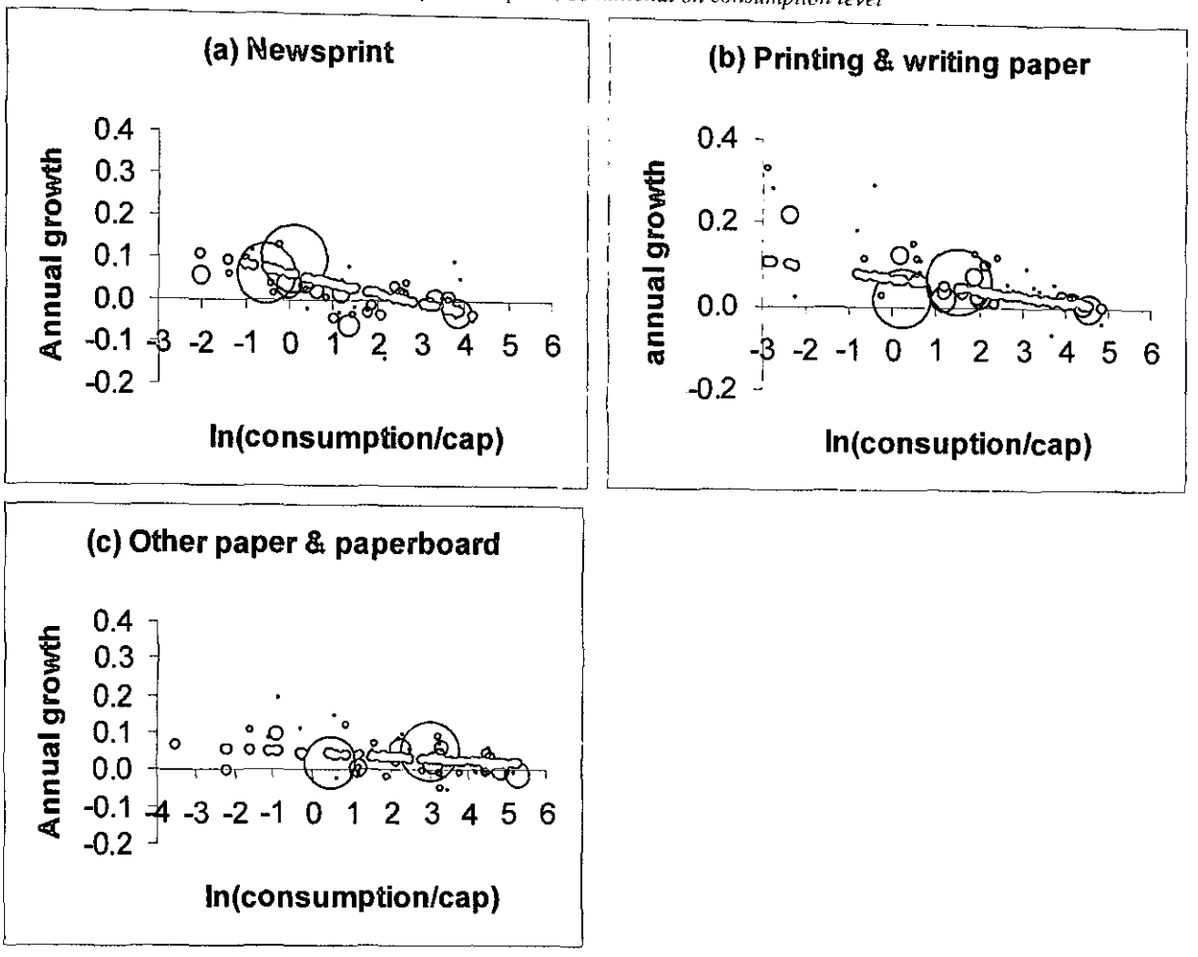

TABLE 3 *Average annual rate of change of the coefficient of variation across countries of GPD per capita, CV_y, and consumption per capita, CV_c*

	Observed 1961-1995		1995-2005 Observed		Predicted[1]
Product	CV_y	CV_c	CV_y	CV_c	CV_c
			%		
Sawnwood	0.41	-0.20	-0.22	1.92	2.14
Plywood	0.37	-0.69	-0.27	-2.30	-6.88
Particleboard	0.20	-1.79	-0.29	1.31	0.06
Fiberboard	0.40	-0.56	-0.32	-5.09	-3.05
Newsprint	0.38	0.07	-0.27	-1.57	-1.53
Printing & writing paper	0.44	-0.04	-0.22	-1.40	-0.99
Other paper & paperboard	0.40	-0.71	-0.21	-1.67	-0.68

[1]Predicted with model (5) from the level of consumption per capita in 2005 and the growth rate of GDP per capita from 1995 to 2005.

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WORLD BANK 2008. World development indicators. World Bank http://www.worldbank.org/ (last accessed in June 2008) or 1 percent level. *SE* is the standard error, R^2 the coefficient of determination corrected for degrees of freedom.