Forest Policy and Economics 106 (2019) 101967

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Country-specific demand elasticities for forest products: Estimation method and consequences for long term projections

Joseph Buongiorno

Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, WI 53706, USA

ARTICLE INFO

Keywords:
Demand
Price and GDP elasticity
Forest products
Forecasting
Econometrics
International

ABSTRACT

Long-term projections for the global forest sector are particularly sensitive to the parameters of the demand equations for the end products. To get more precise estimators, and test statistics with more power than with pure time-series, the elasticities of demand are typically estimated from panel data, pooling time-series across countries, and thus assuming that the elasticities are the same in all countries. The objective of this study was to recognize potential differences between countries, while using the prior information obtained by pooling. The proposed method estimated with quadratic programming country-specific elasticities that minimized the sum of squares of the errors across countries and over time, while keeping the country elasticities within the confidence intervals of the pooled elasticities. The method was applied to international data for seven product groups from 1992 to 2016. Compared with pooling, country-specific elasticities reduced the root mean square error of in-sample predictions by 7% to 43% depending on the product. The country-specific elasticities had smaller standard errors than the pooled elasticities, and they tended to cluster near the bounds of the confidence intervals of the pooled elasticities. With country-specific elasticities in a global sector model the projected world prices in 2065 were 3% to 13% higher, depending on the product, than with pooled elasticities. World consumption in 2065 with country-specific elasticities was from 2% lower to 42% higher depending on the product, with large differences across countries and product groups.

1. Introduction

Accurate estimates of demand equations for forest products are important in forest sector models such as the Forestry and Agriculture Sector Optimization Model (FASOM) (Adams et al., 1996), the Global Forest Products Model (GFPM) (Buongiorno et al., 2003), the European Forest Institute Global Trade Model (EFI-GTM) (Kallio et al., 2004), and the Global Biosphere Management Model (GLOBIOM) (Lauri et al., 2013).

Most of these models applications to international issues assume that the demand equations parameters, in particular the price and income elasticities are the same across countries. Thus, the elasticities are estimated with panel data, i.e. by pooling the data across countries and over time (Simangunsong and Buongiorno, 2001; UNECE, 2012). This approach suits the ideal of simplicity and generality (Baker, 2013) as it minimizes the number of model parameters. Furthermore, by greatly increasing the sample size and data variability compared to pure time-series analysis, it yields more precise estimators and test statistics with more power (Wooldridge, 2006, p. 449).

Yet, countries do differ, for example in the way that wood is being used to build houses. These differences are recognized in part by panel data methods such as fixed- or random-effects estimation (Wooldridge, 2006, p. 485–497). But this still assumes same elasticities across countries, with potentially biased parameters leading to errors in projections and policy analysis.

Past studies of the international demand for forest products have recognized some differences between countries by grouping data by income level or other national characteristics (Kangas and Baudin, 2003; Michinaka et al., 2011; Buongiorno, 2015). The present study continues this course by attempting to estimate country-specific demand equations. It deals with the difficulty of obtaining meaningful (theoretically consistent) elasticities by constraining them to lie within the confidence interval obtained by pooling the data across countries. Within these constraints it seeks the country-specific elasticities that best fit the historical data.

The remainder of the paper is organized as follows. If first describes

E-mail address: jbuongio@wisc.edu.

https://doi.org/10.1016/j.forpol.2019.101967
Received 12 April 2019; Received in revised form 25 June 2019; Accepted 28 June 2019
Available online 10 July 2019

the methods, which consisted in pooling the data to estimate mean and standard error of elasticities, followed by quadratic programming with country-specific elasticities constrained within the 95% confidence interval of the pooled elasticities. It then presents the results of data pooling, the distribution of the country-specific parameters, the gain in the within-sample explanatory power that they obtain, and the consequences of using the country-specific elasticities for long-term projections compared to the pooled elasticities. The conclusion deals with the implications of the findings and potential future research.

2. Methods and data

2.1. Average elasticities and their bounds

When pooling the data across countries and time, the average elasticities of demand were estimated with the following dynamic model (Chas-Amil and Buongiorno, 2000):

$$lnC_{ijt}=\alpha_i lnY_{jt} + \beta_i lnP_{ijt} + \gamma_i lnC_{ijt-1} + \delta_i t + \mu_{ij} + u_{ijt} \quad (1)$$

where the variables were:

C_{ijt} the apparent consumption (production + imports-exports) of product i in country j, and year t,

Y_{jt} the gross domestic product (GDP) in country j and year t, in constant US dollars,

P_{ijt} the price of product i, in country j and year t, estimated as the quantity-weighted average of the unit value of imports and exports, in constant US dollars of 2010, obtained by deflating the current $US data with the United States GDP deflator.

And the parameters were:

α_i the product-specific elasticity of demand with respect to GDP, expected to be positive,

β_i the elasticity of demand with respect to price, expected to be negative,

γ_i the elasticity with respect to lagged consumption, expected to be positive and between 0 and 1,

δ_i the product-specific trend, which could be positive or negative depending on the product,

μ_{ij} the fixed country and product effect, positive or negative depending on the country and product.

u_{ijt} the random residual.

Eq. (1) was estimated with panel data from 1992 to 2016 for the 180 countries used in the GFPM. As the data were pooled across countries and years there was one equation for each of the following groups of end products:

Product	FAOSTAT code
Sawnwood	1892
Veneer & plywood	1634 + 1640
Particleboard	1697
Fiberboard	1874
Newsprint	1671
Printing & writing paper	1674
Other paper & paperboard	1675

The data on production, and on imports and exports quantity and value, in current $US, came from the FAOSTAT forestry data base (FAO, 2018). The data on national GDP and the US GDP deflator were from the World Bank Development Indicators (WBDI, World Bank, 2018) data base. Countries and years that did not have GDP data in the WBDI, or had insufficient trade data in the FAOSTAT to estimate prices, were omitted.

Eq. (1) was estimated independently for each product by ordinary least squares with fixed country effects (Wooldridge, 2006, p. 485). After obtaining the average elasticities and their standard errors, the 95% confidence interval for, say, the price elasticity of demand for a product was estimated as:

$$\hat{\beta}_i \mp 1.96 SE(\hat{\beta}_i) \quad (2)$$

where $SE(\hat{\beta}_i)$ was the standard error of the estimated average price elasticity of product i across all countries.

2.2. Country specific elasticities

The country specific elasticities were estimated with the same theoretical model (1), but allowing the elasticities to differ by country:

$$lnC_{ijt}=\alpha_{ij} lnY_{jt} + \beta_{ij} lnP_{ijt} + \gamma_{ij} lnC_{ijt-1} + \delta_{ij} t + \mu_{ij} + u_{ijt} \quad (3)$$

The parameters of Eq. (3) were obtained by minimizing the sum of the squares of the differences between observed and predicted apparent consumption, given GDP and prices, for all products and countries, and conditional on the upper and lower bounds defined by Eq. (2), based on the pooled estimation. The solution was obtained with the following quadratic programming model:

Find the parameters: α_{ij}^{+}, α_{ij}^{-}, β_{ij}, γ_{ij}, δ_{ij}^{+}, δ_{ij}^{-}, μ_{ij}^{+}, $\mu_{ij}^{-} \geq 0 \; \forall \; ij$.

Such that:

$$\min SSQR_{ijt} = \sum_{ijt} u_{ijt}^2 = \sum_{ijt} (\ln C_{ijt} - \widehat{lnC}_{ijt})^2 \quad (4)$$

Subject to:

$$\widehat{lnC}_{ijt} = \alpha_{ij} lnY_{jt} - \beta_{ij} lnP_{ijt} + \gamma_{ij} lnC_{ijt-1} + \delta_{ij} t + \mu_{ij} \; \forall \; ijt \quad (5)$$

$$\alpha_{ij} = \alpha_{ij}^{+} - \alpha_{ij}^{-} \; \forall \; ij \quad (6)$$

$$\hat{\alpha}_i - 1.96 SE(\hat{\alpha}_i) \leq \alpha_{ij} \leq \hat{\alpha}_i + 1.96 SE(\hat{\alpha}_i) \; \forall \; ij \quad (7)$$

$$\hat{\beta}_i - 1.96 SE(\hat{\beta}_i) \leq \beta_{ij} \leq 0 \; \forall \; ij \quad (8)$$

$$\hat{\gamma}_i - 1.96 SE(\hat{\gamma}_i) \leq \gamma_{ij} \leq \hat{\gamma}_i + 1.96 SE(\hat{\gamma}_i) \; \forall \; ij \quad (9)$$

$$\delta_{ij} = \delta_{ij}^{+} - \delta_{ij}^{-} \; \forall \; ij \quad (10)$$

$$\hat{\delta}_i - 1.96 SE(\hat{\delta}_i) \leq \delta_{ij} \leq \hat{\delta}_i + 1.96 SE(\hat{\delta}_i) \; \forall \; ij \quad (11)$$

$$\mu_{ij} = \mu_{ij}^{+} - \mu_{ij}^{-} \; \forall \; ij \quad (12)$$

In Eqs. (4) and (5) $\widehat{lnC}_{ijt}$ was the predicted logarithm of apparent consumption of product i in country j and year t, given country-specific elasticities. Eq. (6) allowed the GDP elasticity α_{ij} to be free of sign as the difference between the two non-negative variables α_{ij}^{+} and α_{ij}^{-}. Eq. (7) kept the GDP elasticity in the 95% confidence interval of the pooled elasticity. Eq. (8) kept the price elasticity non positive, on theoretical a-priori grounds, and greater than the lower bound defined by the pooled elasticity. Eq. (9) constrained the elasticity of lagged consumption within the bounds of the pooled elasticity. Eq. (10) allowed for a positive or negative time trend, δ_{ij}, since δ_{ij}^{+} and δ_{ij}^{-} were both non negative, and Eq. (11) kept this trend within the 95% confidence interval of the pooled trend. Last, with non-negative μ_{ij}^{+} and μ_{ij}^{-}, Eq. (12) allowed for a best fitting positive or negative constant, μ_{ij}, for each product and country.

2.3. Within-sample prediction errors

After estimating the parameters by pooling the data across countries (Eq. (1)), and by differentiating parameters by country (Eq. (3)), the apparent consumption for each product, country, and year, was predicted from:

$$\widehat{C_{ijt}} = e^{\widehat{lnC_{ijt}}} \tag{13}$$

where $\widehat{lnC_{ijt}}$ was obtained from Eq. (1) or (3).

The average within-sample prediction error was then measured with the root mean square error, which was, for each product and country, and for n years of observation:

$$RMSE_{ij} = \sqrt{\frac{\sum_{t=1}^{n}(C_{ijt} - \widehat{C_{ijt}})^2}{n-1}} \tag{14}$$

2.4. Long-term projections

Within-sample projection errors, like other statistics, do not in and by themselves suffice to determine the economic importance of different hypotheses (McCloskey, 1985). To assess how much they matter, it is useful to do sensitivity analysis of the results for different assumptions (Leamer, 1985). Accordingly, long-term projections were carried out for the global forest sector, starting in year 2015 and up to 2065 with country-specific demand parameters, and alternatively with parameters obtained by pooling the data.

The projections were done with the Global Forest Products Model (Buongiorno et al., 2003).[1] All the other parameters of the model except the demand elasticities were the same in the two projections. The GFPM calculates for every projected year a global dynamic competitive equilibrium of consumption, production, trade, and prices across 180 countries and fourteen product groups, together with projections of forest stock and forest area.

For the purpose of this study, long-term elasticities of demand were used in the GFPM after estimating Eq. (1) with pooled data, or with Eq. (3) with country-specific data. For example, the long-term GDP elasticity, α_{ij}^{L}, of the demand for product i in country j was, based on Eq. (3):

$$\alpha_{ij}^{L} = \frac{\alpha_{ij}}{1-\gamma_{ij}} \tag{15}$$

The assumptions used in the GFPM regarding future GDP and population corresponded to the SSP2 scenario, an intermediate scenario among the five economic and demographic scenarios of the Shared Socioeconomic Pathways (Dellink et al., 2017; KC and Lutz, 2017). While GDP and population were exogenous, equilibrium prices were determined endogenously within the GFPM.

3. Results

3.1. Pooled elasticities

Table 1 shows the results of estimating the parameters of Eq. (1) by pooling the data across countries with the fixed-effects method. For all products the average price elasticity had the expected negative sign, and it was < 1 in absolute value. The corresponding 95% confidence interval was also negative and confirmed a price inelastic demand. The average elasticity with respect to GDP had the expected positive sign for all products, and it was less than unity. The 95% confidence interval was also positive and less than one. The average elasticity of lagged consumption was positive and less than unity as expected from theory, and the 95% confidence interval was also positive and less than one, for all products. Conditional on the other variables, the average trend parameter was positive for fiberboard and other paper and paperboard, and negative for the other products. The 95% confidence interval of the trend was non negative for fiberboard only. It was negative for sawnwood, particleboard, newsprint, printing and writing paper, and of either sign for veneer and plywood and other paper and paperboard.

3.2. Country specific elasticities

Table 2 shows the root mean square errors obtained with Eq. (14), with the product and country-specific elasticities estimated with Eqs. (4) to (12). The RMSE derived by pooling the data across countries are also reported in Table 2. For both pooled and country-specific elasticities, the RMSE was computed only for countries that had completed data on consumption, price, and GDP from 1992 to 2016. The RMSE was markedly less with the country-specific elasticities. The difference between the RMSEs ranged from 61,000 m^3/year or 7% for particleboard to 352,000 m^3/year or 43% for veneer and plywood.

The summary statistics of the country-specific parameters are in Table 3. In accord with the method, the minimum and maximum values were the 95% confidence bounds obtained in Table 1, used as lower and upper limits of the country-specific parameters. Due to these constraints, the standard errors of the country-specific parameters in Table 3 were much smaller than those obtained by pooling the data across countries (Table 1). For example, while the standard error of the mean price elasticity of sawnwood demand was 0.02 with pooled data, the same standard error was only 0.004 for the average country-specific elasticity.

The median of the country-specific parameters tended to be near the upper or lower bound set in the country-specific estimation. For example, the median price elasticity of sawnwood demand across countries was −0.12, equal to the upper bound, and the median GDP elasticity was 0.21, equal to the lower bound. However, there were exceptions. For fiberboard for example, the median GDP elasticity, 0.58, was between its lower and upper limits [0.47, 0.63].

Examination of the distribution of the country-specific parameters showed that they were concentrated at their lower and upper bound. For example, the histograms in Fig. 1 show the distribution of the 85 country-specific parameters for the sawnwood demand equation. In this case, 54% of the country-specific price-elasticities were in the interval $[-0.13, -0.12]$, at or near the upper bound of −0.12, and 39% of the country-specific elasticities were in the interval $[-0.20, -0.19]$, at or near the lower bound of −0.20.

3.3. Consequences for long term projections

Table 4 shows the world prices, measured with the unit value of world exports, observed in 2015, and projected in 2065 with the GFPM, conditional on the SSP2 scenario on GDP and population growth, by product and method.

For all products, the price projected with the country-specific demand elasticities was higher than with the pooled elasticities. The largest relative difference was for newsprint for which the country-specific elasticities led to a price in 2065 13% higher than the pooled elasticities. For sawnwood, particleboard, and fiberboard the projected prices were only 2% to 3% higher with the country-specific elasticities.

Since the price elasticities of the demand for all products were negative with both methods, the higher price projected with the country-specific elasticities reduced the projected consumption. However, this effect was lowered or increased due to the different GDP elasticities and time trends obtained with the two methods. Consequently, the projected consumption in 2065 obtained with the country-specific

[1] The current version of the GFPM software, data, and documentation available at: http://labs.russell.wisc.edu/buongiorno/welcome/gfpm/

Table 1
Average demand parameters and 95% confidence intervals obtained by pooling data across countries and over time.

Product	Average parameters					95% lower bound				95% upper bound			
	$\alpha \ln Y_t$	$\beta \ln P_t$	$\gamma \ln C_{t-1}$	t	n	$\alpha \ln Y_t$	$\beta \ln P_t$	$\gamma \ln C_{t-1}$	t	$\alpha \ln Y_t$	$\beta \ln P_t$	$\gamma \ln C_{t-1}$	t
Sawnwood	0.27 (0.03)**	−0.16 (0.02)**	0.61 (0.013)**	−0.008 (0.002)**	3394	0.21	−0.20	0.58	−0.012	0.33	−0.12	0.63	−0.004
Veneer & Plywood	0.37 (0.03)**	−0.34 (0.02)**	0.55 (0.01)**	−0.002 (0.002)	3190	0.30	−0.38	0.53	−0.007	0.43	−0.29	0.58	0.001
Particleboard	0.30 (0.04)**	−0.42 (0.03)**	0.61 (0.01)**	−0.006 (0.002)*	2293	0.23	−0.47	0.58	−0.010	0.38	−0.37	0.64	−0.001
Fiberboard	0.55 (0.04)**	−0.50 (0.03)**	0.51 (0.01)**	0.005 (0.003)*	2555	0.47	−0.55	0.49	0.000	0.63	−0.45	0.54	0.010
Newsprint	0.31 (0.03)**	−0.24 (0.03)**	0.56 (0.02)**	−0.018 (0.002)**	2807	0.26	−0.30	0.53	−0.020	0.36	−0.18	0.59	−0.015
Printing & writing Paper	0.38 (0.03)**	−0.54 (0.03)**	0.53 (0.01)**	−0.007 (0.002)**	3223	0.33	−0.60	0.50	−0.011	0.43	−0.48	0.56	−0.003
OtherPaper & paperboard	0.23 (0.03)**	−0.28 (0.02)**	0.60 (0.01)**	0.001 (0.002)	3288	0.18	−0.32	0.57	−0.002	0.28	−0.23	0.62	0.005

( ): Standard errors.
**, *: Statistically significant at least at 1% level, or 5% level, respectively.
n: number of observations.

Table 2
Root mean square error (RMSE) of within-sample annual projections of consumption obtained with country-specific elasticities, compared with elasticities derived from data pooled across countries, by product, from 1992 to 2016.

Product	Unit	RMSE		Difference		n
		By country	Pooled	Absolute	Relative	
Sawnwood	1000 m^3	1332	1596	−263	−0.16	2125
Veneer and plywood	1000 m^3	467	819	−352	−0.43	1850
Particleboard	1000 m^3	827	887	−61	−0.07	1000
Fiberboard	1000 m^3	605	727	−123	−0.17	1100
Newsprint	1000 t	175	216	−41	−0.19	1625
Printing & writing paper	1000 t	345	503	−157	−0.31	2000
Other paper & paperboard	1000 t	421	539	−118	−0.22	2100

n: number of observations, for countries with complete data from 1992 to 2016.

elasticities could be more or less with the pooled elasticities.

Table 5 shows the differences in 2065 consumption of solid wood products projected with country-specific elasticities relative to projections with pooled elasticities, by region and selected countries. For sawnwood country-specific elasticities led to 5% lower projected world consumption in 2065. Consumption was 36% lower in India, 27% in the United States, and 24% in Russia. However, it was higher by 45% in Egypt, 37% in Sweden and 14% in Germany.

For wood-based panels, the projection of world consumption was higher with country-specific elasticities for all three product groups. The largest difference was for fiberboard: 42% due to large differences in China (57%), the European Union (15%) and the United States (13%). The 26% higher world consumption of veneer and plywood obtained with country-specific elasticities stemmed from the higher projections for India (75%) and China (41%), while in North America and Europe the country-specific elasticities tended to lead to lower projected consumption, specifically by 27% in the United States and 20% in the European Union. There was less difference at world level between the projections of particleboard consumption obtained with the two methods, while consumption was 27% lower in the United States with country-specific elasticities, it was 14% higher in China, and world consumption was 7% higher with country-specific elasticities.

Within paper and paperboard products (Table 6), the projected world consumption of newsprint was 6% higher in 2065 with country-

Table 3
Summary statistics of country-specific parameters of demand equations, by product.

Product		$\ln Y_t$	$\ln P_t$	$\ln C_{t-1}$	t
Sawnwood (n = 85)					
	min	0.21	-0.20	0.58	-0.012
	max	0.33	-0.12	0.63	-0.004
	average	0.26	-0.15	0.61	-0.0084
	SE	0.006	0.004	0.003	0.0004
	median	0.21	-0.12	0.62	-0.010
Veneer & plywood (n = 74)					
	min	0.30	-0.38	0.53	-0.007
	max	0.43	-0.29	0.58	0.001
	average	0.355	-0.323	0.55	-0.0038
	SE	0.007	0.005	0.003	0.00043
	median	0.30	-0.29	0.53	-0.007
Particleboard (n = 40)					
	min	0.23	-0.47	0.58	-0.010
	max	0.38	-0.37	0.64	-0.001
	average	0.289	-0.40	0.60	-0.0057
	SE	0.011	0.006	0.005	0.00064
	median	0.26	-0.37	0.58	-0.006
Fiberboard (n = 44)					
	min	0.47	-0.55	0.49	0.000
	max	0.63	-0.45	0.54	0.010
	average	0.557	-0.481	0.51	0.00616
	SE	0.011	0.007	0.004	0.0007
	median	0.58	-0.45	0.50	0.010
Newsprint (n = 65)					
	min	0.26	-0.30	0.53	-0.020
	max	0.36	-0.18	0.59	-0.015
	average	0.31	-0.227	0.56	-0.018
	SE	0.006	0.007	0.004	0.00029
	median	0.30	-0.18	0.57	-0.018
Printing & writing paper (n = 80)					
	min	0.33	-0.60	0.50	-0.011
	max	0.43	-0.48	0.56	-0.003
	average	0.372	-0.531	0.52	-0.0068
	SE	0.005	0.006	0.003	0.00042
	median	0.33	-0.48	0.50	-0.007
Other paper and paperboard (n = 84)					
	min	0.18	-0.32	0.57	-0.0020
	max	0.28	-0.23	0.62	0.0050
	average	0.219	-0.267	0.59	0.00118
	SE	0.005	0.005	0.003	0.00035
	median	0.18	-0.23	0.57	0.0008

n = number of countries with complete data from 1992 to 2016. SE = standard error of mean.

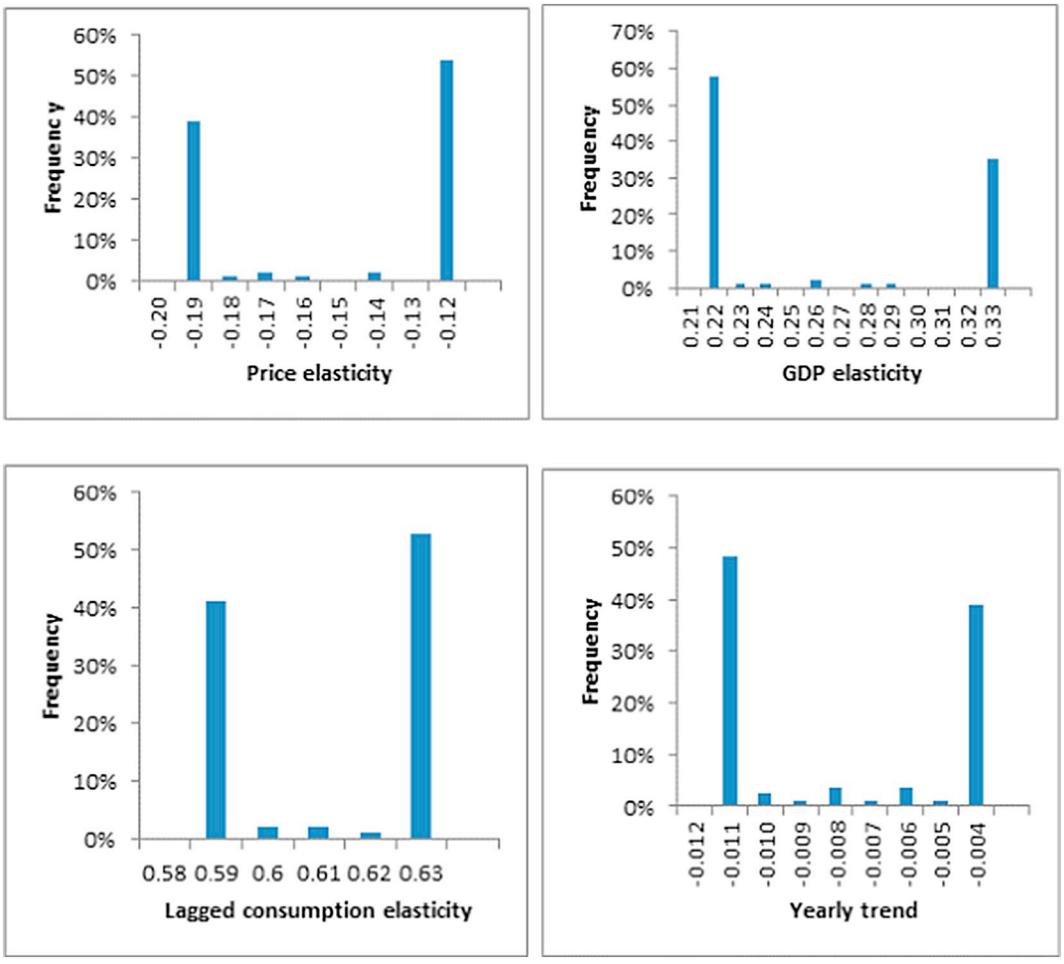

Fig. 1. Distribution of country-specific parameters for sawnwood demand, estimated for 85 countries with data from 1992 to 2016.

Table 4
Observed world export prices in 2015 and projected prices in 2065 obtained with pooled demand elasticities (a) or with country-specific elasticities (b).

Product	Unit	2015	2065 (a)	2065 (b)	Difference (b)/(a)-1
Sawnwood	$US/m^3	249	286	294	0.03
Veneer & plywood	$US/m^3	549	838	899	0.07
Particleboard	$US/m^3	239	393	403	0.03
Fiberboard	$US/m^3	395	754	770	0.02
Newsprint	$US $/t	512	503	570	0.13
Printing & writing paper	$US $/t	842	825	874	0.06
Other paper & paperboard	$US $/t	894	1242	1321	0.06

specific elasticities: 56% higher in India, and 46% higher in Indonesia, but 20% lower in the United States and 21% lower in China. For printing and writing paper, the country-specific elasticities led to 14% lower world consumption in 2065 than the pooled elasticities, with 36% less consumption in China, 27% less in the United States, and 25% less in the European Union. Country-specific elasticities lowered the world consumption of other paper and paperboard by only 2%, as the large negative differences in some countries, −21% in the United States, −28% in the United Kingdom, were compensated by large positive differences in others, such as 51% in India and 22% in Russia.

4. Summary and conclusion

Pooling data across countries and over time is a powerful way of estimating parameters of forest sector models, as it greatly increases the number of observations and their range, compared to single country time series. In the case of the demand for forest products, such panel data lead to useful estimates of price and income elasticities consistent with expected theoretical signs. Nevertheless, the standard errors of these pooled parameters suggest potentially large variations of the elasticities across countries.

This study proposed a way to estimate country-specific elasticities while using the prior information obtained by pooling the data. The essence of the method was a quadratic programming model that minimized the sum of squared residuals across countries and over time, while constraining the country-specific elasticities within the 95% confidence interval of the pooled elasticities. Sensitivity analysis was then carried out with a sector model to determine the economic importance of the differences between pooled and country-specific

Table 5
Differences in 2065 consumption of solid wood products projected with country-specific elasticities relative to projections with pooled elasticities, by region, and selected countries (%).

	Sawnwood	Veneer & plywood	Particleboard	Fiberboard
Africa	**29**	**5**	**1**	**20**
Egypt	45	−14	−44	40
Nigeria		16	45	−28
South Africa	−9	−3	1	87
N/C America	**− 24**	**− 23**	**− 10**	**17**
Canada	−16	−36	63	−2
Mexico	−11	49	63	78
United States	−27	−27	−27	13
South America	**− 15**	**0**	**31**	**44**
Argentina	13	−4	58	60
Brazil	−31	−34	25	55
Chile	−3	46	69	15
Asia	**4**	**36**	**16**	**51**
China	6	41	14	57
India	−36	75	−3	−3
Indonesia	−34	−27	−3	−1
Japan	−14	−10	−2	20
Korea, Republic of	−17	−20	−12	−6
Malaysia	−30	−15		−1
Oceania	**− 19**	**8**	**− 19**	**− 20**
Australia	−21	−10	−18	−19
New Zealand	−20	25	−27	−29
Europe	**− 6**	**− 13**	**5**	**16**
EU-28	−4	−20	−1	15
Austria	14	−11	−4	27
Finland	−18	31	−30	−10
France	−20	−34	−12	75
Germany	14	−24	−20	24
Italy	−30	−29	15	39
Russian Federation	−24	27	42	38
Spain	−28	−28	−27	−28
Sweden	37	−33	0	14
United Kingdom	−12	−27	−20	−33
World	**− 5**	**26**	**7**	**42**

The bold are simply data for the geographic regions.

Table 6
Differences in 2065 consumption of paper and paperboard projected with country-specific elasticities relative to projections with pooled elasticities, by region, and selected countries (%).

	Newsprint	Printing & writing paper	Other paper & paperboard
Africa	**1**	**− 11**	**19**
Egypt	−30	−10	29
Nigeria	−23	−35	−36
South Africa	33	−36	23
N/C America	**− 13**	**− 23**	**− 14**
Canada	−2	−25	−29
Mexico	8	1	21
United States	−20	−27	−21
South America	**− 13**	**− 12**	**5**
Argentina	−19	−3	−32
Brazil	−22	−31	10
Chile	−19	−34	30
Asia	**17**	**− 7**	**4**
China	−21	−36	−7
India	56	59	51
Indonesia	46	−4	−6
Japan	−6	−20	−17
Korea, Republic of	−17	−27	15
Malaysia	21	−29	23
Oceania	**− 18**	**− 35**	**− 26**
Australia	−21	−36	−27
New Zealand	−25	−27	−23
Europe	**− 3**	**− 23**	**− 6**
EU − 28	-2	−25	−8
Austria	−19	−26	9
Finland			−3
France	−27	−29	−28
Germany	16	−20	19
Italy	32	−28	−17
Russian Federation	0	14	22
Spain	−25	−32	−20
Sweden	23	−6	−30
United Kingdom	−21	−29	−28
World	**6**	**− 14**	**− 2**

The bold are simply data for the geographic regions.

elasticities for long-term projections.

The method was applied to international data for seven product groups from 1992 to 2016. Compared with pooling, country-specific elasticities reduced the root mean square error of in-sample predictions by 7% to 43% depending on the product. The country-specific elasticities tended to cluster near the bounds of the confidence intervals of the pooled elasticities, and due to these constraints their standard errors were smaller than those of the pooled elasticities. The bimodal distribution of the parameters suggests that more parsimonious models could be obtained that would fit the data nearly as well by dividing countries in two groups. However, a country price elasticity may be at its lower bound with a GDP elasticity at its upper bound. Thus, more than two groups would be necessary. Pending more research on this issue, country-specific elasticities seem the more straightforward approach.

The country-specific elasticities were used for long-term projections in the GFPM and the results were compared with the projections obtained with pooled elasticities. Projected world prices in 2065 were 3% to 13% higher, depending on the product, with country-specific elasticities. World consumption in 2065 with country-specific elasticities was from 2% lower to 42% higher depending on the product, with large differences across country and product group.

In conclusion, the much better fit of the country-specific elasticities compared with the pooled elasticities for within-sample predictions does seem to favor the country-specific approach. But the clustering of the country-specific parameters at the bounds derived from the pooled elasticities suggests that much future research is needed to understand the inter-country differences in the demand for forest products. In particular, more in-depth studies should be carried out with additional demand shifters that may be available in individual countries. Meanwhile, it is helpful to acknowledge the sensitivity of the results to the choice of parameters (Leamer, 1983, 1985), and consequently the role of judgment in evaluating long-term projections obtained with forest sector models.

Acknowledgments

The research leading to this paper was supported in part by a joint venture agreement between the University of Wisconsin and the U.S. Department of Agriculture Forest Service Southern Forest Research Station (17-JV-11330143-087), in cooperation with Project Leader Jeff Prestemon. The author is grateful to Craig Johnston and Prakash Nepal for providing the long-term projections of GDP and population corresponding to the SSP2 scenario.

References

Adams, D.M., Alig, R.J., McCarl, B.A., Callaway, J.M., Winnett, S.M., 1996. The Forest Agricultural Sector Optimization Model: Model Structure and Applications. Research Paper PNW-495. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR (44p).

Baker, A., 2013. Simplicity. In: Zalta, Edward N. (Ed.), The Stanford Encyclopedia of Philosophy *(Fall* 2013 Edition), . http://plato.stanford.edu/archives/fall2013/entries/simplicity/.

Buongiorno, J., 2015. Income and time dependence of forest product demand elasticities and implications for forecasting. Silva Fenn. 49 (5), 1–17.

Buongiorno, J., Zhu, S., Zhang, D., Turner, J., Tomberlin, D., 2003. The Global Forest Products Model: Structure, Estimation, and Applictions. Elsevier/Academic Press, Amsterdam (301p).

Chas-Amil, M.L., Buongiorno, J., 2000. The demand for paper and paperboard: econometric models for the European Union. Appl. Econ. 32, 987–999.
Dellink, R., Chateau, J., Lanzi, E., Magné, B., 2017. Long-term economic growth projections in the shared socioeconomic pathways. Glob. Environ. Chang. 42, 200–214.
FAO, 2018. FAOSTAT Forestry Data Base. Food and Agriculture Organization of the United Nations, Rome. http://faostat3.fao.org/download/F/FO/E.
Kallio, A.M.I., Moiseyev, A., Solberg, B., 2004. The global forest sector model EFI-GTM—The model structure. In: EFI Technical Report 15. European Forest Institute, Joensuu, Finland (24 p).
Kangas, K., Baudin, A., 2003. Modelling and Projections of Forest Products Demand, Supply and Trade in Europe. UN/FAO European Forest Sector Outlook Studies. UNECE, Geneva. http://www.unece.org/fileadmin/DAM/timber/docs/efsos/03-sept/dp-30.pdf.
KC, S., Lutz, W., 2017. The human core of the shared socioeconomic pathways: population, scenarios by age, sex and level of education for all countries to 2100. Glob. Environ. Chang. 42, 181–192.
Lauri, P., Havlik, P., Kindermann, G., Forsell, N., Bottcher, H., Obersteiner, M., 2013. UNECE Woody biomass energy potential in 2050. Energy Policy 66, 19–31.
Leamer, E.E., 1983. Let's take the con out of econometrics. Am. Econ. Rev. 73 (1), 31–43.
Leamer, E.E., 1985. Sensitivity analysis would help. Am. Econ. Rev. 75 (3), 308–313.
McCloskey, D.N., 1985. The loss function has been mislaid: the rhetoric of significance tests. Am. Econ. Rev. 75 (2), 201–205.
Michinaka, T., Tachibana, S., Turner, J., 2011. Estimating price and income elasticities of demand for forest products: cluster analysis used in grouping. Forest Policy Econ. 13 (6), 435–445.
Simangunsong, B.C.H., Buongiorno, J., 2001. International demand equations for forest products: a comparison of methods. Scand. J. For. Res. 16, 155–172.
UNECE, 2012. The North American Forest Sector Outlook Study. ECE/TIM/29. United Nations Commission for Europe, Geneva (65p).
Wooldridge, J.M., 2006. Introductory Econometrics: A Modern Approach. The MIT Press, Cambridge (889p).
World Bank, 2018. World Bank Development Indicators Data Base. http://databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators.